

LIST OF ELECTIVES

Open Elective	ICH 711	Energy Resources and Utilization
Elective-I	ICH 704	Fuel and Combustion Technology
	ICH 705	Petroleum Refining Technology
	ICH 706	Nanotechnology
	ICH 707	Principles of Polymer Engineering
Elective-II	ICH 802	Process Integration
	ICH 803	Advanced Process Control
	ICH 804	Statistical Design of Experiments
	ICH 805	Mathematical Methods in Chemical Engineering
Elective-III	ICH 806	Fundamentals of Biochemical Engineering
	ICH 807	Advanced Separation Processes
	ICH 808	Colloids & Interface Science and Engineering
	ICH 809	Corrosion Science and Engineering

ICH-301

MATERIAL AND ENERGY BALANCE

UNIT I

Dimensions, system of units and their conversions, Mass and volume relations, Basic stoichiometric principles, limiting and excess reactants, Degree of completion, Conversion, selectivity, yield. Ideal gas law, Dalton's Law, Amagat's Law, Introduction to degrees of freedom analysis.

UNIT II

Vapor pressure of liquids and solids, Vapor pressure plot (Cox chart), Vapor pressures of miscible and immiscible liquids and solutions, Raoult's Law and Henry's Law. Humidity and saturation use of humidity charts for engineering calculations.

UNIT III

Material balance without chemical reactions and its application to unit operations like distillation, absorption etc. Material balance with chemical reaction Recycle, bypass and purging.

UNIT IV

Heat capacity of gases, liquids and solutions Heat of fusion and vaporization. Steady state energy balance for systems with and without chemical reactions. Calculations and application of heat of reaction combustion, formation, neutralization and solution. Enthalpy-concentration charts. Orsat analysis Calculation of theoretical and actual flame temperatures

UNIT V

Simultaneous material and energy balance. Introduction to Unsteady state material and energy balance.

BOOKS:

1. Hougen, O.A., Watson, K.M and Ragatz, R.A., " Chemical Process Principles Part-I ", John Wiley and Asia Publishing, 1970.
2. Himmelblau, D.M., "Basic Principles and Calculations in Chemical Engineering " ,sixth Edition, Prentice Hall Inc., 1996.
3. Felder, R.M. & Rousseau, R.W. "Elementary Principles of Chemical Processes ", 3rd edition. JohnWiley. (1999)
4. Bhatt, B.L., VORA, S.M., "Stoichiometry ", Tata McGraw-Hill, 1976.

UNIT I

Introduction : Types of fluids: Newtonian & non-Newtonian fluids, Compressible & incompressible fluids, Physical properties: Viscosity ,Vapor pressure ,Compressibility and Bulk modulus ,Surface tension ,Capillarity ,Surface Tension .Fluid statics: Pascal's law for pressure at a point in a fluid ,Variation of pressure in a Static fluid ,Absolute, gauge pressure & vacuum, Pressure Measurement : Barometers ,Piezo meters, Manometers :Simple U-tube manometer, Inverted U-tube manometer ,Manometer with one leg enlarged, Two fluid U-tube manometer, Inclined U-tube manometer, Pressure gauges and buoyancy

UNIT II

Fluid flow: Stream line ,Stream tube ,Steady & Uniform flows, One-dimensional & multidimensional flow ,Equation of continuity, Energy equation - Bernoulli's equation ,Momentum equation , Navier stokes equation, , Water Hammer ,Laminar and Turbulent flow, Compressible fluid flow, Two dimensional flow: Velocity potential, Potential function & Irrotational flow.

UNIT III

Boundary layer concepts: Introduction Development of boundary layer for flow over a flat plate Development of boundary layer for flow through circular pipe, Entry length ,Fully developed flow Boundary layer separation Flow of incompressible fluid in pipes: Laminar flow ,Hagen Poiseuille equation Friction factor Pressure drop in turbulent flow Velocity Distribution for turbulent flow Surface roughness Flow through non-circular pipes Flow through curved pipes Expansion losses, Contraction losses, Losses for flow through fittings ,Equivalent length of pipe fittings, Design of piping network

UNIT IV

Closed channel flow measurement: Venturimeter ,Orifice meter ,Venturi - Orifice Comparison, Pitot tube, Rotameter, Flow measurement based on Doppler effect, Hot wire and hot film anemometer ,Magnetic flow meter, Open channel flow measurement: Elementary theory of weirs and notches.

UNIT V

Transportation of fluids: Pump classifications: Suction, discharge , net pressure heads, specific speed and power calculations NPSH Characteristics and constructional details of centrifugal pumps ,Cavitation ,Priming, Positive displacement pumps: Piston pumps - single and double acting Plunger pumps Diaphragm pump, Rotary pumps, Gear pumps ,Lobe pumps Screw pumps ,Airlift pump Jet pump Selection of pumps, compressors types and operation, fans and blowers.

BOOKS:

1. McCabe and Smith, Unit Operations of Chemical Engineering: McGraw Hill
2. Coulson & Richardson , Chemical Engineering Vol. I: Pergamon, 1979 McGraw hill
3. Gupta, Vijay and S. K. Gupta, "Fluid Mechanics and its Applications", Wiley Eastern, New Delhi (1984).
4. Rajput, R. K., "Text Book of Fluid Mechanics", S. Chand and Co., New Delhi (1998).
5. Jain, A. K., "Fluid Mechanics including Hydraulic Machines", Khanna Publishers, Delhi (2007).
6. Bansal, R. K., "Fluid Mechanics and Hydraulic Machines", Laxmi Publications (P) Ltd., New Delhi (2005).

UNIT I

Particle Technology: Particle shape, particle size, different ways of expression of particle size, shape factor, sphericity, mixed particles size analysis, screens – ideal and actual screens, differential and cumulative size analysis, effectiveness of screen, specific surface of mixture of particles, number of particles in a mixture, standard screens industrial screening equipment, motion of screen, grizzly, gyratory screen, vibrating screen, trommels, sub sieve analysis – Air permeability method, sedimentation and elutriation methods.

UNIT II

Size Reduction: Introduction – types of forces used for comminution, criteria for comminution, characteristics of comminuted products, laws of size reduction, work index, energy utilization, methods of operating crushers – free crushing, choke feeding, open circuit grinding, closed circuit grinding, wet and dry grinding, equipment for size reduction – Blake jaw crusher, gyratory crusher, smooth roll crusher, tooth roll crusher, imp actor, attrition mill, ball mill, critical speed of ball mill, ultra fine grinders, fluid energy mill, colloid mill, cutters – knife cutter

UNIT III

Flow of Fluid Past Immersed Bodies: Drag, drag coefficient, pressure drop – Kozeny – Carman equation, Blake- Plummer, Ergun equation, fluidization, conditions for fluidization, minimum fluidization velocity, types of fluidization, application of fluidization, slurry transport, pneumatic conveying.

Motion of Particles Through Fluids: Mechanics of particle motion, equation for one dimensional motion of particles through a fluid in gravitational and centrifugal field, terminal velocity, drag coefficient, motion of spherical particles in Stoke's region, Newton's region and intermediate region, criterion for settling regime, hindered settling, modification of equation for hindered settling, centrifugal separators, cyclones and hydro cyclones.

UNIT IV

Sedimentation: Batch settling test and its application in design of continuous thickener, Coe and Clevenger theory, Kynch theory, thickener design, determination of thickener area.

Filtration: Classification of filtration, cake filtration, clarification, batch and continuous filtration, pressure and vacuum filtration constant rate filtration and cake filtration, characteristics of filter media, industrial filters, sand filter, filter press, leaf filter, rotary drum filter, horizontal belt filter, bag filter, centrifugal filtration – suspended batch centrifuge, filter aids, application of filter aids, principles of cake filtration, modification of Kozeny – Carman for filtration

UNIT V

Agitation And Mixing: Agitation equipment, Types of impellers–Propellers, Paddles and Turbines, Flow patterns in agitated vessels, Prevention of swirling, Standard turbine design, Power correlation and Power calculation, Mixing of solids, Types of mixers- change can mixers, Muller mixers, Mixing index, Ribbon blender, Internal screw mixer, Tumbling mixer.

Storage and Conveying of Solids: Storage of solids, Open and closed storage, Bulk and bin storage, Conveyors – Belt conveyors, Chain conveyor, Apron conveyor, Bucket conveyor, Bucket elevators, Screw conveyor.

BOOKS:

1. McCabe and Smith, Unit Operations of Chemical Engineering, TMH
2. W.L.Badger and J.T.Banchero, Introduction to Chemical Engineering, TMH (1979)

1. To determine and experimentally verify the type of flow using Reynolds apparatus
2. To determine and experimentally verify Bernoulli's equation using Bernoulli's apparatus
3. To find the friction losses in a Straight pipe, Pipe fittings and Valves & Bend pipe.
4. To determine and experimentally verify pressure drop in a packed bed by Ergun's equation.
5. To determine and experimentally verify minimum fluidization velocity in a fluidized bed
6. To determine and experimentally verify discharge coefficient of an orifice meter.
7. To determine and experimentally verify discharge coefficient of a Venturi meter.
8. To determine and experimentally verify discharge coefficient of a Rotameter.
9. To determine and experimentally verify discharge coefficient of a V notch in open channel.
10. To study the principle of a hydro-cyclone and find out the efficiency of separation.
11. To determine the average particle size of a mixture of particles by sieve analysis.
12. To determine and experimentally verify Rittinger's constant of Jaw crusher.
13. To determine reduction ratio, maximum feed size and theoretical capacity of crushing rolls.
14. To determine the effect of no. of balls on grinding in a Ball mill and comparison of its critical speed with the operating speed.
15. To find out enrichment of the coal sample using a froth flotation cell.
16. To determine and experimentally verify reduction ratio using Pulverizer.
17. To determine and experimentally verify the efficiency of separation of a cyclone separator.
18. To determine reduction ratio & experimentally verify reduction ratio of a Gyratory Crusher

UNIT I

Basic Concepts: Modes of heat transfer, conduction, convection and radiation, analogy between heat flow and electrical flow. **Conduction:** One dimensional steady state heat conduction, the Fourier heat conduction equation, conduction through plane wall, conduction through cylindrical wall, spherical wall, variable thermal conductivity, combined mechanism of heat transfer (conduction-convection-radiation systems), conduction through composite slab, cylinder and sphere, thermal contact resistance, critical radius of insulation, Extended surfaces: heat transfer from a fin, fin effectiveness and efficiency, Introduction to unsteady state heat conduction.

