Semester-wise subject distribution as per new academic curriculum:

First Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Humanities | English | 3 | | 3 | | 100 | |
| 2. | | Inorganic Chemistry | Chemistry | 3 | | 3 | | 100 | |
| 3. | | Fundamentals of Chemical Engineering | Chem. Engg. | 3 | | 3 | | 100 | |
| 4. | | Mathematics – I* | Math | 3 | | 3 | | 100 | |
| 5. | | Engineering Mechanics | Mech. Engg. | 3 | | 3 | | 100 | |
| 6. | | Physics | Physics | 3 | | 3 | | 100 | |
| 7. | | Physics Laboratory | Physics | | 3 | | 3 | | 100 |
| 8. | | Inorganic Chemistry Lab | Chemistry | | 3 | | 3 | | 100 |
| 9. | | Basic Engineering Drawing (Drawing board mode) | Mech. Engg. | | 3 | | 3 | | 100 |
| 10. | | Workshop practice – VII | Mech. Engg. | | 3 | | 3 | | 100 |
| | | **TOTAL** | | **18** | **12** | **18** | **12** | **600** | **400** |
| | | | | **30** | | **30** | | **1000** | |

* - Mathematics – I will comprise of Module – I and Module – II (50 marks each)

Second Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Strength of Materials | Mech. Engg. | 3 | | 3 | | 100 | |
| 2. | | Electrical Technology | Elec. Engg. | 3 | | 3 | | 100 | |
| 3. | | Mathematics – II* | Math | 3 | | 3 | | 100 | |
| 4. | | Introduction to Computer Programming | Chem. Engg. | 3 | | 3 | | 100 | |
| 5. | | Organic Chemistry | Chemistry | 3 | | 3 | | 100 | |
| 6. | | Physical Chemistry | Phy. Chem. | 3 | | 3 | | 100 | |
| 7. | | Physical Chemistry Lab – I | Phy. Chem. | | 3 | | 3 | | 100 |
| 8. | | Organic Chemistry Lab | Chemistry | | 3 | | 3 | | 100 |
| 10. | | Workshop practice – VIII | Mech. Engg. | | 3 | | 3 | | 100 |
| | | **TOTAL** | | **18** | **9** | **18** | **9** | **600** | **300** |
| | | | | **27** | | **27** | | **900** | |

* - Mathematics – II will comprise of Module – III and Module – IV (50 marks each)

Third Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Machine Design | Mech. Engg. | 3 | | 3 | | 100 | |
| 2. | | Engineering Thermodynamics | Mech. Engg. | 3 | | 3 | | 100 | |
| 3. | | Mechanics of Fluid | Chem. Engg. | 3 | | 3 | | 100 | |
| 4. | | Numerical Methods | Chem. Engg. | 3 | | 3 | | 100 | |
| 5. | | Mathematics-III* | Math | 3 | | 3 | | 100 | |
| 6. | | Elementary Electronics | ETC | 3 | | 3 | | 100 | |
| 7. | | Physical Chemistry Lab – II | Phy. Chem. | | 4 | | 3 | | 100 |
| 8. | | Workshop Practice – XII | Mech. Engg. | | 4 | | 3 | | 100 |
| 9. | | Computer Aided Drafting | Mech. Engg. | | 3 | | 3 | | 100 |
| | | **TOTAL** | | **18** | **11** | **18** | **9** | **600** | **300** |
| | | | | **29** | | **27** | | **900** | |

*- Mathematics – III will comprise of Module – V and Module –VI (50 marks each)

Fourth Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Chemical Process Calculations | Chem. Engg. | 3 | | 3 | | 100 | |
| 2. | | Material Science & Engineering | Metallurgy | 3 | | 3 | | 100 | |
| 3. | | Chemical Engineering Thermodynamics | Chem. Engg. | 3 | | 4 | | 100 | |
| 4. | | Introduction to Transport Phenomena | Chem. Engg. | 4 | | 4 | | 100 | |
| 5. | | Mechanical Operations | Chem. Engg. | 3 | | 4 | | 100 | |
| 6. | | Applied Numerical Analysis Lab | Chem. Engg. | | 4 | | 3 | | 100 |
| 7. | | Machine Drawing (Computer terminal mode) | Mech. Engg. | | 4 | | 3 | | 100 |
| 8. | | Electrical Engg. Lab. | Elec. Engg. | | 3 | | 3 | | 100 |
| | | **TOTAL** | | **16** | **11** | **18** | **9** | **500** | **300** |
| | | | | **27** | | **27** | | **800** | |

Fifth Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Separation Processes - I | Chem. Engg. | 3 | | 4 | | 100 | |
| 2. | | Chemical Reaction Engineering-I | Chem. Engg. | 4 | | 4 | | 100 | |
| 3. | | Chemical Technology – I | Chem. Engg. | 3 | | 3 | | 100 | |
| 4. | | Process Heat Transfer | Chem. Engg. | 3 | | 4 | | 100 | |
| 5. | | Energy Engineering | Chem. Engg. | 3 | | 3 | | 100 | |
| 6. | | Momentum Transfer & Mechanical Operation Lab | Chem. Engg. | | 4 | | 3 | | 100 |
| 7. | | Computer Applications in Chemical Engg. Lab. | Chem. Engg. | | 4 | | 3 | | 100 |
| 8. | | Process Equipment Design & Drawing- I | Chem. Engg. | | 4 | | 3 | | 100 |
| | | **TOTAL** | | **16** | **12** | **18** | **9** | **500** | **300** |
| | | | | **28** | | **27** | | **800** | |

Sixth Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Principles of Measurements & Instrumentation | Elec. Engg. | 3 | | 3 | | 100 | |
| 2. | | Process Dynamics & Control | Chem. Engg. | 3 | | 3 | | 100 | |
| 3. | | Separation Processes – II | Chem. Engg. | 3 | | 3 | | 100 | |
| 4. | | Chemical Technology – II | Chem. Engg. | 3 | | 3 | | 100 | |
| 5. | | Optimization Methods for Chemical Engineering | Chem. Engg. | 3 | | 3 | | 100 | |
| 6. | | Chemical Reaction Engineering-II | Chem. Engg. | 3 | | 3 | | 100 | |
| 7. | | Reaction Engineering & Thermodynamics Lab. | Chem. Engg. | | 4 | | 3 | | 100 |
| 8. | | Energy Engineering Lab. | Chem. Engg. | | 3 | | 3 | | 100 |
| 9. | | Chemical Engineering Project – I | Chem. Engg. | | 4 | | 3 | | 100 |
| | | **TOTAL** | | **18** | **11** | **18** | **9** | **600** | **300** |
| | | | | **29** | | **27** | | **900** | |

Seventh Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Separation Processes-III | Chem. Engg. | 3 | | 3 | | 100 | |
| 2. | | Mathematical Modeling in Chemical Engineering | Chem. Engg. | 3 | | 3 | | 100 | |
| 3. | | Industrial Pollution Control Engineering | Chem. Engg. | 3 | | 3 | | 100 | |
| 4. | | Elective – I | Chem. Engg. | 3 | | 3 | | 100 | |
| 5. | | Chemical Engineering Project – II | Chem. Engg. | | 4 | | 3 | | 100 |
| 7. | | Process Equipment Design & Drawing – II | Chem. Engg. | | 4 | | 3 | | 100 |
| 8. | | Seminar-I | Chem. Engg. | | 3 | | 3 | | 100 |
| 9. | | Process Instrumentation & Control Lab. | Chem. Engg. | | 3 | | 3 | | 100 |
| | | **TOTAL** | | **12** | **14** | **12** | **12** | **400** | **400** |
| | | | | **26** | | **24** | | **800** | |

| | **Elective – I** |
|---|---|
| 1. | Advanced Heat Transfer |
| 2. | Advanced Numerical methods |
| 3. | Advanced Fluid Dynamics |
| 4. | Advanced Transport Phenomenon |
| 5. | Advanced Mass Transfer |
| 6. | Interfacial Science and Engineering |
| 7. | Multiphase Flow |
| 8. | Operations Research |

Eighth Semester:

| Sl. No | Subject Code | Subject | Service Dept. | Periods/week | | Credit point | | Marks | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Sessional | Theory | Sessional | Theory | Sessional |
| 1. | | Chemical Project Engineering & Economics | Chem. Engg. | 3 | | 3 | | 100 | |
| 2. | | Chemical Process Safety & Risk Management | Chem. Engg. | 3 | | 3 | | 100 | |
| 3. | | Industrial Management | Mech. Engg. | 3 | | 3 | | 100 | |
| 4. | | Elective – II | Chem. Engg. | 3 | | 3 | | 100 | |
| 5. | | Chemical Process Design & Drawing | Chem. Engg. | | 3 | | 3 | | 100 |
| 6. | | Heat & Mass Transfer Lab. | Chem. Engg. | | 4 | | 3 | | 100 |
| 7. | | Seminar - II | Chem. Engg. | | 4 | | 3 | | 100 |
| 8. | | General Viva-voce | Chem. Engg. | | | | 3 | | 200 |
| | | **TOTAL** | | **12** | **11** | **12** | **12** | **400** | **500** |
| | | | | **23** | | **24** | | **900** | |

| | **Elective – II** |
|---|---|
| 1. | High Polymer Technology |
| 2. | Petroleum Refinery Engineering & Petrochemicals |
| 3. | Applied Statistics for Chemical Engineers |
| 4. | Bioenergetics & Bioprocess Engineering |
| 5. | Computational Fluid Dynamics |
| 6. | Environmental Biotechnology |
| 7. | Modern Energy engineering & Energy Management |

# Semester - 1

**HUMANITIES**

**English**

2 classes per week x 14 weeks = 28 classes. Internal Assessment 2 weeks.

Teaching : 24 classes.

1. Basic writing skills : based on Sections 1 and 2 of English for All = 8 classes (4 weeks).
2. Communication skills.
   - Report writing = (4 classes) 2 weeks
   - Precis writing = (4 classes) 2 weeks
   - CVs and resumes = (4 classes) 2 weeks
   - Reading scientific papers ; Scholarly conventions = (4 classes) 2 weeks
3. Two prose extracts from English for All (may be changed from time to time : proposal for this year, JBS Haldane, "Scientific Research for Amateurs" and Rabindranath Tagore " The Religion of the Forest") = (4 classes) 2 weeks.
4. One short story from English for All (may be changed from time to time : proposal for this year, James Thurber, " The Secret Life of Walter Mitty") = (4 classes) 2 weeks.

Group presentations in class to be encouraged.

**Society, Culture and Technology**

1. Understanding technology historically
   - Emergency and growth of technology in response to collective needs
   - Commodity production and expansion of trade; economic imperatives for technological advancement.
2. Technology and work
   - Technology and industrial production : fordism and post-fordism
   - Division of labour and social identities : race, ethnicity, gender.
3. Technology, cultural globalization and global consumerism
   - Computer, Media and Culture
   - Information and communication technology. Role of communication technology : five components of communication, pyramid pf communication
   - Global television and American cultural imperialism.
4. Internet and Community
   - Understanding of Community in the information age.
   - The virtual individual and the virtual social
   - Power and cyberspace
5. The Ecology Approach
   - The natural world and the built environment; nature, man and science; eco-systems and ecofeminism.
   - Technology and sustainable development.
6. The gender question
   - Sex and gender; science and technology ; the malestream
   - Women and technology. Domestic technology : persistence of gender roles.

**INORGANIC CHEMISTRY**

Atomic structure, Bonding and structure. Theory of acids & bases, Stability of nucleus and modes of decay, Nuclear forces, mass defect and nuclear binding energy. Nuclear reaction - fission and fusion. Boron-hydrides, Barazole, Boron nitrides. Silicon silicates, silicones, silica gel, carbon carbides, graphite compounds, Teflon, Freon, General characteristics of transitional metals, Environmental chemistry. Chemical Kinetics -Preliminary approach

**FUNDAMENTALS OF CHEMICAL ENGINEERING**

Features of organized chemical processing- from Chemistry to Chemical Engineering, Chemical Industry- scope, features & characteristics.

Unit Operations in Chemical Engineering - an overview. Units and Dimensions - Systems of units, Conversion of units, Dimensional homogeneity and consistency, dimensional analysis**,** dimensionless groups and their use in chemical engineering. Process Variables - mass, volume, pressure, temperature, chemical composition, flow rates. Single Phase Systems: Solids, liquids, ideal gas and real gases; Equations of State; Compressibility factor charts; estimation of densities and heat capacities of solids, liquids and gases, and their mixtures, Mixing Rules e.g. Kay's Rule. Multi-phase Systems: Outlines of unit operations involved in separating multiphase systems - distillation, crystallization, absorption, adsorption, extraction, leaching, evaporation, drying etc.; Single-component phase equilibrium - phase diagrams, estimation of vapor pressure using Clausius-Clapeyron Equation, Cox Charts and Antoine Equation, Gibbs' Phase Rule; Gas-Liquid Systems - saturation, saturated/ superheated vapor, humidity, psychrometric charts, boiling point, dew point, bubble point, degree of superheat, Raoult's Law and Henry's Law for multi-component gas-liquid systems; Solutions of solids in liquids - solubility and saturation, phase diagrams; Immiscible and partially miscible liquids - miscibility and distribution coefficients, phase diagrams for ternary systems.

Process Data Representation and Analysis - interpolation and extrapolation, curve-fitting and least squares method, fitting a line to scattered data.

*Books*

Elementary Principles of Chemical Processes by Rihard M. Felder and Ronald W. Rousseau.

**MATHEMATICS – I**

Module : I

*Differential Calculus of Single Variable*

Sequence; Infinite series and their convergence and divergence; Cauchy's general principle of convergence; comparison test; D'Alembert's ratio test and Cauchy's root (statement and their applications only); Successive differentiation; Rolle's theorem*; Mean value theorems; Taylor's theorem*; Maclaurin's theorem*; Expansion of elementary functions; Indeterminate form; Curvature and Asymptote; Concavity, convexity and points of inflexion.

*Differential Calculus of several variables*

Limit; Continuity and Differentiability; Directional derivatives; Partial derivatives; Differentials; Euler's theorem on homogeneous functions; Implicit function; Jacobian; Taylor's theorem*; Maxima; minima and Lagrange's method of undetermined multipliers. *Proof not required.

Module: II

*Integral Calculus:*

Reimann integration (Defination and properties); Fundamental theorem of integral calculus; First mean value theorem of integral calculus; First mean value theorem of integral calculus; Improper integrals (Definitions and examples); Gamma and Beta functions; Multiple integrals; Rectification; Quadrature; Volume and surface areas of solids of revolution; Neumerical integration by trapezoidal and Simpson's 1/3 rule.

**ENGINEERING MECHANICS**

**Statics**:

Introduction, Idealizations of Mechanics, Fundamentals of Vector Algebra, Application of Vectors in Mechanics, Equiv System, Equilibrium, FBD Concept, Fundamentals of Friction, Properties of surface, Centroid, Moment of Inertia

**Dynamics:**

Intro to vector calculus, Definition of vectors in Dynamics, Rectilinear Motion, Curvilinear motion of particle and description of different coordinate systems, Kinetics, Newton's Law and D' Alembert's principle and application to rectilinear and curvilinear motion, constrained motion, Energy and Momentum methods.

**PHYSICS – 1A**

1. Scalar and vector fields, Gradient of a scalar field, Physical interpretation of gradient, Divergence and curl of a vector field, Conservative vector fields and their potential functions – gravitational and electrostatic examples. (4)

2. Simple harmonic motion, free vibration, damped and forced vibration, resonance. Wave motion, Superposition principle, phase velocity and group velocity. (4)

3. Motion of fluid, Bernoulli's theorem, Poiseulle's equation for the flow of liquid through a narrow tube, Motion of a body through a viscous medium : Stokes' law (4)

4. Overview of Coulomb's law, Gauss's law, dielectric piolarization, Displacement vector, Overview of Biot Savart law and Ampere's Circuital law. (4)

5. Time-varying field, Faraday's law of electromagnetic induction, Transient phenomena in electric circuits (series L-R, series C-R), Electrical oscillations in L-C circuit. Alternating voltage applied to series L-C-R circuit and the idea of electrical resonance. (5)

6. Macroscopic and microscopic description, Thermal equilibrium, Zeroth law of thermodynamics, Heat and Work, First law of thermodynamics and some applications, Reversible and irreversible processes, Carnot cycle, Second law of Thermodynamics, concept of entropy. (6)

7. Interference of light waves, Young's experiment, Spatial and temporal coherence, Interference in thin film, Newton's rings, Diffraction of light waves, Fraunhoffer diffraction due to single slit and plane diffraction grating, Polarisation of light waves, Polarisation by reflection, Brewster's law. (9)

8. Wave particle duality, de Broglie waves and uncertainty principle, concept of wave function and its physical interpretation. I-D Schrodinger equation – 1 – dimensional (infinite) potential well. (6)

**PHYSICS LABORATORY**

(Selected Experiments from the following)

1. Determination of Galvanometer resistance by half - deflection method.
2. Determination of Galvanometer resistance by Thomson's method.
3. To find high resistance by Galvanometer deflection method.
4. To measure mechanical equivalent of heat, J by electrical method (Joule's) using copper calorimeter (radiation correction to be done).
5. To compare to low resistance by drop of potential method.
6. To determine resistance per unit length of wire by using Carey Foster bridge.
7. To estimate strength of a current by using copper voltmeter.
8. a) To compare the EMF's of two cells by using a potentiometer
   b) To measure current by using a potentiometer
9. To measure the horizontal components of earth's magnetic field intensity using deflection and vibrating magnetometers.
10. Determination of co efficient of linear expansion by optical lever method.
11. Determination thermal conductivity of metal by Searle's method.
12. To determine co-efficient of viscosity by Capillary flow method.
13. Determination of Young's modulus by Flexure method.
14. To draw mutual and anode characteristics of triode and hence too fine Rp, μ, and gm
15. To draw the transistor characteristics (NPN/PNP) in the given configuration and hence to find hi, hf
16. Study of collisions in one dimension using a linear air track
17. Use of an air track for obtaining potential energy curves for magnetic interactions.
18. Study of oscillations under potential wells of various shapes using an air track.
19. To find the wavelength of a monochromatic light by Newton rings.

**INORGANIC CHEMISTRY LABORATORY**

1. Qualitative detection of acid and basic radicals (4 radicals to be detected)
2. Estimation of $Fe^{2+}$ and $Fe^{3+}$ in a mixture
3. Estimation of $Cu^{2+}$ and $Fe^{3+}$ in a mixture
4. Estimation of $Cl^-$, $SO_4^{2-}$
5. Hardness of water
6. Estimation of calcium and magnesium in soil
7. Determination of pH
8. Qualitative determination of rust
9. BOD and COD determination

**BASIC ENGINEERING DRAWING (DRAWING BOARD MODE)**

**Drawing primitives**: instruments, letters, lines, title block, geometric curves & shapes, scale and dimension.

**Projection**: orthographic and isometric, sectional views.
True length, development of surface of simple objects.

**WORKSHOP PRACTICE-VII (Fitter Shop and Welding)**

Introduction to fitter's tools, gauges, measuring instruments etc.; marking of jobs; fitter's job involving chipping, filing, sawing, drilling; use of taps and dies; pipe fittings and plumbing.
Introduction to and practice of different welding processes- gas, SMAW, TIG, MIG, SAW, resistance welding etc.; introduction to gas cutting and its application; soldering, brazing etc.; making welded joints using different welding processes.

# Semester – 2

**STRENGTH OF MATERIALS**

Uniaxial stress field, Thin pressure vessels, Torsion (inclusive of Helical spring), shear force and Bending moment, Bending and shear stress in beams, Deflection beams, Energy methods in Strength of Materials, Problem of Plane stress and strain, Theories of failure, Buckling of columns.

**ELECTRICAL TECHNOLOGY**

DC Circuits: Kirchhoff's Laws. Maxwell's Loop Current Methods of Analysis. Star-Delta Conversion. Superposition Theorem. Thevenin's Theorem. Maximum Power Transfer.
Magnetic Circuit: MMF, Flux ,Reluctance. B-H Loop. Hysteresis and Eddy current loss. Magnetic circuit analysis with air gap.
AC 1 -phase: Periodic Waves and Sinusoids. Average and RMS Values, Form Factor, Peak. Factor. Phasor concept of Sinusoids. Impedance and Admittance. Power, Power Factor, V A, V AR. Series R-L-C Circuit ,Parallel R-L-C circuit. Resonance.
Balanced 3-phase: 3-phase AC balanced circuits. Phase-sequence. Star and Delta connections. Power, V A, V AR, Power Factor _or balanced 3-phase circuits.
Power Measurement: Wattmeter circuit connection. Power Measurment by two wattmeter methods in 3phase system.
DC Machines: Construction and general priciple of operation. Generator EMF Equation. Field connection ,shunt series and compound. Generator characteristics.
Motor-equation and general operation. starting and speed control, torque -speed curve.
1-PhaseTransformer: Construction. EMF equation. Phasor diagram. Equivalent circuits. Losses and Efficiency. Open circuit and Short circuit test.
3-Phase Induction Machine: Types of induction machines. Rotating magnetic field, slip, torque equation, torquespeed curve. DOL starting and reduced voltage starting.
3-Phase Synchronous Machines: Alternator, constructional features, EMF equation, synchronous reactance, power -angle characteristics.
Concept of synchronous motor.
Meters: DC and AC Ammeters and Voltmeters. Megger.Multiplier.

Books :
Electrical Science by Prof. S. Chowdhury, Prof. R. Chakraborty & Prof. P. K.Chatterjee.
Electrical Machines by Prof. P.K. Mukherjee & Prof. S. Chakravorti.

**MATHEMATICS – II**

Module: III

*Linear Algebra*

Matrix and Determinant; Inverse of a square matrix; Elementary row and column operations; Echelon form; Rank of a matrix; Solution of system of linear equations; Cramer's rule; Matrix inversion method. Characteristic equations; Eigenvalues and Eigenvectors; Cayley-Hamilton theorem.

*Geometry of Three Dimensions*

Cartesian co-ordinates in three dimension; Direction Cosines; Angle between two lines; Equation of Planes and Straight lines; Skew lines; shortest distance between skew lines; Condition of coplanarity; Standard equation of spheres.

Module: IV

*Vector Algebra*

Basics of vector algebra; Dot and Cross products of two vectors; Product of three or more vectors; volume of tetrahedron; Work done; Moment; Angular velocity.

*Vector Calculus*

Vector functions of a scaler variable; Limit; Continuity and Derivative of vector functions; Applications to mechanics; Partial derivatives of vector function of more than one variables; Directional derivative; Gradient; Divergence and Curl; Vector Integration; Line integrals; Surface integrals and volume integrals; Greeen's theorem in the plane; Gausss Theorem; Stokes' Theorem and their application; Tangent Normal and Binormal of space curve; Serret-Frenet formulae; Normal plane, Rectifying plane and oscillating plane.