UNIT II

Convection: The convective heat transfer coefficient, thermal boundary layers for the cases of flow of fluid over a flat plate and flow through pipe, dimensionless numbers in heat transfer and their significance, dimensional analysis, Buckingham's pi theorem, application of dimensional analysis to forced convection and natural convection.

Forced Convection: Correlation equations for heat transfer in laminar and turbulent flows in a Circular tube and duct, Reynolds and Colburn analogies between momentum and heat transfer, heat transfer to liquid metals and heat transfer to tubes in cross flow..

Natural Convection: Natural convection from vertical and horizontal surfaces, Grashof and Rayleigh numbers.

UNIT III

Heat transfer by radiation: Basic Concepts of radiation from surface : black body radiation, Planks law, Wien's displacement law , Stefan Boltzmann's law, Kirchhoff's law, grey body, Radiation intensity of black body, View factor , emissivity, radiation between black surfaces and grey surfaces. Solar radiations, combined heat transfer coefficients by convection and radiation

UNIT IV

Boiling and Condensation: Pool boiling, pool boiling curve for water, maximum and minimum heat fluxes, correlations for nucleate and film pool boiling, drop wise and film wise condensation, Nusselt analysis for laminar film wise condensation on a vertical plate, film wise condensation on a horizontal tube, effect of non-condensable gases on rate of condensation.

Evaporation: Types of evaporators, boiling point elevation and Duhring's rule, material and energy balances for single effect evaporator, multiple effect evaporators: forward, mixed and backward feeds, capacity and economy of evaporators

UNIT V

Heat Exchangers: Types of heat exchangers, Principal Components of a Concentric tube & Shell-and-Tube Heat Exchanger, Baffles, Tubes and Tube Distribution ,Tubes to Tube sheets Joint, Heat Exchangers with Multiple Shell & tube Passes, Fixed-Tube sheet and Removable-Bundle Heat Exchangers, log-mean temperature difference, overall heat transfer coefficient, fouling factors, Design of double pipe and shell and tube heat exchangers.

BOOKS:

1. "Heat transfer principles and applications" Dutta, B.K., PHI
2. "Heat Transfer" Holman J.P., 9th Ed., McGraw Hill.
3. "Chemical Engineering:Vol-1", Coulson, J. M. & Richardson, J. F., 6th ed. Butterworth-Heinemann

4. "Principles of Heat Transfer", Kreith F. and Bohn M., 6th Ed., Brooks Cole
5. "Process Heat Transfer", Kern, D. Q McGraw Hill Book.
6. "Fundamentals of Heat and Mass Transfer", Incropera F.P. and Dewitt D.P 5th Ed., John Wiley.

ICH402 CHEMICAL ENGINEERING THERMODYNAMICS

UNIT I

Basic Concepts & First Law of Thermodynamics: Scope of thermodynamics, System & Surroundings, Properties -Force, Temperature & pressure, Equilibrium, Processes- Reversible & Irreversible, Work, Heat, Energy, Phase rule, Joule's Experiment, Internal energy, Enthalpy, Heat capacities, Application of first law to closed & open systems. Volumetric properties of pure fluids: PVT behavior of pure substances, Virial equation of state and its application, ideal gas and cubic equation of state, Generalized correlations for gases and liquids.

UNIT II

Second Law of Thermodynamics: Heat engine and its efficiency, Heat pump, Refrigerator, COP, Second law of Thermodynamics, Kelvin-Planck statement & Clausius Statement, Carnot's cycle and Carnot theorems, Clausius inequality, Entropy balance for open systems, ideal work and lost work, Principle of entropy increase. Thermodynamic properties of fluids: property relations for homogenous phases, Maxwell relations, various equations of enthalpy, entropy and internal energy.

UNIT III

Residual properties, two phase systems: Clapeyron equation, Estimation of thermodynamic properties by using graphs and tables. Solution thermodynamics Theory: Fundamental property relation, Chemical potential and phase equilibria, Partial properties, Ideal gas mixture model, fugacity and fugacity coefficient for pure species and in solution, Ideal solution model and excess properties

UNIT IV

Solution thermodynamics Application: Liquid phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing. Phase Equilibria: Nature of equilibrium, phase rule, VLE qualitative behavior, Simple Models for VLE, VLE by Modified Raoult's law and VLE from K-value charts, Equilibrium and stability, Osmotic Equilibrium and osmotic pressure, liquid- liquid equilibrium and solid liquid equilibrium.

UNIT V

The reaction coordinates, Application of the criteria for equilibrium to chemical reactions, the standard Gibbs free energy change and the equilibrium constant, effect temperature on equilibrium constant, evaluation of the equilibrium constants, Relation of equilibrium constants to composition, equilibrium conversions for reactions, phase rule for reacting systems

BOOKS:

1. "Introduction to Chemical Engineering Thermodynamics" by J.M. Smith and H.C. Van Ness, McGraw Hill International Ltd, 2005.
2. "Chemical Engineering Thermodynamics" by Y.V.C. Rao, Universities Press (India) Ltd. Hyderabad.
3. "Chemical and Process Thermodynamics", Kyle B.G., 3rd ed., Prentice Hall. 1999

4. Chemical, Biochemical & Engineering Thermodynamics by S. Sandler. 4th Ed., John Wiley & sons, 2006.
5. “Chemical Engineering Thermodynamics”, by Narayanan, K.V., Prentice Hall. 2007

ICH 403 INDUSTRIAL POLLUTION CONTROL AND WASTE MANAGEMENT

UNIT I

Introduction: Industrial Pollution and types of pollution from chemical process industries, Characterization of emission and effluents, Global consideration of environmental pollution, Environmental legislation - Water Act 1974, Air Act 1981, Environmental Protection Act 1986; Standards for liquid effluents from chemical process industries, air quality, nuclear radiation emission, noise emission.

UNIT II

Pollution Prevention: Process modification, Alternative raw material, Recovery of by product from industrial emission/effluents, Recycle and reuse of waste, Energy recovery and waste utilization, Material and energy balance for pollution minimization, Water minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.

UNIT III

Air Pollution Control: Air pollutants classification, Equipments for controlling particulate and gaseous pollutants, lapse rate, atmospheric stability, Dispersion models, Plume behavior, Stack design, Design of gravity settling chamber, cyclones, electrostatic precipitator, fabric filters and absorbers, Air pollution control for petroleum refineries and cement plants.

UNIT IV

Water Pollution Control: Waste water characteristics, Primary, secondary and tertiary treatments for wastewater, Anaerobic and aerobic treatment biochemical kinetics, Design of trickling filter, activated sludge systems, ponds and lagoons and aeration systems, Water pollution control for petroleum refineries, fertilizer industry, pulp and paper industry.

UNIT V

Solid Waste Management: Characterization of solid wastes-hazardous and non-hazardous wastes, Waste disposal and management laws and guidelines, Non-hazardous industrial wastes-treatment, disposal, utilization and management, Value-extraction from the wastes, Handling, storage and disposal of hazardous wastes, Waste disposal for nuclear power plants.

BOOKS:

1. Metcalf & Eddy, “Wastewater Engineering - Treatment and Reuse”, Revised by G. Tchobanoglous, F. L. Burton, and H. D. Stensel, 4th edition. Tata McGraw-Hill, 2003.
2. Mahajan S. P., Pollution control in process industries, Tata McGraw-Hill, 1985
3. Peavy H.S., Rowe D.R. and Tchobanoglous G., Environmental Engineering, McGraw-Hill edition, 1985
4. Kreith F. and Tchobanoglous G., “Handbook of Solid Waste Management”, 2nd Ed., McGraw Hill, 2002
5. Pichtel J., “Waste Management Practices: Municipal, Hazardous and Industrial”, CRC, 2005

6. Conway R.A. & Ross R.D., "Handbook of Industrial Waste Disposal", Van-Nostrand Reinhold, 1980
7. Vallero D., "Fundamentals of Air Pollution", 4th Ed., Academic Press, 2007

ICH 404

CHEMICAL PROCESS UTILITIES

UNIT I

Utilities, their role and importance in chemical plants; Water- Sources of water and their characteristics; Requisites of industrial water and its uses; Methods of water treatment-Chemical softening, Demineralization; Resins used for water softening; Reverse osmosis and membrane separation; Effects of impure boiler feed water & its treatments-Scale & sludge formation, Corrosion, Priming & foaming, Caustic embrittlement; Reuse and conservation of water; Water resource management.

UNIT II

Types of electrical process heating system- Dielectric heating, Resistance heating, Induction heating, Infrared heating Properties of steam; Problems based on enthalpy calculation for wet steam, dry saturated steam, superheated steam; Steam generation, distribution and utilization; Types of steam generator / boilers: water tube & fire tube; Solid fuel fired boiler; Waste gas fired boiler; Waste heat boiler; Fluidized bed boiler; Scaling, trouble shooting, preparing boiler for inspection; Design of efficient steam heating systems; steam economy, Steam condensers and condensate utilization, Expansion joints, flash tank design, Steam traps-Characteristics, selection and application. Heat-transfer fluids: Heat-transfer fluid systems-Liquid-phase, vapour-phase systems, Heat-transfer fluids-Steam, synthetic organic fluids, Silicone fluids, Glycol-based fluids, Water, Paraffinic and mineral oils, Molten salts, Desirable properties of a heat-transfer fluid- Thermal properties, Containment properties, Stability properties, Fire safety, Environmental and toxicological properties, Selection of proper heat-transfer fluid-Liquid or vapour phase heat transfer, Maximum temperature, Minimum temperature, Vapour pressure, Thermal stability, Heat-transfer fluid degradation, Heat-transfer mist explosion,

UNIT III

Importance of thermal insulation for meeting the process requirement, Insulation materials and their effect on various material of equipment, piping, fitting and valves etc. Insulation for high, intermediate, low and sub zero temperatures, including cryogenic insulation.

UNIT IV

Refrigeration and air conditioning: Refrigeration cycles, Different methods of refrigeration used in industry-Vapour compression, Vapour absorption: Lithium bromide (eco-Friendly); Different refrigerants-Monochlorodifluoro methane (R-22), Chlorofluorocarbons (CFC-Free), Secondary refrigerants: Brines; Simple calculation of C.O.P. Refrigerating effects.Properties of Air-water vapours; Use of humidity chart, Equipment used for humidification, dehumidification, Evaporative cooling, spray ponds, cooling towers

UNIT V

Pressure and Vacuum Systems: Compressors, blowers and vacuum pumps and their performance characteristics; Methods of developing vacuum and their limitations, material handling under vacuum, Piping systems; Lubrication and oil removal in compressors and pumps. Air filters, Air and gas leakage, Inert gas systems, compressed air for process, Instrument air.Storage and Movement of Utilities within Plant

BOOKS:

1. Nordell, Eskel, "Water Treatment for Industrial and Other Uses", Reinhold Publishing Corporation, New York.(1961).
2. Goodall, P. M., "The Efficient Use Of Steam" IPC Science and Technology (1980).
3. P. L. Balleney, Thermal Engineering, Khanna Publisher, New Delhi
4. S.T. Powel, Industrial water treatment, McGraw Hill, New York
5. Chattopadhyya, Boiler operations, Tata McGraw Hill, New Delhi

6. Perry R.H. and Green D.W., Perry's Chemical Engineer's Handbook, McGraw Hill, New York
7. R.C. Patel and C.J. Karmchandani, Elements of Heat Engines Vol –II,III, Acharya Book Depot., Vadodara
8. P .N .Ananthanarayan, Refrigeration & Air Conditioning, Tata McGraw Hill

ICH 451

HEAT TRANSFER OPERATION LAB

1. To find out the thermal conductivity of liquids.
2. To find out the thermal conductivity of a metal rod.
3. Find out the Heat Transfer Coefficient during drop wise and film wise condensation.
4. Find out the Heat Transfer Coefficient in a vertical and a horizontal condenser.
5. To find out the emissivity of a surface.
6. To find out the overall thermal conductance and plot the temperature distribution in case of a composite wall.
7. To find out the average heat transfer co-efficient of vertical cylinder in natural convection.
8. To find out the Stefan Boltzman"s constant and compare with the theoretical value.
9. To find out the relation between insulation thickness and heat loss.
10. To find out the overall heat transfer co-efficient of a double pipe heat exchanger.
11. To find out the overall heat transfer co-efficient of 1-2 shell & tube heat exchanger.
12. Study and operation of a long tube evaporator.

ICH 501

INSTRUMENTATION AND PROCES CONTROL

UNIT I

Introduction to Process control systems, Use of Laplace & Inverse Laplace Transformation in study of Process Dynamics & Control . Dynamic Modeling of a Process, Dynamic behavior of First order system, First order systems in series & second & higher order systems for various kind of inputs, Linearization of nonlinear systems, Transportation & Transfer Lag.

UNIT II

Classification of control systems ,Regulator & Servo control, Feed Forward & Feed backward control, Negative & Positive Feed back Control, Modes of control action, Controllers & Final control Elements, Reduction of Block & Signal Flow Diagrams.

UNIT III

Closed loop transfer function, Response of closed loop control system for various type of control actions. Concept of stability, Stability Criterion, Routh test for stability, Frequency response analysis and its applications.

UNIT IV

Principles of measurements and classification of process control instruments, Functional elements of an instrument, Static & Dynamic Characteristics of instruments, Transducers, Error analysis, Measurement of temperature: expansion thermometers, Resistance Thermometers, thermocouples, Thermistors, Pyrometers.

UNIT V

Measurement of pressure: Manometers, Elastic pressure transducers, Measurement of Vacuum, flow measurement: Inferential flow measurements, Quantity flowmeters, Mass flowmeters, Liquid level measurements: Direct methods, indirect methods, electrical methods, and viscosity.

BOOKS:

1. Coughnour and Koppel, " Process Systems Analysis and Control ", McGraw-Hill, New York, 1986.
2. S. K. Singh, " Industrial Instrumentation and Control ", Tata McGraw-Hill, 2008.
3. George Stephanopolous, " Chemical Process Control ", Prentice-Hall of India Pvt-Ltd., New Delhi, 1990.
4. Nakra and Chaudhary, " Instrumentation Measurement and Analysis", Tata McGraw Hill, 1978.
5. P. K. Sarkar, " Process Dynamics and Control", Prentice Hall India, 2014.
6. D. N. Considine, "Process Instrumentation and Controls Handbook", Considine, McGraw Hill.

UNIT I

Rate of Reaction, Elementary and non-elementary homogeneous reactions, Molecularity and order of reaction, Mechanism of reaction, temperature dependency from thermodynamics, collision and activated complex theories. Integral and differential methods for analyzing kinetic data, interpretation of constant volume reactor, zero, first, second and third order reactions, half life period, irreversible reaction in parallel and series, catalytic reaction, auto catalytic reaction, reversible reactions.

UNIT II

Interpretation of variable volume batch reactions for zero, first and second order reactions, Space-time and state-velocity, design equation for ideal batch, steady-state continuous stirred tank, steady-state plug flow reactors for isothermal reaction.

UNIT III

Design for single reactions, Size comparison of single reactors, Multiple reactor systems, plug flow/mixed flow reactors in series and parallel, reactors of different types in series, optimum reactor size, recycle reactor, autocatalytic reactions.

UNIT IV

Introduction to multiple reactions, qualitative discussion about product distribution, quantitative treatment of product distribution and of reactor size, selectivity, the side entry reactor, irreversible first-order reactions in series, Quantitative treatment: plug flow or batch reactor, Quantitative treatment: mixed flow reactor, Successive irreversible reactions of different orders, reversible reactions, irreversible series-parallel reactions, the Denbigh reactions and their special cases, Heat of reaction from thermodynamics, equilibrium constants from thermodynamics, General graphical design procedure for non-isothermal reactors, Optimum temperature progression, Heat effects: Adiabatic operations and non-adiabatic operations, Exothermic reactions in mixed flow reactors.

UNIT V

Residence time distribution of fluids in vessels, State of aggregation of the flowing systems, Earliness of mixing, Role of RTD, State of Aggregation and earliness of mixing in determining reactor behavior, E, F and C curves, Conversion in Non-ideal flow reactors.

BOOKS:

1. Levenspiel, O., "Chemical Reaction Engineering", 3rd edition, John Wiley (1998).

UNIT I

Distillation: Pressure-composition, Temperature-composition, Enthalpy-composition diagrams for ideal and non-ideal solutions; Raoult's law and its application; Maximum and minimum boiling mixtures; Concept of relative volatility; Single Stage Distillation-Differential distillation, Flash vaporization; Vacuum, molecular and steam distillations.

UNIT II

Continuous Distillation of Binary Mixtures: Multistage contact operations, Characteristics of multistage tower, McCabe-Thiele method, Ponchon-Savarit method, Concept of theoretical or ideal stage; Reflux ratio-maximum, minimum and optimum reflux ratio, Use of open steam, Tray efficiency, Determination of height and diameter of distillation column, Binary batch rectification with constant reflux and variable distillate composition, constant distillate composition and variable reflux; Principles of azeotropic and extractive distillation, Introduction to multicomponent distillation system.

UNIT III

Liquid-Liquid Extraction: Applications; Ternary liquid-liquid equilibria; Triangular graphical representation; Equipment used for single stage and multistage continuous operation; Analytical and graphical solution of single and multistage operation.

UNIT IV

Solid-Liquid Extraction: Applications; Solid-liquid equilibrium; Equipment used in solid-liquid extraction; Single and multistage crosscurrent contact and countercurrent operations; Overall stage efficiency; Determination of number of stages.

UNIT V

Adsorption: Description of adsorption processes and their application, Types of adsorption, Nature of adsorbents; Adsorption isotherms and adsorption hysteresis; Stagewise and continuous contact adsorption operations, Determination of number of stages, Equipments; Ion exchange-Equilibrium relationship; Principle of ion-exchange, techniques and applications,

BOOKS:

1. Treybal, R.E. "Mass Transfer Operations", 3rd ed. New York: McGraw-Hill, (1980).
2. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).
3. Sherwood, T. K., Pigford, R. L. and Wilke, C.R. "Mass Transfer" McGraw Hill (1975).
4. Geankoplis, C.J. "Transport Processes and Separation Process Principles", 4th ed., PHI Learning Private Limited, New Delhi (2012).

UNIT I

Concepts and definition, safety culture, storage of dangerous materials, Plant layout Safety systems, Occupational Safety and Health Administration (OSHA) incidence rate, Fatal accident rate (FAR), The accident Process: Initiation, Propagation, and Termination, Toxicology: Ingestion, Inhalation, Injection, Dermal Absorption, Dose versus response curves, Relative toxicity, Threshold Limit Values.

UNIT II

Industrial Hygiene: Government regulations, Identification, Industrial hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiation etc. Evaluation: Evaluating Exposures to volatile toxicants by monitoring, Estimating worker exposures to toxic vapors, Evaluating workers Exposures to dusts, noise.