**INTRODUCTION TO COMPUTER PROGRAMMING**

Formulation of algorithms and flow-charts for computer-based solutions of engineering problems.
Introduction to programming using some languages like FORTRAN 90, C/C++.

Syntax of the languages: Variables, assignment, expressions, input/output, conditions and branching, iteration, functions, recursion, arrays, pointers, structures, dynamic allocation, data structures.

**ORGANIC CHEMISTRY**

*UNIT I: GENERAL*

Electronegativity, Inductive effect, Resonance, Hyper conjugation, Steric effect, strength of organic acids and bases. Conformational analysis of ethane and n-butane with energy diagram, elementary idea of Fischer projection, Newman projection and sawhorse representation of organic compounds with simple examples. Cis, Trans, E, Z, optical rotations, specific and molecular rotations.

*UNIT II: ALIPHATIC COMPOUNDS*

Homolytic and Heterolytic cleavage of bonds, classification of reagents, (Electrophiles and Nucleophiles) and reactive intermediates. Outline of preparations and reactions of different classes of organic compounds (alkanes, alkenes, alkynes, alkyl halides, alcohols, ethers, aldehydes and ketones, carboxylic acids and their derivatives, amines) with elementary idea on reaction mechanisms ( Nucleophilic substitution reactions, El, E2, Electrophilic addition to olefins, Nucleophilic addition to carbonyl groups).

*UNIT III: AROMATIC COMPOUNDS*

Elementary idea on aromaticity, mechanism of electrophilic aromatic substitution reactions. Outline of preparations and reactions of aromatic hydrocarbons, aryl halides, nitro compounds, amines, phenols, aldehydes and ketones, carboxylic acids and their derivatives.

*UNIT IV: INDUSTRIAL PREPARATION OF ORGANIC COMPOUNDS*

Synthesis of commercially important compounds (e.g. phenol from isopropylbenzene, phthalic anhydride from xylene and naphthalene, DDT from chlorobenzene, aspirin and methyl salicylate from phenol) Elementary idea on Addition, condensation and coordination polymerization. Elementary idea of IR spectroscopy and its application in the detection of common functional groups.

**PHYSICAL CHEMISTRY**

Electrochemistry:

Electrolytic conductance, Transference Number, Specific and Equivalent Conductance (Debye-Huckel, Onsager relations (no derivations), absolute velocity of ions, degree of ionization and conductance, application of conductance (solubility of sparingly soluble salts, conductometric titrations), concept of activity and activity coefficient

Cells (reversible and irreversible cells), electromotive force, standard cells, cell relation and electromotive force (EMF), convention on the sign of EMF, single electrode potential, calculation of cell EMF from single electrode potential, thermodynamics of electrode potentials

(electromotive series, standard electrode potentials) equations for cell EMF, standard potentials and equilibrium constants, types of electrodes (hydrogen and calomel electrodes in particular)

Electrochemical Cells

Application: solubility product and EMF, potentiometric determination of pH, potentiometric titration, electrolysis and polarization, decomposition potential, overvoltage (its measurement), electrolytic separation of metals, commercial cells, fuel cells.

Surface Chemistry:

Surface tension, surface energy, flat and curve surface, pressure differential across a curved surface and capillary rise and fall, Kelvin equation, influence of soap molecules on surface tension, Gibbs monolayer and Gibbs equation ( derivation optional) and surface energymicro heterogeneous systems and their uses (micelles, emulsions, microemulsions with reference to the basis of their formation, vesicles and lipozomes), contact angle, wetting, spreading and adhesion, adsorption and colloidal dispersions, types of colloids, colloid solubility, concept of zeta potential and electrokinetics (electro osmosis, electrophoresis, straining potential, sedimentation potential), nano dispersions, their preparation, synthesis and uses.

**PHYSICAL CHEMISTRY LABORATORY-I**

1. Determination of viscosity coefficient
2. Determination of surface tension
3. Determination of distribution coefficient
4. Determination of equilibrium constant (homogeneous)
5. Determination of phase diagram (ternary system)
6. Determination of adsorption isotherm.

**ORGANIC CHEMISTRY LABORATORY**

Experiments to supplement the course on "Organic Chemistry". Preparation of simple organic compounds and its characterization by physical and spectroscopic method (IR). Qualitative analysis of organic compound (Detection of special elements and functional groups)

**WORKSHOP PRACTICE-VIII (Forging and Moulding)**

Forging: Introduction to forging tools, furnaces and forging machines; to practice basic forging operations- drawing out, upsetting, necking etc.; introduction to forge welding. Introduction to moulding practice- preparation of moulding sand and use of moulder’s tools; making of moulds

by using selected pattern's; introduction to melting and pouring practice; experiments sand testing like permeability, moisture content, shutter index, mould strength, grain fineness number etc.; demonstration of injection moulding machine.

# Semester – 3

**MACHINE DESIGN**

Basic idea of design, factor of safety, modes of failure, theories of failure, design under

static and fatigue loading. Design of Cotter/knuckle Joint, threaded and riveted joint, eccentric loading. Shaft coupling (rigid / flexible). Belt-pulley drive. Pressure vessel.

**ENGINEERING THERMODYNAMICS**

Basic concepts: Systems-isolated, closed and open; thermodynamic state; state variables-intensive and extensive; process-cyclic process, reversible process; Zeroth law of thermodynamics-concept of temperature, properties of pure substances, energy interaction between system and surroundings-work and heat; adiabatic and isothermal processes. Concept of internal energy; conservation of energy; first law of entropy; entropy change of the universe-possible and impossible processes; reversible and irreversible processes; internal and external reversibility; thermodynamic temperature.

Open systems- first and second law applications; second law efficiency and availability, irreversibility, lost work and energy.

Third Law of thermodynamics.
Thermodynamic properties- enthalpy, Gibb's free energy and Helmholtz free energy; application of first and second law to closed systems; heat engines - Carnot cycle; Introduction to refrigeration and gas liquefaction processes, introduction to power cycles.

**MECHANICS OF FLUID**

Introduction:

Fluid, Concept of continuum, Method of analysis: System and Control volume, Methods of description - Lagrangian and Eulerian

Fundamental Concepts: Velocity field, Streamlines, Streaklines, Pathlines, Timelines, Stress field, Viscosity, Newtonian fluid and Non-newtonian fluids, Description and Classification of fluid flow-inviscid viscous, laminar, turbulent, internal, external, incompressible, compressible

Fluid Statics: Pressure variation in a static fluid

Control volume analysis (integral approach): - Reynolds transport theorem, conservation of mass and momentum theorem, The first and second law of Thermodynamics

Differential analysis of fluid motion: Conservation of mass; Stream function for two-dimensional incompressible flow, Kinematics of flow field: Acceleration of a particle in a Velocity Field, Fluid Rotation, Vorticity, Fluid Deformation. Momentum equation: Forces acting on a Fluid particle, Differential momentum Equation Incompressible Inviscid flow: Momentum Equation for frictionless flow, Euler's equation, Bernoulli equation, Static, Stagnation and Dynamic pressures.

Incompressible Viscous flow, pipes and channels - laminar and turbulent flow, nature of turbulence, deviating velocities in turbulent flow, Intensity and scale of turbulence, Reynolds stress, Prandtl mixing length, boundary layer, Universal velocity distribution, corrections to Bernoulli's equation, Friction factor, Friction factor vs Reynold number, flow through circular and noncircular conduits, Flow in agitated vessels, Hagen Poiseuille equation, Fanning equation, major and minor frictional losses, skin friction and form friction, pressure drop in flow through multiple paths, pipeline design.

External flows: Boundary layer Drag and lift, drag coefficient, Stokes law, Drag coefficient, Drag coefficient vs Reynold s number plot

Flow measuring devices: design considerations
Flow through packed bed and fluidized bed

*Books*
Introduction to Fluid Mechanics – Fox and McDonald
Fundamentals of Fluid Mechanics – Philip M. Gerhart, Richard J. gross, John I. Hochstein
Fluid Mechanics – Victor L. Streeter
Fluid Mechanics and its Application – Vijay Gupta & Santosh K. Gupta

**NUMERICAL METHODS**

Linear Algebraic Equations: Solution of simultaneous linear algebraic equations, Gaussian elimination, Thomas algorithm, Determination of inverse of a matrix: Gauss-Jordan method; Iterative solution of a set of simultaneous linear algebraic equations: Jacobi method, Gauss-Seidel method, Relaxation method.

Nonlinear algebraic equations: Single nonlinear equation: Bisection method, Successive substitution, Secant (Regula falsii) method, Newton-Raphson method, Determination of roots of a polynomial, Solution of simultaneous nonlinear algebraic equations: Successive substitution, Newton-Raphson method.

Regression: Method of Least Squares, Linear and Nonlinear Least Squares.

Interpolation/Extrapolation: Newton's Divided Difference Formulae, Lagrange Interpolation; Equispaced base-point methods - Newton's Forward Difference and Backward Difference Formula. Numerical Differentiation - based on interpolation formulae. Numerical Integration - Newton-Cotes formulae, Trapeziodal Rule, Simpson's Rule, Composite formulae

Ordinary Differential Equations - Initial Value Problem (IVP): Explicit methods: Adam-Bashforth techniques; Implicit methods: Adams-Moulton techniques; Predictor-Corrector Formulae; Runge-Kutta and Runge-Kutta-Gill methods.

Ordinary Differential Equations - Boundary Value Problem (BVP): Shooting Method, Finite Difference Methods

Partial Differential Equations: Elliptic, Hyperbolic and Parabolic PDEs; Nonlinear PDEs, Laplace's equation

Application of Finite Difference method for solution of Parabolic and Elliptic partial differential equations

*Books*
Numerical Methods for Scientific and Engineering Computation by M.K. Jain, S.R.K. Iyengar, R.K. Jain.
Numerical methods for engineers by Santosh K. Gupta.
Nonlinear Analysis in Chemical Engineering, Bruce A. Finlayson.

**MATHEMATICS –III**

Module V

Fourier Series and Integral Transforms:

Fourier series; Periodic functions; Trigonometric series of sine and cosines; Euler's formula; Even and odd functions; Dirichlet's conditions; Half range sine and cosine series; Fourier transform, definitions and properties; Inverse Fourier transform; Convolution; Laplace transform; Convolution; Z transform and properties.

Module VI

Ordinary Differential Equation (ODE) and Series solutions:

First order exact differential equation and first order linear differential equation; Second and higher order linear differential equations with constant coefficients; Euler and Cauchy equation; Method of variation of parameters; Ordinary point and regular singularity of a second order

linear differential equation; Series solutions; Solution of Legendre and Bessel's equations; Generating functions; Recurrence relations and their Orthogonal properties.

Partial Differential Equation (PDE):

First order PDE; Lagrange method; Second order PDE with constant coefficients and their classification to Elliptic, Parabolic and Hyperbolic type, Solution of PDE by method of separation of variables; Solution of one-dimensional wave and diffusion equation; Laplace equation of two dimensions.

**ELEMENTARY ELECTRONICS**

1. Introduction to electronics and electronic Systems, Semiconductor and devices like diodes, Zenner and Avalanche breakdown, rectifiers, filters and Voltage regulators,BJT and its characteristics in CB and CE configuration, FET, MOSFET,Transistor biasing. Small signal transistor amplifiers.

2. Integrated Circuits (ICs), Different types, fabrication of Integrated circuits, CVD techniques, Advantages and limitations of ICs. Operational Amplifiers- characteristics and some applications.