UNIT III

Technology and process selection, Scale of disaster, Fire triangle, Distinction between fires and explosion, Definitions of Ignition, Auto-ignition temperature, fire point, flammability limits, Mechanical explosion, Deflagration and detonation, Confined explosion, Unconfined explosion, Vapors cloud explosions, Boiling liquid expanding vapor explosion (BLEVE), Dust explosion, shock wave, Flammability characteristics of liquids and vapors, Minimum oxygen concentration (MOC) and Inerting.

UNIT IV

Control of toxic chemicals, Storage and handling of flammable and toxic chemical, Runway reactions, Relief system risk and hazards management, Design to prevent Fires and Explosions: Inerting, Static Electricity, Explosion proof equipment and Instrument, Ventilation, sprinkler systems and Miscellaneous Design for preventing Fires and Explosion.

UNIT V

Hazards Identification: Process hazards checklists, Hazard Surveys, Hazard and Operability Studies (HAZOP), Safety reviews. Risk Assessment: Review of probability Theory, Interaction between process units, Revealed and unrevealed failure, probability of coincidence, Fault trees and Event trees, Hazard models and risk data. Tackling disasters, plan for emergency. Risk management routines, Emergency shutdown systems, Role of computers in safety, Prevention of hazard human element, Technology and process selection.

BOOKS:

1. Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with applications, Prentice Hall, Inc, 1990.
2. F. P. Lee's, Loss prevention in the process Industries, Volume 1 and 2 Butterworth, 1983.
3. Hoboken, N. J., Guidelines for Chemical Process Quantitative Risk Analysis, Wiley-Interscience, 2000.
4. R. W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982.
5. G. L. Wells, Safety in Process Plant Design, John Wiley and Sons Inc., 1980.
6. Fawcett, H.H. and W.S. Wood, Safety and Accident Prevention in Chemical Operations, 2nd Edition, Wiley-Interscience, New York, 1982.

UNIT I

Introduction of chemical process industry with reference to Indian resources, industries, trade and export potential, small scale industries and rural development. Preparation of process flow diagrams, Instrumentation diagrams and Process symbols. Introduction to the following industries lying emphasis on process flow sheet, material requirements, process conditions, material of construction and design aspects.

Carbohydrates: Introduction – Monosaccharides, Disaccharides and Polysaccharides, Important reactions, Starch and its derivatives, Cellulose, Structural aspects of cellulose, Derivatives of Cellulose - Carboxy Methyl Cellulose and gun cotton.

UNIT II

Sugar, Glucose, Production of sugar from sugar cane, Fermentation products such as Alcohol, Acetic acid, Citric acid and antibiotics. Dyes and Pesticides.

UNIT III

Soap, detergent and Surfactants, Glycerin, Fatty acids, Hydrogenation of edible oils, Pulp and paper, Recovery of chemicals from black liquor.

UNIT IV

Synthetic and natural fibers: Nylon, Dacron, Terylyne, Polyester and other new products, Viscose rayon, acetate rayon, natural and synthetic rubber, vulcanization and reclaiming of rubber, SBR, Thermosetting and Thermo Plastics (PVC, Polyethylene, Polyurethane, Teflon)

UNIT V

Petroleum and Petrochemicals: Crude oil distillation, Thermal conversion processes (cracking, coking and visbreaking), Catalytic conversion processes (fluid catalytic cracking, catalytic reforming, hydro cracking, alkylation, isomerisation and polymerization), Finishing processes, sulphur removal process, lube oil manufacture; Petrochemicals (ethylene, propylene, formaldehyde, methanol, ethylene oxide, ethanolamine, cumene, ethylene glycol, ethyl benzene)

BOOKS:

1. Dryden, C. E. "Outlines of Chemical Technology" (Edited and Revised by M.Gopal Rao and Sittig M.) East West Press Pvt. Ltd., New Delhi, 3rd Edition (1997).
2. Austin G. T., Shreve's Chemical Process Industries", 5th ed., McGraw Hill (1984).

ICH 551**INSTRUMENTATION AND PROCESS CONTROL LAB**

1. Transient response to single tank system with storage & Flow to (a) step change (b) impulse change in put.
2. Transient response of non interacting system in series.
3. Transient response of interacting system in series.
4. Study the operation of ON-OFF electronic temperature controller & determination of its performance to control the temperature of a system having capacity to store thermal energy.
5. Transient response of a CSTR System to step change.
6. Study the dynamics of parallel & counter flow shell & tube heat exchanger.
7. Controlling of Parallel Flow & counter flow STHE using digital PI controller to have desired output.
8. Dynamics characteristics of mercury & water manometers.
9. Study of control valve characteristics.
10. Study the performance of cascade control system & to maintain desired level in a tank, with flow.

ICH 552**CHEMICAL REACTION ENGINEERING LAB**

1. Study and operation of a packed bed reactor
2. Study of saponification reaction in a batch reactor
3. Study of esterification reaction in a batch reactor
4. RTD study in a CSTR
5. RTD study in a plug flow reactor
6. Study and operation of a plug flow reactor
7. Study and operation of a CSTR
8. Study and operation of a cascade CSTR
9. Study and operation of a coiled tubular reactor
10. Study and operation of an adiabatic batch reactor

UNIT I

Mass Transfer and Diffusion: Steady-state ordinary molecular diffusion: Fick's law of diffusion; Velocities in mass transfer, Equimolar counterdiffusion; unimolecular diffusion, Diffusion coefficients: Diffusivity in gas mixtures, diffusivity in liquid mixtures, Diffusivity in solids, One-dimensional, steady-state, molecular diffusion through stationary media, Mass transfer in turbulent flow: Reynolds analogy; Chilton-Colburn analogy; Other analogies, Models for mass transfer at a fluid-fluid interface: Film theory; Penetration theory; surface-renewal theory; film-penetration theory, Two-film theory and overall mass transfer coefficients

UNIT II

Absorption and Stripping: Equipments, Gas-liquid equilibrium, Henry's law, Selection of solvent, Absorption in tray column, Graphical and analytical methods, Absorption in packed columns, HTU, NTU & HETP concepts, Design equations for packed column

UNIT III

Humidification and Dehumidification: Vapour-liquid equilibrium and enthalpy for a pure substance, vapour pressure temperature curve, Vapour gas mixtures, Definition and derivations of relationships related with humidity, Fundamental concept of humidification, Dehumidification and Water cooling, Wet bulb temperature, Adiabatic and non-adiabatic operations, Evaporative cooling, Classification and design of cooling towers.

UNIT IV

Drying: Solid-gas equilibrium, Different modes of drying operations, Definitions of moisture contents, Types of batch and continuous dryers, Rate of batch drying, Time of drying, Mechanism of batch drying, Continuous drying,

UNIT V

Crystallization: Crystal geometry-Crystal-size distribution; Thermodynamic considerations-Solubility and material balances, Enthalpy balance; Kinetic and transport considerations-Supersaturation, Nucleation, Crystal growth; Equipment for solution crystallization-Circulating, batch crystallizers, Continuous, cooling crystallizers, Continuous, vacuum evaporating crystallizers; MSMPR crystallization model-Crystal-population balance; Precipitation; Melt Crystallization-Equipment for melt crystallization; Zone melting.

BOOKS:

1. Treybal, R.E. "Mass Transfer Operations", 3rd ed. New York: McGraw-Hill, (1980).
2. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).
3. Sherwood, T. K., Pigford, R. L. and Wilke, C.R. "Mass Transfer" McGraw Hill (1975).
4. Geankoplis, C.J. "Transport Processes and Separation Process Principles", 4th ed., PHI Learning Private Limited, New Delhi (2012).

UNIT I

Introduction to heterogeneous reactions, Fluid-fluid reactions :kinetics, the rate equation, The rate equation of straight mass transfer (Absorption) from gas to liquid, Rate equation for Mass Transfer and Reaction, Instantaneous reaction with respect to mass transfer- Different cases, Review of the Role of the Hatta modulus, Clues to Kinetic Regime from Solubility Data, Fluid-fluid reactors Design: Factors to consider in selecting a contactor, Straight mass transfer-Plug Flow Gas/Plug Flow Liquid-Countercurrent flow in a Tower, Mass Transfer plus not very slow reaction: Different cases.

UNIT II

Fluid-solid reactions: kinetics, Selection of a model, Progressive-conversion model, Shrinking-core Model, Comparison of Models with real situation, Shrinking core model for spherical particles of unchanging size, Diffusion through gas film controls, Diffusion through ash layer controls, Chemical reaction controls, Rate of reaction for shrinking spherical particles, Chemical reaction controls, film diffusion controls, Extensions, Particles of different shape, Combination of resistances, Limitations of shrinking core model, Determination of the rate controlling step, Fluid-particle reactors: Design, Particles of a single size, plug flow of solids, Uniform Gas composition, Mixture of particles of different but unchanging size, Plug flow of solids, Uniform gas composition, Mixed flow of particles of a Single Unchanging size, Uniform Gas Composition, Mixed flow of a size mixture of particles of Unchanging size, Uniform Gas Composition, Instantaneous Reactions.

UNIT III

Nature of catalysis, Adsorption isotherms, Physical properties of catalysts, preparation, testing and characterization of solid catalysts, catalyst selection, catalyst poisoning and mechanisms of catalytic reactions.

UNIT IV

Reaction and diffusion within porous catalysts, effectiveness factor, heat effects during reaction, Experimental methods for finding rates, design of solid catalytic reactors.

UNIT V

Packed bed reactor, Staged Adiabatic Packed Bed Reactors, Staged Mixed Flow Reactors, Bubbling fluidized bed reactor, Hydrodynamic Flow Models, the K-L Model for Bubbling fluidized bed reactor.

BOOKS:

1. Levenspiel, O., "Chemical Reaction Engineering", 3rd edition, John Wiley, (1998).
2. Smith, J, M, "Chemical Engineering Kinetics", 3rd edition, McGraw-Hill (1990).

UNIT I

Introduction: Classification of engineering materials, properties of Ferrous metals, Non ferrous metals, alloys & Ceramic materials Structure-Property relationship in materials. Deformation of Materials-Fracture: Elastic deformation, Plastic deformation, Creep, Visco-elastic deformation, Different types of fracture, Corrosion And Prevention: Direct Corrosion, electro-chemical corrosion, Galvanic cells, High temperature corrosion, Passivity, factor influencing corrosion rate, Control and of corrosion-modification of corrosive environment, Inhibitors, Cathodic protection, protective coatings. Corrosion charts, Metal forming techniques (bending, Rolling, Forming) & Metal joining techniques – welding (Gas of Arc & Electric) for various types such as Butt, Lap, fillet, corner. Inspection of vessel by radiography

UNIT II

Pressure Vessels: Type of pressure vessels, Thin cylinder theory for internal pressure. Code & standard for pressure vessels (IS:2825: 1969), Design considerations, classification of pressure vessels as per codes, design of cylindrical and spherical shells under internal and external pressure, selection and design of closures and heads such as Flat, hemispherical, tori-spherical, elliptical & conical.; Introduction to compensation for opening such as nozzles & manholes etc ; .

UNIT III

Flanges: Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges. Inspection and testing of vessels, heads and flanges as per code specifications. **Piping:** Pipe thickness calculation under internal and external pressure, introduction to flexibility analysis of piping system

UNIT IV

Tall Tower Design: Design of shell, skirt, bearing plate and anchor bolts for tall tower used at high wind and seismic conditions.

Supports: Design of lug support and saddle support including bearing plates and anchor bolts.

UNIT V

Storage Tanks: Introduction to Indian standards, filling and breathing losses; classification of storage tanks; Design of liquid and gas storage tanks with and without floating roof. High-pressure vessels, Fundamental equations, Compound vessels, Liquid storage tanks, Mechanical design of centrifuges, Centrifugal pressure, Bowl and spindle motion: critical speed.

BOOKS:

1. Brownell L. E. and Young H. E., "Process Equipment Design", John Wiley and Sons.2004
2. Bhattacharya B. C., "Introduction of Chemical Equipment Design", CBS Publisher.2003
3. I.S.:2825-1969, "Code for Unfired Pressure Vessels", Bureau of Indian Standards.1969
4. I.S.:803-1962, "Code of Practice for Design, Fabrication and Erection of Vertical Mild Steel Cylindrical Welded Oil Storage Tanks", Bureau of Indian Standards.1962
5. Moss D. R., "Pressure Vessel Design Manual", 3rd Ed., Gulf Publishers.2004
6. Annartone D., "Pressure Vessel Design", Springer-Verlag2007
7. M.V.Joshi and V.V.Mahajani, "Process Equipment Design "Macmillan India
8. J.M.Coulson, J.F.Richardson and R.H.Sinnott," Chemical Engineering Volume 6- Design"Pergamon Press.

UNIT I

Introduction to process optimization; formulation of various process optimization problems and their classification. Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.

UNIT II

Optimization of one dimensional functions, unconstrained multivariable optimization- direct search methods. Bracketing methods: Exhaustive search method, Bounding phase method Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic estimation method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method. Root-finding using optimization techniques.

UNIT III

Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers, Direct search for constraint minimization: Variable elimination method, complex search method.

UNIT IV

Linear Programming: Graphical solution, Primal Simplex method, Artificial starting solution, Dual Simplex method, Primal-Dual relationship, Duality, Sensitivity analysis. Revised Simplex method.

UNIT V

Transportation problem, Optimization of staged and discrete processes. Dynamic programming, Introduction to Specialized & Non-traditional Algorithms.

BOOKS:

1. T.F.Edgar and D.M.Himmelblau, "Optimization of Chemical Processes", Mc Graw Hill, International editions, chemical engineering series, 1989.
2. G.S. Beveridge and R.S. Schechter, "Optimization theory and practice", Mc Graw Hill, Newyork, 1970.
3. Hamdy A. Taha, " Operation Research", Pearson, 2008

UNIT I

Introduction of chemical process industry with reference to Indian resources, industries, trade and export potential, small scale industries and rural development. Preparation of process flow diagrams, Instrumentation diagrams and Process symbols. ; Introduction to the following industries lying emphasis on process flow sheet, material requirements, process conditions, material of construction and design aspects.

Chlor-alkali industry: Common salt, Caustic soda and Chlorine, Soda Ash, Hydrochloric acid.

UNIT II

Sulfur and Phosphorus Industry: Sulfur and sulfuric acid, Oleum, Phosphorus, Phosphoric acid and super phosphates

UNIT III

Nitrogen Industry: Ammonia, Nitric acid, Urea and other nitrogen fertilisers, Mixed fertilisers (NPK, KAP, DAP, Nitrophosphate), Bio fertilizers.

UNIT IV

Industrial Gases: Oxygen, Nitrogen, Hydrogen, Carbon dioxide, Inert gases, Synthesis gases

UNIT V

Electrothermal industries, Aluminum, Magnesium, Lithium, Titanium etc., Electro-chemical sources of energy and storage, Fuel cells, Cement.

BOOKS:

1. Dryden, C. E. "Outlines of Chemical Technology" (Edited and Revised by M.Gopal Rao and Sittig M.) East West Press Pvt. Ltd., New Delhi, 3rd Edition (1997).
2. Austin G. T., Shreve's Chemical Process Industries", 5th ed., McGraw Hill (1984).
3. Faith, W. L., Keyes, D. B. and Clark, R. L., "Industrial Chemicals" John Wiley.(1975).
4. Kirk and Othmer, "Encyclopaedia of Chemical Technology" Wiley (2004).

1. Determination of diffusivity of acetone in air.
2. Determination of mass transfer coefficient in an agitated vessel.
3. Determination of mass transfer coefficient for steady state surface evaporation of water at different temperature.
4. Determination of mass transfer coefficient in a wetted wall column.
5. Determination of T-x-y diagram for a binary batch distillation.
6. Verification of *Rayleigh equation* in a binary batch distillation process.
7. Verification of steam distillation equations.
8. Determination of ternary curve for the system acetic acid-water-carbon tetrachloride.
9. Determination of distribution coefficient of a solute in two immiscible liquids.
10. Solid-Liquid extraction – Soxhlet's experiment.
11. Liquid - liquid extraction in packed bed.
12. Determination of adsorption kinetics and isotherm at solid-liquid interface.
13. Determination of the rate of drying in a tray dryer.
14. Estimation of efficiency of the fluidized bed dryer

ICH 711 (OPEN ELECTIVE) ENERGY RESOURCES AND UTILIZATION

UNIT I

Energy Scenario: Indian and global, energy crisis, Classification of various energy sources, Renewable and non-renewable energy sources, Remedial measures to some energy crisis. Energy Conservation Energy: Biogas plants and their operation, Biomass and its conversion routes to gaseous and liquid fuels. Wind energy, its potential and generation by wind mills.

UNIT II

Alternative Sources of Energy : Fuel cell ,Solar Energy : Photo thermal and photovoltaic conversion and utilization methods , solar water heating , cooking , drying and its use for other industrial processes ,solar cells their material and mode of operation . direct and indirect methods solar energystorage , sensible heat and latent heat storage materials Solar ponds .Bio energy, biogas plants and their operation , biomass and its conversion roots to gaseous and liquid fuels ,wind energy , its potential and generation by wind mills.

UNIT III

Hydroelectric potential, its utilization & production, Geothermal energy its potential status and production, Nuclear energy : Status, nuclear raw materials, nuclear reactors and other classification, Generation of Nuclear power, Nuclear installations in India and their capacity of generation, Limitations of nuclear energy, Reprocessing of spent nuclear fuel, Cogeneration of fuel and power, Energy from tidal and ocean thermal sources, MHD systems.

UNIT IV

Fossil and Processed Fuel: Coal its origin and formation, Coal analysis, Coal classification, Coal preparation, Coal washing and coal blending, Coal carbonization, Treatment of coal gas and recovery of chemical from coal tar, Coal gasification, liquid fuel synthesis from coal, CBM.

UNIT V

Petroleum crude , Types of crude ,emergence of petroleum products as energy, Gaseous Fuels: Natural gas, Water gas, producer gas, L.P.G., bio- gas, coke oven gas, blast furnace gas, LNG ,CNG, Gas hydrates ,GTL Technology (gas to liquid), Biodisel.

BOOKS:

1. Brame J.S.S. and King J.G., Edward Arnold "Fuel Solid, Liquid and Gases" Edward Arnold (1967).
2. Sukhatme S.P, "Solar Energy - Principles of Thermal Collection and Storage", 2nd Ed., Tata McGraw- Hill.,(1996).

UNIT I

Introduction to mathematical modeling; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes; Classification of models: Linear vs. Non linear, Lumped parameter vs. Distributed parameter; Static vs. Dynamic, Continuous vs. Discrete; Numerical Methods: Iterative convergence methods, Numerical integration of ODE- IVP and ODE-BVP.

UNIT II

Concept of degree of freedom analysis: System and its subsystem, System interaction, Degree of freedom in a system e.g. Heat exchanger, Equilibrium still, Reversal of information flow, Design variable selection algorithm, Information flow through subsystems, Structural effects of design variable selection, Persistent Recycle.

UNIT III

Simple examples of process models; Models giving rise to nonlinear algebraic equation (NAE) systems, - steady state models of flash vessels, equilibrium staged processes distillation columns, absorbers, strippers, CSTR, heat exchangers, etc.; Review of solution procedures and available numerical software libraries.

UNIT IV

Steady state models giving rise to differential algebraic equation (DAE) systems; Rate based approaches for staged processes; Modeling of differential contactors – distributed parameter models of packed beds; Packed bed reactors; Modeling of reactive separation processes; Review of solution strategies for Differential Algebraic Equations (DAEs), Partial Differential Equations (PDEs), and available numerical software libraries. Introduction to unsteady state models and their applications.

UNIT V

Simulation and their approaches, Modular, Sequential, Simultaneous and Equation solving approach, Simulation softwares and their applications, Review of solution techniques and available numerical software libraries. Review of thermodynamic procedures and physical property data banks.