3. Digital Systems; Elements of Digital Circuits- AND, OR, NOT, NOR, NAND gates. Sequential logic and Flip-flops. Memory System and its application.

**PHYSICAL CHEMISTRY LAB – II**

I. Conductometric titration
II. Potentiometric / pH-metric titration
III. Verification of Beer's law
IV. Determination of specific rotation
V. Determination of CMC
VI. Analytical application of refractive index measurement
VII. Determination of decomposition voltage

**WORKSHOP PRACTICE – XII (Machine shop)**

Introduction to machine tools - lathes, drilling machines, shaping machines, planning machines, slotting machines, milling machines, grinding machines; machine shop work involving different operations by using the above mentioned machines through making of jobs.

Experiments on: Study of the speed structure of a lathe, study of apron mechanism and calibration of feeds in a lathe.

Study and grinding of various cutting tools.

**COMPUTER AIDED DRAFTING**

Introduction to a Computer Aided Drafting software, basic commands of 2D drafting, dimensioning, concept of layer, view ports, layouts, model space, paper space. blocks, attributes, accessing internal & external data base files, isometric drawing using isoplanes,3D-modelling,Introduction to Auto-Lisp.
Assignments. (Mode: Computer Terminal)

# Semester – 4

**CHEMICAL PROCESS CALCULATION**

Concepts of chemical similitude and scale up, Material balances: Fundamentals; Batch and flow processes, Steady-flow and unsteady processes, material balance calculations for single-unit and multiple-unit processes, material balance for reactive and non-reactive systems, processes with recycle and/or bypass with or without purge, material balance for combustion reactions, unsteady-state and transient processes. Energy balances: Introduction to energy balances, energy balances on closed and open systems - the steady-flow energy equation, mechanical energy balances, tables of thermodynamic data. Energy balances on nonreactive processes - state properties and hypothetical process paths employed for their estimation, energy balances for phase change operations, heat of mixing and heat of solution - energy balance for mixing and dissolution processes. Energy balances on reactive processes - heats of reaction, measurement and calculation of heats of reaction - Hess's Law, formation reactions and Heats of Formation, Heats of Combustion, Energy balances for combustion reactions - adiabatic reaction temperature, theoretical flame temperature. Combined material and energy balances including some typical industrial problems.

Flow sheeting- analysis of degrees of freedom with its importance in flow sheeting- recycle calculations; convergence

Unsteady state material and energy balances with special reference to batch and semi-batch reactive and non-reactive processes.

*Books*
Basic Principles and Calculation in Chemical Engineering by David M. Himmelblau.
Chemical Process Principles, O. A. Hougen, K. M. Watson, R. A. Ragatz.
Elementary Principles of Chemical Processes, R. M. Felder and R. W. Rousseau.

**MATERIAL SCIENCE AND ENGINEERING**

Metal extraction processes: Unit processes involved in extraction of metals from oxide and sulphide ores; Flow sheets for iron & steel, zinc, copper, lead, aluminum, titanium and nickel

Materials for construction pertaining to chemical processing and equipment: Classification – metals & alloys, ceramics, polymers, composites, nanostructured materials.

Properties – corrosion resistance, thermal resistance, catalytic properties

Specific application in Chemical Industries

**CHEMICAL ENGINEERING THERMODYNAMICS**

Application of thermodynamics to flow processes: flow through ducts, pipes, nozzle for compressible fluids; turbines, compression processes; ejectors.

Volumetric Properties of pure fluids: Cubic Equations of State (EOS); Virial EOS, Benedict-Web-Rubin EOS; Generalized compressibility factor correlation – acentric factor; Lee-Kesler method; Generalized virial coefficient correlation.

Thermodynamic property relations for homogenous phase of constant composition: Maxwell Relations, Relation between heat capacities; Relation of thermodynamic potentials with measurable properties; For pure species - Clapeyron equation; Kirchhoff relation, Residual properties and estimation from EOS, thermodynamic diagrams; fugacity and fugacity coefficient and estimation from EOS, Vapor/Liquid equilibrium, fugacity of compressed liquid; extension to gas mixtures.

Solution Thermodynamics: partial properties, relation between molar and partial properties, Gibbs'-Duhem equation, relation among partial properties, partial properties in binary solution; chemical potential, Ideal gas mixtures;
fugacity coefficient of species in solution and estimation, Ideal solution model, Lewis-Randall rule, Henry's Law; Excess property relations, Excess property and activity coefficient, nature of excess properties, Excess Gibbs free energy models; property changes of mixing; heat effects of mixing process.

Phase Equilibria: equilibrium and stability, chemical potential and phase equilibria; Gibbs' phase rule;
Vapor/Liquid equilibrium (VLE)- basic equations for low and high pressures VLE, Raoult's Law, Bubble point and dew point calculations; binary systems- Equilibrium for miscible, partially miscible and immiscible systems; estimation of excess Gibbs free energy model parameters from experimental data;
Liquid/Liquid equilibrium; Solid/liquid equilibria; Equilibrium adsorption of gases on solid; Osmotic pressure.

Chemical Reaction Equilibria: Extent of reaction; Equilibrium constant; Effect of operating conditions on equilibrium conversion; determination of equilibrium compositions for homogeneous gas-phase reactions - single and multiple reactions; liquid-phase reaction equilibria; phase rule for reacting systems.

*Books*

Introduction to Chemical Engineering Thermodynamics by J.M. Smith, H C Van Ness, M M Abbott.

Chemical Engineering Thermodynamics by Y V C Rao

**INTRODUCTION TO TRANSPORT PHENOMENA**

Introduction and overview: Importance of heat, mass and momentum transfer in chemical engineering operations using specific examples/case studies. difference between a thermodynamic process and transport process. Overview of transport mechanisms – Diffusion and Convection.

Diffusive transport : Convective transport : Natural convection and forced convection

Difference between unit operations and transport processes. Dimensional analysis: usefulness and limitations: Major three class of non-dimensional numbers based on their significance.

Momentum Transport

Newtonian and Non-Newtonian fluids: constitutive relationships. Shell momentum balance and its application to determine shear stress and velocity distribution for one dimensional one directional flow

Derivation of equation of continuity, equation of motion, Navier Stokes equation, Euler's equation for Cartesian coordinate system. Generalized vector form of equation of continuity and Navier Stokes equation. Fluid-solid, liquid-gas/vapor and liquid-liquid boundary conditions for fluid flow systems

Nondimensionalization of Navier stokes equation and nondimensional numbers (Reynolds number, Froude number, Strouhal number , Euler number) concept of scale up

One directional one dimensional steady flow: Laminar incompressible flow of film along an inclined plane, Incompressible laminar flow of fluid through slit made up of two parallel vertical plates, Coutte flow, flow through circular pipe, flow through annulus: Exact analytical solutions for shear stress profile and velocity profile, determination of average velocity and flow rates, net force acting on a surface for Newtonain fluid, Binghum plastic fluid, power law fluid. Boundary Layer theory over a flat plate:

Energy/ Heat Transport:

Derivation of Generalized equation for heat diffusion/conduction in solid. Fourier's law of heat conduction. Thermal Properties. Boundary and initial conditions: Steady state one dimensional heat conduction: Resistance to heat transport, multiple resistances in series and in parallel: Analysis for Plane wall, cylinders and spheres. Analysis of steady state heat conduction with heat source: electrical heat source, heat conduction with nuclear heat source (nuclear reactor) Transient heat conduction in solid: Lumped capacitance model, Definition of Biot number and validity of lumped capacitance model. Transient heat conduction with spatial Effects: Semi-infinite Solid: Solution using similarity variable/ Laplace transform: expression for temperature distribution and heat flux. Convective transport in flow system: Thermal boundary layer, definition of heat transfer coefficient, Nusselt number. Derivation of generalized two dimensional thermal boundary layer equation (with viscous heat generation) and boundary conditions: Analysis of Couette flow with heat transfer : Exact solution of velocity and temperate profiles

Mass Transport:
Definition of diffusion velocity, diffusive flux ($j_A$) and mass flux with respect to stationary coordinate ($n_A$), derivation of relationship between $n_A$ and $j_A$; Fick's first law and Mass Diffusion coefficient. Derivation of generalized species mass diffusion equation, boundary and initial conditions. Steady state Mass Diffusion without chemical reaction: Derivation of concentration profile, average concentration and mass flux: Counter diffusion and Diffusion through a 'stagnant' media. Steady State Mass diffusion with heterogeneous catalytic surface reaction, Steady State Mass diffusion with homogeneous chemical reactions,Transient Diffusion: Biot number for mass transfer, Lumped capacitance mode, Transient Diffusion with special variation: Fick's 2$^{nd}$ law, Semi infinite media: Analytical solution using similarity variable/ Laplace transform. Convective mass transfer: concentration boundary layer and definition of mass transport coefficient. Generalized two dimensional concentration boundary layer equations and boundary conditions.

**Boundary Layer Similarity**: Velocity, thermal and concentration boundary layers: Approximation
and Normalized convection transfer equations : Boundary layer similarity parameters, Functional form of the solution, Physical significance of Dimensionless Numbers, Boundary Layer Analogy: The Heat and Mass transport analogy: Evaporative cooling; The Reynolds Analogy, Chilton Colburn Analogy.

*Books*
Transport Phenomena by R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot
Momentum Heat and Mass Transfer by C. O. Bennett and J. E. Myres.
Fundamentals of Heat and Mass Transfer by Frank P. Incropera, David P. DeWitt

**MECHANICAL OPERATIONS**

Particulate Solids, particle characterization, sphericity, particle size distribution, mean particle size of solids.

Size Reduction of solids: Crushing, Grinding, Mechanism of size reduction, Energy for size reduction, Kick's law, Rittinger's law, Bond's law, Energy utilization; Method of operating crushers: free crushing, choke feeding, open circuit grinding and closed circuit grinding; Classification of size reduction equipment based on feed size and product size: Coarse crusher: jaw crusher, Blake Crusher, Intermediate crusher: Rolls, angle of nip, determination of roll diameter, fine grinding: Ball mills: factors influencing the size of the product, critical speed of rotation.

Size separation & gas cleaning:

Classification of different methods of separation based on particle size. Screen analysis

Motion of particles in a fluid: Drag, Stokes law regime, Newton's law regime, terminal velocity, free settling, hindered settling, accelerating motion of a particle in the gravitational field and in centrifugal field.

Separation of materials by size and by difference in density: Gravity settling, Working principle & design of Elutriator, double cone classifier, spitzkasten, Rake classifiers, Hydraulic Jig; Sedimentation: design of continuous thickener, role of flocculation and agglomeration

Centrifugal separators: Working principle and design of Cyclone separator: cyclone efficiency, hydrocyclone, centrifuge

Froth flotation and its application

Electrostatic precipitator

Filtration - Theory of filtration, Filter equipment: Filter press, leaf filter, continuous rotary filter; filter medium, filter aid, filter auxiliaries; Centrifuges and centrifugal filtration.

Mixing of solids, liquids and slurries**:** Mixing mechanism, Scale up of Stirred vessels, Power consumption in stirred vessel, flow pattern in stirred tank, Mixing Equipment: Mechanical Agitator, Extruder, Static mixer.