BOOKS:

1. Luyben W.L., "Process Modeling, Simulation, and Control for Chemical Engineering", Mc Graw Hill.
2. D. F. Rudd and C. C. Watson, "Strategy of Process Engineering", Wiley international.
3. M.M. Denn, "Process Modelling", Wiley, New York, (1990).
4. A. K. Jana, "Chemical Process Modelling and Computer Simulation", PHI,(2011)
5. C.D. Holland, "Fundamentals of Modelling Separation Processes", Prentice Hall, (1975)
6. Hussain Asghar, "Chemical Process Simulation", Wiley Eastern Ltd., New Delhi, (1986)

UNIT I

Newton's law of viscosity, non-Newtonian fluids, pressure & temperature dependence of viscosity, estimation of viscosity from critical properties. Shell momentum balances, boundary conditions, flow of a falling film, flow through a circular tube, flow through annular, creeping flow along a solid sphere.

UNIT II

Time derivatives, The equation of continuity, the equation of motion, the equations of change in curvilinear, co-ordinates, use of the equations of change to set up steady flow problems.

UNIT III

Unsteady viscous flow, flow near a wall suddenly set in motion Boundary layer theory.

UNIT IV

Shell energy balances, temperature profiles, average temperature, energy fluxes at surfaces, Equations of change (non-isothermal), equation of continuity, equation of motion for forced and free convection, equation of energy (non-isothermal).

UNIT V

Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity, Maxwell's law of diffusion. shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with heterogeneous chemical reaction, Diffusion with homogeneous chemical reaction, Diffusion in to a falling liquid film.

BOOKS:

1. Bird, R. B., Stewart, W. E. and Lightfoot, E. N., "Transport Phenomena", 2nd edition John Wiley (1960).
2. Bannet, C. O. and Myers J. E., "Momentum Heat and Mass Transfer" Tata McGraw Hill, (1973)..
3. RS Broadkey dan HC Hersey, "Transport Phenomena: A Unified approach", McGraw-Hill Book, (1988).

UNIT I

Introduction , Basic design procedure and theory , Heat exchanger analysis: the effectiveness NTU method , Overall heat-transfer coefficient , Fouling factors (dirt factors) ,Shell and tube exchangers: construction details , Heat-exchanger standards and codes ,Tubes , Shells , Tube-sheet layout (tube count) ,Shell types (passes) , Shell and tube designation ,Baffles , Support plates and tie rods , Tube sheets (plates) ,Shell and header nozzles (branches) ,Flow-induced tube vibrations ,Mean temperature difference (temperature driving force) , Shell and tube exchangers: general design considerations , Fluid allocation: shell or tubes ,Shell and tube fluid velocities ,Stream temperatures , Pressure drop ,Fluid physical properties ,Tube-side heat-transfer coefficient and pressure drop (single phase) ,Heat transfer , Tube-side pressure drop ,Shell-side heat-transfer and pressure drop (single phase) ,Flow pattern , Design methods ,Kern's method ,Bell's method , Shell and bundle geometry ,Effect of fouling on pressure drop , Pressure-drop limitations.

UNIT –II

Condensers ,Heat-transfer fundamentals , Condensation outside horizontal tubes ,Condensation inside and outside vertical tubes , Condensation inside horizontal tubes , Condensation of steam , Mean temperature difference , Desuperheating and sub-cooling Condensation of mixtures Pressure drop in condensers , Design of forced-circulation reboilers , Design of thermosyphon reboilers ,Design of kettle reboilers , Heat transfer to vessels ,Jacketed vessels , Internal coils , Agitated vessels .

UNIT –III

Design methods for binary distillation systems , Basic equations , McCabe-Thiele method ,Low product concentrations , The Smoker equations ,Batch distillation , Steam distillation, Plate efficiency, Prediction of plate efficiency :O'Connell's correlation , Van Winkle's correlation , AIChE method , Entrainment , Approximate column sizing , Plate contactors , Selection of plate type , Plate construction , Plate hydraulic design,Plate-design procedure ,Plate areas ,Diameter , Liquid-flow arrangement ,Entrainment ,Weep point , Weir liquid crest , Weir dimensions , Perforated area , Hole size , Hole pitch ,Hydraulic gradient ,Liquid throw , Plate pressure drop , Downcomer design [back-up] ,

UNIT-IV

Design of packed columns for absorption/stripping, Types of packing, Packed-bed height- Prediction of the height of a transfer unit (HTU), Prediction of the number of transfer units (NTU), Column diameter (capacity) , Column internals , Wetting rates , Column auxiliaries

UNIT –V

Analysis of Cost Estimates: Factors affecting investment and production costs, Capital investment, Types of capital cost estimates, Methods for estimating capital investment, Estimation of Revenue, Estimation of total product cost, Gross Profit, Net Profit and Cash flow Simple and Compound interest, Loan Payments, Cash flow pattern -Discrete cash flow & Continuous cash flow, Profitability, Alternative investments by different profitability methods, Effect of inflation on profitability analysis, Methods of profitability evaluation for replacements. Depreciation: Straight line, Declining balance, Double declining balance, sum-of-the-digit, Sinking-fund, Accelerated cost recovery system, Modified accelerated cost recovery system.

BOOKS:

1. Towler G. and Sinnott R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann.2008
2. Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India.2006
3. I.S.: 4503-1967, "Indian Standard Specification for Shell and Tube Type Heat Exchangers", Bureau of Indian Standards.2007
4. Hewitt G. F., Shires G. L. and Bott T. R., "Process Heat Transfer", CRC Press.1994
5. Serth R.W., "Process Heat Transfer: Principles and Applications", Academic Press.2007
6. Coker A. K., "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol. 1, 4th Ed., Gulf Publishers.2007
7. Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 2, 3rd Ed., Gulf Publishers.1997
8. Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 3, 3rd Ed., Gulf Publishers.
9. Peters M. S. and Timmerhaus K. D., "Plant Design And Economics For Chemical Engineers", 5th Ed., McGraw Hill, International Ed.2004

ELECTIVE-I (ICH 704-707)

ICH 704

FUEL AND COMBUSTION TECHNOLOGY

UNIT I

History of Fuels-Solid fuels, liquid fuels and gaseous fuels; Production, present scenario and consumption pattern of fuels; Fundamental definitions, properties and various measurements-Definitions and properties of solid fuels, Definitions and properties of liquid and gaseous fuels, Various measurement techniques

UNIT II

Coal classification, composition and basis; Coal mining; Coal preparation and washing; Combustion of coal and coke making-Action of heat on different coal samples, Different types of coal combustion techniques, Coal tar distillation; Coal liquefaction-Direct liquefaction, Indirect liquefaction; Coal gasification

UNIT III

Exploration of crude petroleum; Evaluation of crude; Distillation-Atmospheric distillation, Vacuum distillation; Secondary processing-Cracking-Thermal cracking, Visbreaking, Coking, Catalytic cracking, Reforming of naphtha, Hydrotreatment, dewaxing, deasphalting, Refinery equipments

UNIT IV

Natural gas and LPG, Producer gas, Water gas, Hydrogen, Acetylene, Other fuel gases

UNIT V

Fundamentals of thermochemistry; Combustion air calculation, Calculation of calorific value of fuels; Adiabatic flame temperature calculation; Mechanism and kinetics of combustion; Flame properties; Combustion burners; Combustion furnaces; Internal combustion engines

BOOKS:

1. S. Sarkar, Fuels and combustion, 2nd ed., Orient Longman Ltd., (1990).

ICH 705

PETROLEUM REFINING TECHNOLOGY

UNIT I

Petroleum Exploration Production and Refining of Crude oils, Crude oils: Characteristics and constituents of crude oils, Classification of crude oils.

UNIT II

Quality Control of Petroleum Products. Classification of laboratory tests, distillation, vapour pressure, flash and fire points, octane number, performance number, cetane number, aniline point, viscosity index, calorific value, smoke point, char value, viscosity, viscosity index, penetration tests, cloud and pour points, drop point of grease, melting and settling points of wax, softening point of Bitumen, induction period of gasoline, thermal stability of jet fuels, gum content, Total Sulphur, Acidity and Alkalinity,, Copper Strip Corrosion Test, Silver – Strip Corrosion Test for ATF, Ash, Carbon Residue (Conradson method, Ramsbottom method) Colour, Density and Specific gravity, Refractive index of hydrocarbon liquids, water separation index (modified) (WSIM), ductility.

UNIT III

Petroleum Products: Composition, Properties & Specification of LPG, Naphthas, motor spirit, Kerosine, Aviation Turbine Fuels, Diesel Fuels, Fuel Oils, Petroleum Hydrocarbon Solvents, Lubricating oils (automotive engine oils, industrial lubricating oils electrical insulating oils, Jute Batching oils, white oils, steam turbine oils, metal working oils, etc.) Petroleum Waxes Bitumens, Petroleum coke. **Crude Oil Distillation:** Desalting of crude oils, Atmospheric distillation of crude oil, Vacuum distillation of atmospheric residue. Thermal Conversion Process: Thermal Cracking Reactions, Thermal Cracking, Visbreaking, (Conventional Visbreaking and Soaker Visbreaking) Coking (Delayed Coking, Fluid Coking, Flexicoking), Calcination of Green Coke.

UNIT IV

Catalytic Conversion Process: Fluid catalytic cracking; Catalytic reforming; Hydrocracking Catalytic Alkylation, Catalytic Isomerization; Catalytic Polymerization.

Finishing Process: Hydrogen sulphide removal processes; Sulphur conversion processes; Sweetening processes (Caustic treatment, Solutizer process; Doctor treating process; Copper chloride sweetening; Hypochlorite sweetening ;Air and inhibitor treating process; Merox processes; Sulphuric acid treatment; Clay treatment); Solvent extraction processes (Edeleanu process, Udex process, Sulfolane process), Hydrotreating processes.

UNIT V

Lube Oil Manufacturing Process: Evaluation of crude oils for lube oil base stocks, Vacuum distillation, Solvent deasphalting Solvent extraction of lube oil fractions (Furfural, NMP and Phenol), Solvent dewaxing, Hydrofinishing, Manufacture of petroleum waxes (Wax sweating, Solvent deoiling)

Manufacture of Bitumens: Selection of crude oil, Methods of manufacture of bitumens, (Distillation, Solvent precipitation, Air blowing).

BOOKS:

1. Ram Prasad, Petroleum Refining Technology, Khanna Publishers, Delhi (2000)
2. Nelson, W.L., Petroleum Refining Engineering, McGraw Hill

UNIT I

Introduction: Introduction to Nanotechnology - its emergence and challenges, Nanomaterials and its classification, Properties of individual nanoparticles, Methods of synthesis, Reactivity of nanoparticles, List of stable carbon allotropes extended, Synthesis of carbon buckyballs, fullerenes, metallofullerenes, solid C60, bucky onions, nanotubes, nanowires, nanocones, Carbon nanostructures

UNIT II

Synthesis procedures of nanomaterials: Methods of Synthesis of Nanomaterials: Bottom-up (building from molecular level) and top-down (breakdown of microcrystalline materials) approaches. Manufacturing of nanoscale materials: Chemical vapor deposition of carbon nano tubes, Plasma deposition of ultra thin functional films on nano materials, Solution based Synthesis of Nanoparticles, Vapour Phase Synthesis & Synthesis with framework, Nanolithography, Dip Pen Lithography. Artificially Layered Materials: Quantum Well, Quantum Dots, Super lattices & Layered Structures.

UNIT III

Characterizations of nanomaterials : Top down approach vs Bottom up approach, Optical Microscopy, Electron Microscopy, Secondary electron scattering, back scattering, Scanning Probe Microscopes, Focussed Ion Beam Technique, X-ray imaging, Transmission Electron Microscope (TEM), Scanning Probe Microscope (SPM)- Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM).

UNIT IV

Nano colloids and Chemistry : Surface Tension and Interfacial Tension, Surfaces at Equilibrium, Surface Tension Measurement, Contact Angles, Colloidal Stability, Electrical Phenomena at Interfaces, Vander Waals Forces between Colloidal Particles, Photocatalysis Nanostructured materials, Self-assembly and Catalysis.

UNIT V

Commercial Processes for Nanotechnology and Chemical Engineering Applications: Nanobiotechnology : Drug Delivery, Nanoclay, Nanocomposites, Surface coatings, Self cleaning Materials, Hydrophobic Nanoparticles, Biological nanomaterials, Nanoelectronics, Nanomachines & nanodevices, Nanohydrogel, Photocatalytic reactors, Nanoclay Synthesis, Polymer nanocomposite, Waste Water Treatment, Societal, Health and Environmental Impacts, Introduction to industries which produces commercial nanomaterials.

BOOKS:

1. G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, Introduction to NanoScience, CRC Press of Taylor and Francis Group, 2008
2. Pools C.P. and Owens F.J., Introduction to Nanotechnology, Wiley-Interscience, 2003
3. Bhusan B., Springer Handbook of Nanotechnology

UNIT I

Addition polymers, Condensation polymers, Copolymers, Cross-linked polymers, Molecular symmetry and the tendency to form crystals, Distribution of relative molecular mass, Structure of the crystal, Crystal shape, Crystallinity, Crystallization and melting, the glass transition temperature, Molecular conformation in the amorphous polymer, the freely jointed chain, the Gaussian chain, Molecular orientation.

UNIT II

Structure of an ideal rubber, Entropy elasticity, elasticity of a network, Stress-strain relationship, Engineering rubbers, The nature of viscoelasticity, Creep, Stress relaxation, Dynamic properties, Theory of linear viscoelasticity, Polymer selection:stiffness.

UNIT III

Yielding, Crazing, Linear elastic fracture mechanics, Elastic-plastic fracture mechanics, Brittle fracture of polymer, rubber toughening, Reinforced plastics, Forming of reinforced plastics, the mechanics of fibre reinforcement, Reinforced rubbers.

UNIT IV

The flow properties of polymer melts, Cooling and solidification, Extrusion, Injection moulding, Compression and transfer moulding.

UNIT V

Materials selection, Designing for manufacture, Designing for stiffness, Designing for strength, Case Histories.

BOOKS:

1. N. G. McCrum, C. P. Buckley and C. B. Bucknall, Principles of Polymer Engineering, 2nd Edition, Oxford University Press, (1997).

ICH 801 ENERGY RESOURCES AND ENERGY CONSERVATION

UNIT I

Energy scenario, Classification of energy sources, Need for conserving energy, Government initiative for conserving energy (Role of Bureau of Energy Efficiency, Energy conservation bill 2001), Energy efficiency based on first and second laws of thermodynamics; Thermodynamic analysis of processes.

UNIT II

Coal - Coal analysis, Coal classification, Coal preparation, Coal washing and Coal blending, Coal carbonization, Coal gasification, liquid fuel synthesis from coal; Crude petroleum-Chemistry, composition, classification; Crude oil distillation, Composition, properties and application of liquid fuels-Gasoline, Kerosene, ATF, Diesel, Fuel oil; Gaseous Fuels: Natural gas, Water gas, Producer gas, L.P.G., Bio-gas, Coke oven gas, Blast furnace gas, LNG, CNG, CBM, Gas hydrates.

UNIT III

Nuclear energy: Nuclear raw materials, Nuclear reactors, Generation of Nuclear power, Nuclear installations in India and their generation capacity; Solar Energy: Solar thermal and photovoltaic conversion and utilization methods, Solar cells, their material and mode of operation; Solar thermal energy storage-Sensible heat and latent heat storage materials, Chemical energy storage; Solar ponds.

UNIT IV

Biomass: Conversion routes to gaseous and liquid fuels; Biodiesel; Wind energy: Basic principles of Wind Energy Conversion, Performance of wind mills, Electric generation for wind; Hydroelectric energy-Potential and production; Geothermal energy-Potential and production; Ocean Energy conversion Technologies, Tidal power plants.

UNIT V

Equipment-oriented approaches for energy conservation-Fired heater, Boiler, Evaporators, Distillation column, absorption/stripping column, Dryer, Liquid-liquid extraction column; Waste heat recovery: Sources of waste heat, Feasibility of waste heat recovery, Types of heat recovery equipments, Applications; Energy conservation opportunities in chemical process utilities - Steam systems, Compressed air systems, Insulation; Cogeneration-A plausible approach for energy conservation

BOOKS:

1. Brame J.S.S. and King J.G., Edward Arnold "Fuel Solid, Liquid and Gases" Edward Arnold (1967).
2. Sukhatme S.P, "Solar Energy - Principles of Thermal Collection and Storage",2nd Ed., Tata McGraw- Hill.,(1996).
3. Murphy W.R. and Mckay G., Energy Management(BH)
4. Boyle "Renewable Energy : Power for a sustainable future" Oxford.
5. Rao S. & Parulckar B.B. "Energy technology" Khanna Publisher

ELECTIVE II (ICH 802-805)

ICH 802

PROCESS INTEGRATION

UNIT I

Introduction to Process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram. Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve.

UNIT II

Key steps of Pinch Technology: Concept of ΔT_{min} , Data Extraction, Targeting, Designing, Optimization-Super targeting Targeting of Heat Exchanger Network: Energy Targeting, Area Targeting, Number of units targeting, Shell Targeting and Cost targeting.

UNIT III

Designing of HEN: Pinch Design Methods, Heuristic rules, stream splitting, and design of maximum energy recovery (MER). Use of multiple utilities and concept of utility pinches, Design for multiple utilities pinches, Concept of threshold problems and design strategy. Network evolution and evaluation-identification of loops and paths, loop breaking and path relaxation. Design tools to achieve targets, Driving force plot, remaining problem analysis, diverse pinch concepts, MCp ratio heuristics.

UNIT IV

Targeting and designing of HENs with different ΔT_{min} values, Variation of cost of utility, fixed cost, TAC, number of shells and total area with ΔT_{min} Capital-Energy trade-offs. Process modifications-Plus/Minus principles, Heat Engines and appropriate placement of heat engines relative to pinch. Heat pumps, appropriate placement of heat pumps relative to pinch Steam Rankin Cycle design, Gas turbine cycle design, Integration of Steam and Gas turbine with process

UNIT V

Refrigeration systems, Stand alone and integrated evaporators. Heat integrations and proper placement of Reactors for batch Processes as well as continuous processes. Retrofit of distillation systems. Various case studies

BOOKS:

1. Shenoy U. V.; "Heat Exchanger Network Synthesis", Gulf Publishing company.
2. Smith R.; "Chemical Process Design", McGraw-Hill .
3. Linnhoff B., Townsend D. W., Boland D, Hewitt G. F., Thomas B. E. A., Guy A. R., and Marsland R. H.; "A User Guide on Process Integration for the Efficient Uses of Energy", Inst. Of Chemical Engineers .

UNIT I

Feedback Control Schemes: Concept of feedback control., Dynamics and analysis of feedback-controlled processes., Stability analysis., Design of Feedback Controller, Frequency response analysis and its applications. Design of Feedback Control Systems using Frequency Response Techniques.

UNIT II

Controller Tuning: Controller tuning, Tuning rules, Online trial and error method, Ziegler-Nichol's method, auto tuning by forced cycling, process reaction curve (PRC), Ziegler-Nichol's formulae based on PRC, Cohen and Coon formulae based on PRC, Integral error criterions.

UNIT III

Advanced Control Schemes: Feedback control of systems with large dead time or inverse response., Control systems with multiple loops., Feedforward and ratio control. Adaptive and inferential control systems.