Pumping of fluids:

Pumping equipment for liquids- Reciprocating pump, Rotary pumps, Centrifugal pump: Characteristic curves, Cavitation, NPSH, Priming;

Pumping equipment for gases-Rotary blower and Compressors, centrifugal blowers & compressors, Power required for compression of gas, multistage compressors, compressor efficiency; Vacuum producing equipments

Material handling: storage of bulk solids- concept of sizing of bins; conveying of fluids, slurries and solids;

*Books*

Unit Operations in Chemical Engineering by Warren L. McCabe, Julian C. Smith and C. Smith.
Principles of Unit Operations by Alan S. Foust, Leonard A. Wenzel and Curtis W. Clump
Unit Operations by George G. Brown
Unit Operations of Chemical Engineering: vol-1 Mechanical Operation by R. S. Hirenmath and A.P. Kulkarni

**APPLIED NUMERICAL ANALYSIS LAB**

Application of Numerical techniques and program developments using any suitable language(FORTRAN 90, C/C++) for Solution of Linear and nonlinear algebraic equations, Function approximation, Solution of ODEs and PDEs.

**MACHINE DRAWING (Computer terminal mode)**

Stuffing Box, Pipe Joints, Valves, Tool head of shaping machine, Plummer Block, Engine Parts.

**ELECTRICAL ENGINEERING LAB**

Experiments to supplement the course on “Electrical Technology-B”.

# Semester – 5

**SEPARATION PROCESS – I**

Molecular diffusion, Convective and diffusive mass transfer, Mass-transfer coefficients, relation between mass transfer coefficients, Mass transfer coefficient in laminar and turbulent flow, Theory of mass transfer (Film theory, Penetration theory, Surface renewal theory), simultaneous mass and heat transfer.

Interphase mass transfer: Local two-phase mass transfer, Local overall mass transfer coefficient; material balances for steady state concurrent and countercurrent processes- dilute solution approximation; stages, stage efficiency, Murphree stage efficiency; cross flow and countercurrent cascades.

Equipment for Gas-Liquid Operations - Selection of equipment for mass transfer operation;
Gas dispersed equipment; Operating characteristics of Tray towers, Point and Murphree tray efficiency; overall efficiency; Liquid Dispersed equipment; End effect and Axial mixing.

Absorption (one component transferring, isothermal operation): equilibrium data representation; co-current operation and countercurrent operation, minimum liquid-gas ratio; countercurrent multistage operation; estimation of stages corrected for Murphree tray efficiency;
Continuous contact: HETP, number and height of gas, liquid and overall transfer units, graphical construction of transfer unit.

Humidification: humidity, percentage saturation, relative saturation, humid volume, humid heat, enthalpy, adiabatic saturation curve, wet bulb temperature, Psychrometric chart and its use; Design of water cooling towers, Dehumidification of air-water vapour mixture, recirculating liquid-gas humidification-cooling, Equipment.

Drying: Equilibrium data representation; Movement of moisture within the solid; Calculation of rate of drying in cross circulation drying, through circulation drying and continuous direct heat driers (high and low temperature); equipment.

*Books*

Mass Transfer Operations by Rober E. Treybal.
Principles of Unit Operations by Alan S. Foust, Leonard A. Wenzel and Curtis W. Clump.
Unit Operations in Chemical Engineering by Warren L. McCabe, Julian C. Smith and C. Smith.

**CHEMICAL REACTION ENGINEERING-I**

Kinetics of homogeneous reactions (*elementary and non-elementary*); autocatalytic Reactions; reversible reactions; interpretation of kinetic data; temperature and reaction rate.

Mole Balances, Stoicheometry (*Batch and Flow processes*), Isothermal Reactor Design (*Batch, CSTR, PFR*), constant and variable volume reactions, Ideal reactors for a single reaction, Space time, Damkohler number, Multiple reactor systems including reactor staging.

Semi-Batch Reactors, Recycle reactors: performance and optimum recycle ratio.

Multiple Reactions: design for irreversible series-parallel reactions; choice of reactors, selectivity and yield in specific combination of reactors.

Non-isothermal reactors: Overview of energy balance equation; temperature and pressure effects on single and multiple reactions, relative rates; design considerations; adiabatic reactors: operating line and design considerations.

Reversible reactions in non-isothermal reactors: van't Hoff equation; equilibrium constant as a function of temperature; specific design considerations for exothermic and endothermic reactions; optimum temperature progression in various types of reactors; Reversible exothermic reaction with inter-stage and cold-shot cooling.

Non-ideal reactors: Basics of non-ideal flow; contacting pattern; RTD: definitions of RTD functions; evaluation through tracer experiments (inputs: *step and pulse*); introduction to non-ideal reactor models: zero and one parameter models; calculation of conversion in non-ideal reactors.

*Books*
Chemical Reaction Engineering by Octave Levenspiel (3rd Edition)
Elements of Chemical Reaction Engineering by H. Scott Fogler (4th Edition)
Chemical Engineering Kinetics, J. M. Smith (3rd Edition)

## CHEMICAL TECHNOLOGY I

*Water for the chemical process industry and its treatment:* Boiler feed-water, Cooling tower water, Process Plant water, Treatment of water: lime-soda process, Flocculation, aeration, deaeration, ion-exchange
*Acid industries:* Sulfuric, hydrochloric and nitric.
*Chlor-Alkali industries:* Caustic soda, Sodium carbonate, Chlorine, Bleaching powder.
*Pulp and paper*
*Paints and Varnishes.*

*Cement.*
*Fertilizers:* Nitrogen fertilizers - synthetic ammonia, urea, ammonium chloride, CAN, ammonium sulphate. Phosphorous fertilizers - phosphate rock, phosphoric acid, superphosphate and triple super phosphate, MAP, DAP. Potassium fertilizers – potassium chloride and potassium sulphate.

*Books*
Shreve's Chemical Process Industries by George T. Austin
Dryden's Outlines of Chemical Technology for the 21st Century 3rd Edition

**PROCESS HEAT TRANSFER**

Conduction: Mechanism of heat transfer, Fourier's law, steady state heat transfer through composite slabs, composite cylinders and unsteady state heat transfer.- use of Gurney-Lurie chart.
Convection: Heat flow mechanism by convection, Individual & overall heat transfer coefficient, log-mean temperature difference, forced convection inside tubes and ducts - Dittus-Boelter equation, Reynold's analogy, Colburn analogy, Natural convection, condensation of single and mixed vapors, heat transfer to boiling liquids. Types of heat exchange equipment and design of heat exchangers; Shell-and-tube heat exchangers, Double-pipe heat exchanger,
Condenser and Reboile, Fin
Radiation: Concept of black body and laws of black body radiation, Kirchhoff's law, emissivity, radiant heat transfer between surfaces separated by non-absorbing media, radiation error in Pyrometry.
Evaporation: The mechanism of vaporization, single & multiple effect evaporators, types of evaporators with accessories, design calculations for evaporators and optimum number of effects, Thermo-compression evaporator.
Transient heat conduction in solid: Lumped capacitance model, Definition of Biot number and validity of lumped capacitance model.

*Books*
Heat Transfer by J.P. Holman
Process heat Transfer by Donald Q. Kern

**ENERGY ENGINEERING**

Introduction -Survey of different sources of energy and their utilization.

Fossil Fuels – Coal: characterization, coal beneficiation circuit**;** Petroleum based fuels and characterization:, Natural gas: Characterization, processing and distribution; Shale oil and gas

Processed Fuels - Charcoal, coke, water gas, producer gas, refinery gas, LPG, CNG, LNG and synthetic petrol.

Nuclear Fuels - Sources of nuclear fuels and introduction to nuclear reactions.

Solar Energy-photovoltaic cell, Effective utilization of solar energy for room heating, water heating and other industrial processes.

Wind energy, geothermal energy and tidal energy.

Energy from Biomass- bio-ethanol, biogas, bio-butanol, biodiesel, pyrolysis oil. Concept of biorefinery.

Energy utilization - Thermodynamic and economic aspects of utilization. Burners, stokers, and furnaces for combustion of various conventional fuels. Waste Heat Recovery – Recuperators. Fuel cell - working principle, application.

*Books*

Renewable Energy Resources: Basic Principles and Applications by G. N. Tiwari and M. K. Ghosal
Solar Energy: Principles of thermal Collection and Storage by S. P. Sukhatme
Elements of Fuels, Furnaces and Refractories by O. P. Gupta
Nuclear Reactor Engineering by Samual Glasstone and Alexander Sesonske
Handbook of Natural Gas Engineering, D. L. Katz.
Thermochemical Processing of Biomass, A. V. Bridgwater

**MOMENTUM TRANSFER AND MECHANICAL OPERATION LABORATORY**

Study of pipe fittings, valves and other equipment, pressure drop for flow through pipe line - valves and fittings, Pump characteristics, Flow measurement by orifice meter, venturimeter, rotameter, pitot tube, weirs. Pressure drop for flow through packed bed and fluidised bed, studies on crushing and grinding, screening efficiency. Studies on filtration and other mechanical operation.

**COMPUTER APPLICATIONS IN CHEMICAL ENGINEERING LAB**

Solution of chemical engineering problems using FORTRAN, C/C++, MATLAB, CHEMCAD or HYSIS

## PROCESS EQUIPMENT DESIGN AND DRAWING-I

Pipe flow network, Pressure vessel, Filtration unit, sedimentation unit, centrifuge, cyclone separator, agitated vessel

# Semester – 6

**PRINCIPLES OF MEASUREMENT AND INSTRUMENTATION**

Introduction: Need for measurement of Process variables, Classification of measurement errors (Deterministic and Probabilistic)
Steady state and Dynamic characteristics of instruments, Instrument calibration technique, Selection of instruments.
Process transducers and application:
Temperature Measurement - Thermocouple, RTD, Optical & Radiation pyrometer. Pressure measurement- manometers, instruments based on mechanical elastic element, strain gauge, electrical transducers, High vacuum and differential pressure measurement. Flow measurement- Constant and variable area flow meters, Anemometers, Open channel flow - Weirs, Special flow measurement devices, Granular solid flow measurement.
Level measurement - Direct and Inferential type instruments, Granular solid level measurement.
Chemical composition measurement based on - Optical properties, Thermal conductivity, para-magnetic properties, conductivity of solution, Combustion products, adsorption properties, Chomatography, Molecular and Atomic Properties.
Density, Viscosity and Humidity measurement.
Instrumentation Devices and Systems:
Controller - Pneumatic, electronic, analog and digital controller, self-tuning and multifunction controllers.
Actuators: Pneumatic, Hydraulic, Valve positioner.
Indicating, Recording and Data acquition devices.
Final controlling elements - Control valve and their types and characteristics, Valve sizing.
Industrial Instrumentation Systems:
Components, structure, specification, planning, monitoring and design, case study.

**PROCESS DYNAMICS AND CONTROL**

Introduction to dynamics of processes - dynamic characteristics as an extension of steady state behavior - examples, dynamic model of a process; SISO, MIMO and MISO processes – examples. Properties of Linear systems. Concept of deviation variables. Application of Laplace Transforms for dynamic characterization of processes – concept of Transfer function. Properties of transfer functions – additivity and multiplicity. Definition and characterization of some standard inputs/ forcing functions viz. step, ramp, pulse – rectangular and trapezoidal, impulse, sinusoidal, exponential etc. Characterization of First order, Pure Integrator and Second order (Interacting and non-interacting) systems in time domain and Laplace domain – standard forms of corresponding ODEs and Transfer Functions. Dynamic Responses of First Order, Second Order and Pure Integrator systems to some standard inputs/ forcing functions.
Nonlinearities in chemical process models, examples – linearization. Responses of linearized systems and comparison to actual nonlinear responses by numerical simulation. Systems with

dead time – non-polynomial transfer functions and use of Pade approximation for polynomial approximations to such transfer functions. First-order plus dead time (FOPDT) systems.
Stability – concept of BIBO stability. Pole-zero characterization of transfer functions of processes - location and movement of poles on complex s-plane and impact on stability. Transfer functions of processes with numerator dynamics.
Concept of feedback control of linear systems – control systems and their constituent elements, block diagram based representation, open-loop and closed-loop dynamics of controlled processes; effect of recycle on dynamics of chemical processes – examples.
Controllers – proportional, integral and derivative modes of control action - the PID Control Algorithm, P, PI and PID controllers – their dynamic characteristics and effects on the dynamics of controlled processes; Concept of offset.
Stability of dynamic systems - Routh-Hurwitz criteria; Root Locus method.
Selection and Tuning of Controllers - Methods based on FOPDT model and Process Reaction Curve (PRC); Integral Error Criteria; Direct Substitution Method; Model-independent methods based on field trials - Continuous Cycling and Frequency Response. Bode Stability Criterion. Nyquist Stability Criterion; Ziegler-Nichols and Cohen-Coon optimum controller settings.
Advanced Control Strategies – (Preliminary treatment only)- Ratio Control, Feed forward control, Cascade control, Selective Override control, Adaptive control. Computer Based Control.

*Books*
Process Dynamics and Control by Del E Seborg, Thomas F. Edgar and Duncan A. Mellichammp
Chemical Process Control: An Introduction to Theory and Practice by George Stephanopoulos

**SEPARATION PROCESS II**

Distillation: vapor-liquid equilibrium; steam distillation; single stage batch and flash distillation; multistage fractionating column (single feed, multi-feed and side stream) using McCabe Thiele & Ponchon-Savarit method; Azeotropic, extractive; Molecular distillation.

Liquid-liquid Extraction: Equilibrium data representation; Method of calculation for single stage, Multistage Crosscurrent and Counter-current operation for one component transferring and all three component transferring; Equipment.

Adsorption: Equilibrium data representation; Method of calculation for Single stage, multistage crosscurrent, multistage countercurrent adsorber(one and two component transferring); Fixed bed Adsorber - Break-through curves, Determination of time required to reach breakthrough point, length of unused bed; chromatography; Equipment.

Leaching: Mass transfer in leaching operation, Equilibrium data representation; Method of calculation for Single stage, Multistage Crosscurrent, Multistage Countercurrent Operation; Equipment.

Crystallization: Equilibrium data representation, mechanism of crystallization, Estimation of crystal size distribution (CSD) in idealized crystallizers (MSMPR), equipment.

*Books*
Mass Transfer Operations by Rober E. Treybal
Principles of Unit Operations by Alan S. Foust, Leonard A. Wenzel and Curtis W. Clump
Unit Operations in Chemical Engineering by Warren L. McCabe, Julian C. Smith and C. Smith

**CHEMICAL TECHNOLOGY II**

Petroleum Refining Operations: NG and LPG, Principles and details of Crude Distillation, Vacuum Distillation, Coking, Cracking, Catalytic reforming, Hydrotreatment and Merox.

Petrochemicals: Raw materials and principles involved in the production of petrochemical precursors - olefins and aromatics, Butadiene and typical intermediates from olefins and aromatics such as ethylene glycol, ethyl benzene, phenol, cumene.

Polymer industries: Plastics, rubbers, fibres, production of thermoplastic and thermosetting materials such as polyethylene, polypropylene, PVC, polyesters, phenolic resins and epoxy resins, natural and synthetic rubbers. Cellulose and cellulose products.

Synthetic detergents

Coal based chemical industries

Oils and fats: Fat-splitting, refining, bleaching, deodorization, applications, e.g. soap manufacture, glycerine manufacture

Sugar, Industrial fermentation and ethyl alcohol

Leather

*Books*
Shreve's Chemical Process Industries by George T. Austin
Dryden's Outlines of Chemical Technology for the 21st Century 3rd Edition
Modern Petroleum Refining Processes by Bhaskar Rao, B. K.
Petrochemical technology by Bhaskar Rao.

**OPTIMIZATION METHODS FOR CHEMICAL ENGINEERING**

Introduction to optimisation; Basic concepts; Formulation of objective function; functions, regions, necessary and sufficient conditions for an extremum of an unconstrained function.

One dimensional Search: Scanning and bracketing; Newton, quasi-Newton and secant methods, Region elimination method, Polynomial approximation methods.

Unconstrained multivariable optimization:
Direct methods-random search, grid search, univariate search, simplex method, conjugate search direction and Powell's method.
Indirect method- gradient and conjugate gradient methods, Newton's method, movement in search direction, secant method.

Linear programming: Basic concepts in linear programming; Graphical solution; Simplex method; Standard LP from obtaining first feasible solution.

Non-linear programming: Lagrange multiplier method; Quadratic programming; Penalty function and augmented Lagrangian methods; Successive quadratic programming; Optimization of dynamic processes.
Optimization of staged and discrete processes: Dynamic programming; Integer and mixed integer programming.

Application in design of separation process, chemical reactor and process plant.

*Books*
Optimization for Engineering Design – Algorithms and Examples by Kalyanmoy Deb
Optimization of Chemical Processes by Thomas F. Edgar, David M. Himmelblau, Leon Lasdon

## CHEMICAL REACTION ENGINEERING - II

Non-catalytic Heterogeneous Reactions: Selection of model: Progressive Conversion model and Unreacted core model; Determination of controlling step, Application to design.

Catalysis and Catalytic Reactors: overview of solid catalyzed reactions: rate equations for surface kinetics; mass transfer between the bulk fluid phase and external catalyst surface in isothermal reactors; pore and film diffusion resistances; deactivation and regeneration of catalysts.

Porous catalyst particles: Deriving the global reaction rate expression; determination of rate controlling step; effectiveness factor for flat-plate, cylindrical and spherical catalyst pellets.

Performance equation for catalytic reactors with porous catalysts; pressure drops in packed bed catalytic reactors; Heat effects in catalytic reactors; adiabatic packed bed catalytic reactors.

Biochemical reaction kinetics and bioreactors: Enzymatic Reaction: Michaelis-Menten Kinetics; Competitive and Non-competitive Inhibition.

Microbial Reaction: Microbial growth kinetics (Monod); substrate and product limiting scenarios for Batch, plug and Mixed flow, optimum operation of bioreactors.

Multiplicity: Steady state multiplicity in CSTRs.

*Books*
Chemical Reaction Engineering by O. Levenspiel (3rd Edition)
Chemical Engineering Kinetics by J. M. Smith (3rd Edition)
Elements of Chemical Reaction Engineering by H. S. Fogler (4th Edition
Reaction Kinetics for Chemical Engineers by S. M. Walas
Chemical Reactor Analysis and Design by K. B. Bishop and G. F. Froment

**REACTION ENGINEERING AND THERMODYNAMICS LAB**

Kinetic study in a batch reactor.
Kinetic study in adiabatic batch reactor.
Study of the performance of a mixed flow reactor under isothermal condition.
Study of the performance of a tubular reactor under isothermal condition.
Kinetic study of a mixed reactor.
Polymerization reaction study in a batch kettle.
Study on a immobilized enzyme Reactor.
Kinetic study of a gas-liquid reaction in a packed bed.
Kinetics of a combustion reaction.

**ENERGY ENGINEERING LAB**

Proximate analysis of coal
Properties of liquid fuels: Flash point & Fire point, Carbon residue, Viscosity & Viscosity Index, Distillation characteristics.
Hard groove grindability index of coal.
Calorific values of solid, liquid & gaseous fuels. Ors at analysis of gaseous mixture.
Washability of coal
Caking Index of coal, Swelling Index of coal.
Studies of operating character of solar collectors.
Studies on flame stability and burner characteristics.
Studies on properties of bio-mass.

**CHEMICAL ENGINEERING PROJECT - I**

Specific projects/designs will be assigned by the teachers concerned

# Semester – 7

**SEPARATION PROCESS III**

Specification of design variables: Stream variables, Adiabatic equilibrium stage, Equilibrium stage with heat addition, feed stream and side stream, Condenser and boiler, Combinations of elements by an enumeration algorithm

Multicomponent flash calculation: Isothermal flash calculation, Adiabatic flash calculation

Approximate methods for multicomponent – multistage separation: Design methods and simulation methods for multistage contactor, Fenske – Underwood – Gilliland (FUG) method for distillation, Multistage counter-current cascade – Group method for absorber and stripper, Kremser method, Horton and Franklin method, Edmister method (without derivation)

Rigorous method for multicomponent – multistage separation: Introduction to MESH equation, Classification of different method based on solution scheme, Thiele – Geddes method with theta ($\theta$) method of convergence,

Membrane Separation Process: Different types of membranes, module design, concentration polarization and other effects, characterization of membranes, process design

Classifications of different membrane separation processes: Pressure-driven membrane processes - microfiltration, ultrafiltration, nanofiltration and reverse Osmosis.

Other membrane separation processes - Dialysis, Electrodialysis, Pervaporation

Liquid membrane: Emulsion Liquid membrane, supported liquid membrane, New membrane separation processes like Membrane Distillation, Membrane Contactor and hybrid processes.

*Books*

Mass Transfer Operations by Rober E. Treybal
Transport Processes & Unit Operations by Chrislie J. Geankoplis.
Unit Operations in Chemical Engineering by Warren L. McCabe, Julian C. Smith and C. Smith
Membrane Handbook by W. Ho & K. Sirkar.
Equilibrium-Stage Separation Operations in Chemical Engineering by Ernest J. Henley, J. D. Seader

**MATHEMATICAL MODELLING IN CHEMICAL ENGINEERING**

Introduction: Mathematical Modeling of a process, Equation Organization, Development of Information flow diagram.

Development of Information flow diagram based on macroscopic mass, energy and momentum balance: Heating of a solution inside a well stirred tank, Temperature response of a slurry tank, Analysis of piping network, Consecutive reversible reaction in a constant volume batch reactor
Steady State Lumped system: Algebraic equations, Structural analysis and functionality matrix, determination of design variables
Unsteady state Lumped system: ODEs, Stiff ODEs.

Thermodynamic and Mass transfer Operations: Boiling in jacketed vessel, Batch distillation, Plate type absorption column, Binary distillation column

Heat Transfer Operations: evaporation of a sugar solution in an evaporator

Reaction kinetic System: Stirred Tank Reactor Modeling: Temperature effects in a stirred tank

Distributed parameter systems: microscopic balance, Heat conduction with chemical heat source, Mathematical Modeling for a Styrene monomer Tubular reactor.

Split Boundary Value Problem for Distributed systems- Tubular reactor with dispersion, Annular Chemical Reactor, Countercurrent heat exchanger

Stability analysis - multiple steady states, bifurcation theory and applications

Books:
Computational Methods in Process Simulation by W. Fred Ramirez
Mathematical Methods in Chemical Engineering by V. G. Jenson and G.V. Jeffreys
Mathematical Methods in Chemical Engineering: Matrices and Their Application by N. R. Amundson
Mathematical Methods in Chemical Engineering by S. Pushpavanam
Mathematical Methods in Chemical Engineering by A. Verma and M. Morbidelli
Applied Numerical Methods with Personal Computer by A. Constantinides

**INDUSTRIAL POLLUTION CONTROL ENGINEERING**

Definition of pollution
Air Pollution: Types of Pollutants, Sources of Pollutants, Classification of Pollutants: particulates, gaseous, hydrocarbons, CO, $SO_x$, $NO_x$, Criteria pollutants, GHGs and global warming, Control Devices for Particulate Contaminants: Gravitational Settling Chambers, Impact separator, centrifugal Collectors, Wet Collectors, Fabric Filters, Electrostatic Precipitators, Control Devices for gaseous Contaminants: Adsorption, Absorption, Venturi scrubber, Bio-scrubbers.

Water Pollution: Introduction, Water quality standards and parameters, Types of pollution, Wastewater Treatment: Pre-treatment of water—screening, degritting, filtration, coagulation and flocculation; Primary Treatment -- primary sedimentation and clarification; Secondary Treatment- types of microorganism, growth and food utilization, activated sludge process, biotrickling filters, ponds and lagoons, secondary clarification; Tertiary Treatment-- membrane separation processes, ion exchange.

Solid waste management: Landfilling, Bioremediation of soil, Waste to energy concept, incineration, Hazardous Waste Treatment: introduction, definition of hazardous waste, hazardous waste treatment facility, disposal of hazardous waste.

Anaerobic digestion: microbiology of anaerobic digestion, sizing of anaerobic digesters, characteristics of methane production.

**ADVANCED HEAT TRANSFER (ELECTIVE – I)**

General equation of heat conduction. Application of general heat conduction equation under steady state heat conduction with internal heat generation in large slab, cylinder, hollow cylinder etc. Transient heat conduction numerical and analytical methods for the solution of transient heat conduction problems. Series-parallel resistances and contact resistances in heat transfer concept of conduction shape factor, critical radices and optimum thickness of insulation.
Free convective heat transfer under different situations and application of dimensional analysis to estimate the convective heat transfer coefficients. Forced convective heat transfer in laminar-transition and Turbulent zone.
Heat transfer factor Reynolds Number plot. Analogy equation for Heat Momentum Transfer. Convective heat transfer in molten method. Boiling heat transfer with particular reference to Nucleate and film boiling and estimation of boiling heat transfer coefficient. Heat transfer from condensing vapors. Nusselt equation for film type condensation of vapors over vertical surfaces and inclined tubes.
Selection and design of condensers, single pass and multipass heat exchangers.
Radiation heat transfer. Estimation of view factors and emmisivity factors for

different situation. Radiation shield and radiation error in pyrometry.
Combined conduction, convention and radiation heat transfer. Convection and
Radiation heat transfer furnaces.

**ADVANCED NUMERICAL METHODS (Elective – I)**

Numerical solution of simultaneous linear algebraic equations: LU Decomposition – Dolittle algorithm, Matrix inversion using LU factorization, Iterative methods of solution – Convergence analysis, Eigenvalues & Eigen vectors: Fadder-Laverrier method, elementary similarity transformation, Householder's method, Given's method

Solution of non-linear equation (1D and multidimensional problem), Determination of roots of n-th degree polynomial equation, Different methods for solution of non-linear equations and convergence analysis

Interpolation & Approximation: Cubic-spline interpolation, Pade approximation, Hermite interpolation

Orthogonal polynomial – Legendre, Chebyshev, Hermite polynomial and their characteristics, Gaussian quadrature

Solution of ordinary differential equation (ODE): classification of ODEs – initial value problem (IVP), boundary value problem (BVP), Stiffness ratio, Different explicit & implicit methods for solution of IVP problem, Semi-implicit Runge-Kutta method, Error analysis, Gear algorithm, Stability analysis, Boundary value problem (BVP): Finite Difference (FD), Orthogonal Collocation (OC), Finite Element Method (FEM)

Partial Differential Equation (PDE): parabolic, elliptic and hyperbolic PDEs, Finite Difference (FD), Orthogonal Collocation (OC), alternating directional implicit (ADI) methods, Stability analysis

Book:

Non-linear analysis in Chemical Engineering by Bruce A. Finlayson
Numerical methods for engineers by Santosh K. Gupta

**ADVANCED FLUID DYNAMICS (ELECTIVE – I)**

Vector and Tensor Methods
The Physical Properties of Fluids
Kinematics of the Flow Field: Specification of the flow field, conservation of mass,
Analysis of relative motion near a point,
Expression for the velocity distribution with specified rate of expansion and vorticity,

Sources and Sinks, The voriticity distribution, velocity distribution with zero rate of expansion and zero vorticity.
Equations Governing Motion of a Fluid: Material Integrals in a moving fluid, The Equation of motion, The expression for the stress tensor, Constitutive relationships, Non-Newtonian Fluids, Navier Stokes Equation, Bernoulli's theorem for steady flow of a frictionless non-conducting fluid, Boundary conditions for real fluid, Fluid mechanics at the interface.
Flow of a Uniform Incompressible Viscous Fluid: Steady unidirectional flow, Unsteady unidirectional flow, Flow with circular streamlines, Flow fields in which inertial forces are negligible, Flow due to moving body at small Reynolds number, The viscosity of dilute suspension of small particles.
Flow at Large Reynolds Number: Vorticity dynamics, Kelvin's circulation theorem, vorticity laws for an inviscid fluid, Steady two dimensional flow in a converging or diverging channel.
Boundary Layers: Integral methods, Scaling, Blasius flow, Falkner-Skan flow, Separation of boundary layer
Transition and Turbulence: Turbulent flow fluctuating velocity, turbulent stress, mean fluctuating velocity, mixing length, Prandtl's and Karman's theories, theory of momentum transfer
Two phase flow conditions at gas liquid interface: equation for mean velocity of two phase streams, flow in their film, wave formation on surface, frictional losses.
Hydrodynamic instabilities in open and closed flows: Linear instability concept, Nonlinear instability concept

*Books*

An Introduction to Fluid Dynamics, G.K. Batchelo, Cambridge University Press, Indian Edition 1993, Reprint 1997.
Physical Fluid Dynamics, D. J. Tritton, Oxford Univ. Press., 1988.
Analysis of Transport phenomena, M. Deen, Oxford University Press, 1998

**ADVANCED TRANSPORT PHENOMENA (ELECTIVE – I)**

Derivation of equation of continuity, motion, Navier Stokes equation, stream function and vorticity; Theory of potential flow; Incompressible flow: Exact and approximate solution, Boundary Layer theory; Compressible flow;
Unsteady state heat conduction in solid; Derivation of Energy transport equation; Thermal boundary layer; Natural convection; Two phase flow;
Mass transfer theories; mass transfer with chemical reaction; concentration boundary layer; Analogy.

**ADVANCED MASS TRANSFER (ELECTIVE – I)**

Absorption with chemical reaction
Simulation of cascade processes
Multi-component Mass Transfer
Recent developments in separation processes

**INTERFACIAL SCIENCE AND ENGINEERING (ELECTIVE-I)**

Physics of surfaces
Surface and Interface- molecular origin, the work of cohesion and adhesion
Interaction forces and potential, chemical and physical interaction, classification of physical forces. Van der Waals force, interaction between surface and particles – Lifshitz theory, hydrodynamic flow effects in interfacial interactions
Electrostatics forces and electric double layer, DLVO theory, Boltzmann distribution, Debye length, specific ion adsorption, ion adsorption, Stern layer, Electrphoresis
Theory of capillarity – Young Laplace equation, capillary flow and spreading process, wetting and spreading, contact angle and its measurement technique, contact angle hysterisis, Thermodymanics of wetting, Young's equation, spreading coefficient
Equilibrium dynamics and stability of free liquid surfaces
Chemical equilibrium across a curved interface, generalized Kelvin equation, Oswald ripening, Capillary condensation, Theory of heterogeneous nucleation
Effects of solutes on surface tension, Adsorption, Gibbs surface excess, Gibbs adsorption equation, Adsorption isotherms, surfactant adsorption
Surfactants, self assembly thermodynamics, bilayers, vesicles, phase diagram
Stability of colloids – emulsions, microemulsions, foams, aerosols, polymers at Interface, Application involving various colloidal system.
Nnaotechnlogy: Nanostructured materials, Nanofabrication and material characterizations.

**MULTIPHASE FLOW (ELECTIVE – I )**

Importance of multiphase flow.
Principle of analysis of two-phase cocurrent gas-liquid flow, different flow patterns and their transitions.
Homogeneous and separated flow models.
Void fraction. Drift flux model. Frictional pressure drop analysis, methods of Lockhart – Martinelli, Chisholm, separate-cylinders, Chenoweth-Martin correlation. Integral analysis of annular flow pattern.
Vapour-liquid flow in heat transfer.
Fluid-particle flow systems.

**OPERATIONS RESEARCH (Elective I)**

Overview of operations research.

**(A) Deterministic Methods:**

Introduction to Linear Programming - The Simplex Algorithm, Dual Simplex Method, Primal -Dual computations, sensitivity analysis.

Transportation Model and its variants - Transportation algorithm, the Assignment model - the Hungarian method, the Transshipment model.

Network Models and Algorithms - Scope and definitions, Minimal spanning tree algorithms, Shortest route problem, Maximal flow model.

Advanced Linear Programming - Efficient Computational algorithms, Duality, parametric linear programming, Karmarkar Interior Point algorithm.

Goal Programming - Problem Formulation, Algorithms- Weighting Method and Preemptive Method.

Integer Linear Programming - illustrative applications (Sequencing - processing 'n' jobs through 'm' machines; the Travelling Salesman problem), Algorithms - Branch & Bound (B&B), Cutting-Plane, Zero-One Implicit Enumeration Algorithms.

Deterministic Dynamic Programming - Forward and backward recursion, applications - cargo-loading model, work force size model, equipment replacement model, investment model, inventory models.

Deterministic Inventory Models - Static and Dynamic 'Economic Order Quantity' (EOQ) models.

**(B) Stochastic Methods:**

Forecasting - Moving averages, exponential smoothing, regression.

Decision Analysis - Decision-making under certainty, under risk and under uncertainty.

Game Theory - Introduction, Optimal solution of two-person zero-sum games, solution of mixed strategy games.

Probabilistic Dynamic Programming - A game of chance, the Investment Problem.

Probabilistic Inventory Models - Continuous Review, Single-Period and Multi-Period models.

Queueing Theory - role of exponential distribution, pure birth and death models, generalized Poisson queueing model, specialized Poisson queues.

Simulation Modelling - Monte Carlo Simulation, Discrete Event Simulation.

Markovian Decision Processes.

*Books*

Operations Research by Hamdy A. Taha

Introduction to Operations Research by Billy E. Gillet

Principles of Operations Research by H. H. Wagner.

**CHEMICAL ENGINEERING PROJECT II**

Specific projects/designs will be assigned by the teachers concerned

## PROCESS EQUIPMENT DESIGN AND DRAWING-II

Distillation column, Cooling tower, Liquid-liquid extractor, Absorption column, Multi effect Evaporator, Heat exchanger network (HEN), Dryer Design, Heterogeneous Reactor

**SEMINAR - I**

**PROCESS INSTRUMENTATION & CONTROL LAB**

Testing of the characteristics of Pneumatic Control Valve; Measurement of liquid level by pressure bulb type level indicator and recorder; Testing of a Pressure Gauge; Studies on a Bubbler type Liquid level Measuring Device; Studies on the Dynamics and Two position Control of a level Control Set up; Studies on the dynamic and Control of Pressure of an Air Reservoir; Determination of Dynamic Model from the Response Characteristics of a Thermocouple; Dynamics and Temperature Control of a Hot Air Blower (Process Trainer).

# Semester – 8

**CHEMICAL PROJECT ENGINEERING & ECONOMICS**

Introduction to Chemical Plant Design; Functions of Project Engineer. Process selection and evaluation;
Essential Flow Diagrams for understanding chemical processes - Block Flow Diagrams (BFD), Process Flow Diagrams (PFD), Piping and Instrumentation Diagram (PID).
Plant Layout - Location of Chemical plant, raw materials and utilities.
Project Costs - Capital Costs and Manufacturing Costs - their estimation.
Engineering Economic Analyses - Return on Investments and the Time Value of Money, Simple and Compound Interest, Discrete and Continuous compounding, Inflation, Inflation-adjusted interest rates.
Cash Flow Diagrams - Discrete and Cumulative. Annuities - their present and future worth, discount factors. Depreciation of Capital Investment - Type of depreciation. Taxation, Cash Flow and Profit.
Profitability Analysis of Projects and Equipments - Discounted and non-discounted profitability criteria, Incremental Economic analysis, Evaluation of Process Equipment alternatives, Incremental Analysis for Retrofitting Facilities - Discounted and non-discounted methods.
Methods of cost calculations of chemical process equipment.
Optimum design of pipe line, lagging thickness, heat exchanger, distillation column, reactor, storage vessels, evaporators etc.
Scale-up - Introduction; Principles and theory; Concept of similarity - different types of similarity. Scale equations for common chemical engineering systems - applications and limitations.
Application of Scale-up techniques to the selection and specification of chemical process equipment - solid-liquid separations, reactors, heat exchangers etc. Limitations of scale-up.

*Books*
Plant Design and Economics for Chemical Engineers by Max S. Peters, Claus D. Timmerhaus.
Analysis, Synthesis and Design of Chemical processes by Richard Turton, Richard C. Bailie and Wallacce B. Whiting.

**CHEMICAL PROCESS SAFETY & RISK MANAGEMENT**

The Importance of Process Safety; Terminology, Safety Assurance, Safety Culture, Safety Assessment, Safety in Design and Operation.
The Concept of Risk – Definitions; Accepted and Imposed Risk; Perception of Risk, Acceptance Criteria, ALARP, Cost Benefit Analysis.
Measurement, Calculation and Presentation of Risk Estimates for Risk Indices, Individual Risk and Societal Risk.

Consequence Analysis – Source and Effect Models
Source Models – Discharge rate models; Flash and Evaporation; Dispersion Models;
Explosions and Fires – Vapour Cloud Explosions (VCE), Flash Fires, Physical Explosions, BLEVE and Fireball; Confined Explosions, Pool Fires, Jet Fires.
Effect Models – Toxicity Effects, Thermal Effects, Explosion Effects.

Event Probability and Failure Frequency Analysis –
Frequency Data from historical records;
The logic tree approach - Fault Tree Analysis (FTA) and Event Tree Analysis (ETA).
Quantification of Logic Trees – Introduction, Fractional Dead Time, Dependent Failure Analysis, Application of Failure Data to Fault Trees; Quantification of Event Trees.
Common Cause Failure (CCF) Analysis; External Events Analysis (EEA); Failure Mode and Effect Analysis (FMEA) – Methodology of FMEA, Criticality Analysis; Corrective Action and Follow-Up.

HAZOP – Introduction, Basic Concepts, Conducting HAZOP studies.

Human Reliability Analysis (HRA) - The role of the Operator, Control System Design, Human Error Assessment Methods, Application of HAZOP to Human Reliability; THERP – (Technique for Human Error Rate Prediction), HEP – Human Error Probability; HRAET – Human Reliability Assessment Event Tree.

*Books*

Process Safety Analysis by an Introduction by Bob Skelton. (IChemE, UK).
Guidelines for Chemical Process Quantitative Risk Analysis – AIChE – CCPS (Center for Chemical Process Safety).

**INDUSTRIAL MANAGEMENT**

Growth of Industries, Management thoughts and scientific management, Taylorism; Factory system of production, Introduction to management problems, Types of manufacture, Planning analysis and control aspects in industries. Types of business ownership, means of finance and business combinations, organization structures, committee organization, authority and responsibility, duty and span of control.

Plant location, factory buildings and physical facilities, plant layout, tools and techniques of plant layout, materials - handling arrangements. Product development, standardization, simplification and diversification. Functions of production, planning and control, production forecasting, production scheduling and network techniques, Gantt chart, CPM, PERT etc. Work study, job evaluation and merit rating; purchase system and inventory control. Inspection and quality control of systems, statistical quality control, maintenance and replacement policies for machine and equipments; decision making theories, breakeven analysis cost benefit analysis,

evaluation of financial and managerial efficiencies. Introduction to operational research techniques. Application of fuzzy logic in modern management concepts. Human relations in industry and labour compensation. Personnel management, provision of industrial legislations in India. Wage and salary administrations. Welfare and safety provisions, trade union acts. Study of environmental impacts and environmental laws.

**HIGH POLYMER ENGINEERING (ELECTIVE –II)**

Fundamental concepts of High polymers, classification of High polymers, polymerization methods, kinetics of course
Addition, Condensation and Ring opening polymerization, Reactor Design, Determination of Molecular weight and Molecular weight distribution, Rubbery State and compounding of natural and synthetic rubber, classification of polymer forming operations, Principles of Injection Moulding, Extrusion, Calendering, Blow moulding, Lamination.

**PETROLEUM REFINERY ENGINEERING AND PETROCHEMICALS (ELECTIVE-II)**

Origin, formation and composition of petroleum. Evaluation of crude oil. Properties and testing of petroleum products. Pretreatment of crude oil and crude oil distillation.

Fuel quality management of transportation fuels. Secondary conversion processes in petroleum refineries – cracking, alkylation, isomerisation, polymerization, hydrocracking, coking, visbreaking. Treatment and purification of petroleum products. Corrosion in refineries. Design of pipe-still heaters and multicomponent distillation systems.

Scope of petrochemical industry, Feedstock identification – conventional and alternate. Synthesis gas and chemicals from petroleum hydrocarbons. Polymers of olefins. Synthetic fibres. Synthetic rubber. Plastics, synthetic detergents, and petroleum coke & carbon black.

**APPLIED STATISTICS FOR CHEMICAL ENGINEERING (ELECTIVE-II)**

Fundamentals of Statistical Analysis
Concept of Histogram, Frequency polygon and other pictorial representations;
Central Tendency;
Dispersion measure;
Testing of hypothesis: Z, t, F, Chi-square distributions;
Annova Analysis of variant;

Contingency Test & goodness of fit;
Non parametric method ( H, U );
Nonlinear least square technique – parametric sensitivity;

Problems related to Chemical Processes.

**BIOENERGETICS AND BIOPROCESS ENGINEERING (ELECTIVE –II)**

Biochemical reaction engineering, Kinetics of homogeneous reactions, reaction mechanism, Temperature dependency from Arrhenius law, Interpretation of batch kinetic data, Kinetics of enzyme catalyzed reaction in free and immobilized states, Michaelis –Menten kinetics of substrate utilization, product formation and biomass production, Monod growth model and its various modifications with special reference to inhibition by substrate, product and toxic materials, structured and unstructured kinetic rate model, thermal death kinetics of cells and spores, bioreactors for suspension and immobilized cultures, solid-state fermentation, protein-protein and DNA-protein interaction, basics of genetic engineering, Chemical mechanisms of biological energy conversion in mitochondria and chloroplasts, application of bioprocesses in energy generation( generation of bioethanol, biodiesel, biogas etc., microbial fuel cell ), introduction to algal biotechnology, factors affecting algal growth, photo bioreactors, photosynthesis in high density medium.

**COMPUTATIONAL FLUID DYNAMICS (ELECTIVE-II)**

OVERVIEW OF CFD: Role of CFD, Problem solving in CFD, Components of CFD Softwares

GOVERNING EQUATIONS, Complete Navier-Stokes Equations, Complete Energy Equations Complete Mass conservation Equations, Parabolized Navier-Stokes Equations, Euler Equations, Turbulence Modeling

COSERVATION LAWS AND CONSERVATION FORM OF EQUATIONS
Conservative and non conservative forms, Source terms and boundary conditions, Approximation of Governing Equations, Finite difference methods, Finite Volume methods Finite Element methods

GRID GENERATION
Structured Grid generation, Unstructured Grid generation, Adaptive Grid generation

SOLUTION ALGORITHMS AND TECHNIQUES
LU decomposition, Approximate factorization, Relaxation algorithms, Hybrid Schemes

CFD METHODS FOR THE EULAR EQUATION
Linearization and Jacobian Matrix, Eigenvalues and Eigenvectors, Flux splitting methods

CFD METHODS FOR NAVIER-STOKES EQUATIONS
Beam-Warming algorithm, MacCormack's scheme, Upwind Techniques

PRESENTATION OF CFD RESULTS
INTRODUCTION PARALLEL COMPUTING

*Books*

Computational Fluid Dynamics by J. D. Anderson, McGraw-Hill.
Computational Fluid Mechanics and Heat Transfer by J.C. Tannehill, D.A.Anderson, R.H. Pletcher, Taylor and Francis.
Computational Fluid Dynamics by T. J. Chung, Cambridge University Press.

**ENVIRONMENTAL BIOTECHNOLOGY (ELECTIVE II)**

Basics of microbiology related to Environmental Biotechnology, Biofilm Kinetics, Suspended Floc, Dispersed Growth and Slurry Reactors, Fixed Film Reactors, Attached Growth Reactors, Immobilized Cell Reactors, Activated Sludge Process, Bulking and other Sludge Settling Problems, Lagoons, Aerobic Biofilm Processes, Trickling Filter and Biological Towers, Rotating Biological Contactors, Granular Media Filters, Fluidized Bed Circulating Bed Biofilm Reactors, Hybrid suspended growth/Biofilm processes, Nitrification. ANAMMOX process, Denitrification, Anaerobic Treatment by methanogenesis, Detoxification ofhazardous chemicals, Bioremediation, Ex-situ and In-situ applications., Degradation of polymers, Degradation of dyes, Tannery effluent, Semiconductor waste treatment, treatment of pulp and paper industry effluent, Desulfurization and aromatic removal of petroleum fractions. Bioremediation of water, soil and air.

**MODERN ENERGY ENGINEERING AND ENERGY MANAGEMENT (ELECTIVE-II)**

Concept of "waste to energy"; Thermo-chemical and biochemical conversion of Biomass; Kinetics of incineration, Pyrolysis and Gasification (low and medium Joule) of Biomass and polymeric Wastes; Design of incinerator, Green House effect of Incineration; Design of Updraft, downdraft and fluidized bed Gasifiers for Biomass;
Design of low temperature pyrolyser and Fast/Flash Pyrolyser; bio-diesel, Kinetics of Biogas generation from wastes; Design of Bio-digesters for the generation of Biogas; Gas Turbines and Dual-fuel IC engines for power generation from low and medium Joule gases; use of Natural gas for the substitution of liquid fuels; Dehydration and
Desulfurization processes of natural gas; gathering and transport of natural gas and Biogas; concept and operation of fuel cell.
Energy Management & Energy Planning. Definition & Objectives of Energy Management. Duties and responsibilities of energy managers and auditors. Energy Audit and Energy Monitoring. Integrated energy management— case studies. Maximizing System Efficiency

**CHEMICAL PROCESS DESIGN AND DRAWING**

Problem based on integrated chemical processes

**HEAT & MASS TRANSFER LAB**

Determination of heat transfer coefficient, Unsteady state heating in a jacketed vessel, Studies on heat loss from a pipe, Studies on heat exchanger performance, evaporator performance, Refrigerator performance, Determination of mass transfer coefficient, Experiment on batch distillation, Studies on distillation column performance, humidification column performance, dehumidifier performance, drier performance, Determination of drying rate.

**SEMINAR – II**

**GENERAL VIVA-VOCE**