UNIT IV

Multivariable process control: Design of controllers for interactions, Loop interaction, Decoupling of interacting loops

UNIT V

Multi loop multivariable control: Process and control loop interaction., Cascade control, Ratio control, Singular Value Decomposition (SVD), Relative Gain Array (RGA), I/O pairing., Sensitivity to model uncertainty; failure sensitivity., Decoupling and design of non-interacting control loops. Example - Design of controller and control structure for common industrial processes such distillation, heat exchangers,etc.**Batch Process:** Introduction to advanced control strategies, use of microprocessors in process control.

BOOKS:

1. Coughnour and Koppel, " Process Systems Analysis and Control ", McGraw-Hill, NewYork, 1986.
2. George Stephanopolous, " Chemical Process Control ", Prentice-Hall of India Pvt-Ltd.,New Delhi, 1990.
3. P. K. Sarkar, " Process Dynamics and Control", Prentice Hall India, 2014.
4. D. N. Considine, "Process Instrumentation and Controls Handbook", Considine, McGraw Hill.
5. Emenule, S.Savas, " Computer Control of Industrial Processes ", McGraw-Hill, London, 1965.
6. Principals and Practice of Automatic Process Control, Carlos A. Smith and Armando B.Corripio, John Willy & Sons, 2nd Ed.

UNIT I

Introduction to statistics for engineers: Simplest discrete and continuous distributions, Statistical inference, Statistical estimation, tests and estimates on statistical variance, Analysis of variance, Regression analysis (Simple linear, multiple, polynomial, nonlinear), Correlation analysis (Correlation in linear regression, correlation in multiple linear regression)

UNIT II

Design and analysis of experiments: Introduction to design of experiments, Preliminary examination of subject of research, Screening experiments

Basic experiment-mathematical modeling: Full factorial experiments and fractional factorial experiments, Second-order rotatable design (Box-Wilson design).

UNIT III

Orthogonal second order design (Box Benken design), D-optimality, B_k -designs and Hartleys second order design.

Statistical analysis: Determination of experimental error, Significance of the regression coefficients, Lack of fit of regression models

UNIT IV

Experimental optimization of research subject: Problem of optimization, Gradient optimization method, canonical analysis of response surface.

UNIT V

Mixture design `composition-property`: Screening design `composition-property`, Simplex lattice design, Scheffe simplex lattice design, Simplex centroid design, Extreme vertices design, D-optimal design, Draper-Lawrence design, Factorial experiments with mixture, Full factorial combined with mixture design

BOOKS:

1. Z.R.Lazic, Design of experiments in chemical engineering: A practical guide, Wiley (2005).

ICH 805 MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

UNIT I

Ordinary Differential Equations, Separable equations, Equations made separable by change of variables, Homogeneous Equations, Equations with first order and first degree with linear coefficients, Exact equations, Linear equation of first order, Bernoulli's equation, Other integrating factors, Integration of Exact equations, Equations of first order and higher degree, Clairaut's equation, Singular solutions, Equations with missing terms, General properties of Linear equations, Linear equations with constant coefficients, Determination of the complementary function, exponential functions, Determination of the particular integral, the Euler equation, Simultaneous Linear Differential equations.

UNIT II

Power series method, theory of the power series method, Legendre's equation, Legendre's Polynomials, Frobenius Method.

UNIT III

Bessel's equation, Bessel Functions $J_\nu(x)$, Bessel Functions $J_\nu(x)$ for any $\nu \geq 0$. Gamma Function, Solution $J_{-\nu}(x)$ of the Bessel Equation, Backbones of Bessel's Theory, $J_\nu(x)$ with $\nu = \pm 1/2, \pm 3/2, \pm 5/2$.

UNIT IV

Definition of matrix, Some special definitions and operations involving matrices, Determinants, Theorems on determinants, Inverse of a matrix, Orthogonal and unitary matrix. Orthogonal vectors, System of linear equations, Systems on n equations with n unknowns, Cramer's Rule, Eigen values and eigen vectors.

UNIT V

Analysis of Stagewise Processes by the Calculus of Finite Differences, Countercurrent Liquid-Liquid Extraction, Solution of Difference Equations, Stirred-tank Reactor System, Distillation in a Plate Column, Unsteady-state Operation, Starting a Stirred-tank Reactor, Rate at which a Plate Absorber Approaches Steady State.

BOOKS:

1. Mickley, Reid and Sherwood, "Applied Mathematics in Chemical Engineering", Tata McGraw Hill, New Delhi (1981).
2. E. Kreyszig, "Advanced Engineering Mathematics", 8th edition, John Wiley and Sons (1999).
3. M. R. Spiegel, "Advanced Mathematics for Engineers and Scientists", Schaum Outline Series, McGraw Hill, (1971).

ELECTIVE-III (ICH 806-809)

ICH 806 FUNDAMENTALS OF BIOCHEMICAL ENGINEERING

UNIT I

Introduction - principles of microbiology, structure of cells, microbes, bacteria, fungi, algae, chemicals of life - lipids, sugars and polysaccharides, amino acids, proteins, nucleotides, RNA and DNA, hierarchy of cellular organization, Principles of genetic Engineering, Recombinant DNA technology, mutation

UNIT II

The kinetics of enzyme catalyzed reactions - the enzyme substrate complex and enzyme action, simple enzyme kinetics with one and two substrates, determination of elementary step rate constants. Isolation and utilization of Enzymes -production of crude enzyme extracts, enzyme purification, applications of hydrolytic enzymes, other enzyme applications, Enzyme production intercellular and extra cellular enzymes. Immobilized Enzymes: effects of intra and inter-phase mass transfer on enzyme kinetics

UNIT III

Metabolic pathways and energetic of the cell, concept of energy coupling, ATP and NAD, Photosynthesis, Carbon metabolism, EMP pathway, Tricarboxylic cycle and electron transport chain, aerobic and anaerobic metabolic pathways, transport across cell membranes, Synthesis and regulation of biomolecules.

UNIT IV

Typical growth characteristics of microbial cells, Microbial Growth: Continuum and Stochastic Models, Factors affecting growth, Batch and Continuous cell growth , nutrient media, enrichment culture, culture production and preservation Immobilisation Technology– Techniques of immobilisation, Characteristics and applications, Reactors for immobilized enzyme systems.

UNIT V

Introduction to bio reactors, types, Continuously Stirred aerated tank bioreactors, Determination of volumetric mass transfer rate of oxygen from air bubbles and effect of mechanical mixing and aeration on oxygen transfer rate, heat transfer and power consumption, Fermentation-methods and applications, Downstream processing and product recovery in bio processes Design, Analysis and Stability of Bioreactors.

BOOKS:

1. Biochemical Engineering Fundamentals by J. E. Bailey & D. F. Ollis, McGraw Hill Book Company, 1986.
2. Biochemical Engineering by H. W. Blanch & D. S. Clark, Marcel Dekker, Inc., 1997.
3. Bioprocess Engineering (Basic Concepts) by M. L. Shuler & F. Kargi, Prentice Hall of India, 2003.

UNIT I

Multicomponent distillation – Bubble point and dew point calculations, Lewis and Matheson calculation, Method of Thiele and Geddes; Azeotropic distillation; Extractive distillation; Molecular distillation; Reactive distillation

UNIT II

Absorption with chemical reaction; Enhancement factor; Simultaneous diffusion and chemical reaction near an interface – Film theory, Penetration theory, Surface renewal theory for a first-order irreversible reaction; Effect of reversibility of the chemical reaction on the mass-transfer rate; Computation of reaction effect for a few chemical situations – absorption of CO_2 and H_2S from a gas stream into aqueous solution of KOH etc.

UNIT III

Supercritical fluid extraction – Supercritical fluids, Phase equilibria, Industrial applications; Important supercritical processes – Decaffeination of coffee, Extraction of oil from seeds, Residuum oil supercritical extraction (ROSE), Supercritical fluid chromatography, Supercritical fluid reactions etc.

UNIT IV

Classification of membrane processes; Liquid permeation membrane processes or dialysis – Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis; Gas permeation membrane processes – Types of membranes and permeabilities for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes); Types of flow in gas permeation; Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes; Effect of processing variables on gas separation by membranes

UNIT V

Reverse osmosis membrane processes – Osmotic pressure of solution, flux equation, Types of equipment and Complete mixing model; Effect of operating variables; Concentration polarization; Permeability constants
Ultrafiltration membrane processes – Types of equipment, flux equation, effects of processing variables

BOOKS:

1. C.J.Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi (2000).
2. T.K.Sherwood, R.L.Pigford and C.R.Wilke, Mass Transfer, McGraw-Hill, New York (1975).
3. R.E.Treybal, Mass-Transfer Operations, McGraw-Hill, New York (1980).

ICH 808 COLLOIDS & INTERFACE SCIENCE AND ENGINEERING

I

UNIT I

Surface tension, adhesion and capillarity

Effects of confinement and finite size, concepts of surface and interfacial energies and tensions, Apolar (van der Waals) and polar (acid-base) components of interfacial tensions. Young-Laplace equation of capillarity, examples of equilibrium surfaces, multiplicity, etc., Stability of equilibrium solutions, contact angle and Young's equation, Determination of apolar (van der Waals) and acid-base components of surface/interfacial tensions. Free energies of adhesion, kinetics of capillary and confined flow.

UNIT II

Intermolecular, nanoscale and interfacial forces in organic, polymeric, biological and aqueous systems

Van der Waals, electrostatic double layer, acid-base interactions including hydrophobic attraction and hydration pressure

UNIT III

Mesoscale thermodynamics and Mesoscale phenomena in soft matter & applications

Gibb's treatment of interfaces, concept of excess concentration, variation of interfacial tension with surface concentration, Adhesion, wetting, nucleation, flotation, patterning of soft material by self organization and other techniques.

UNIT IV

Stability of nanoparticle dispersions

DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement.

UNIT V

Nanofluidics and Advanced & Functional Interfaces

Stability of thin (< 100 nm) film, self-organization in confined systems, mesoscale patterning. Superhydrophobicity, functional coatings, structural colours, nano-adhesives, nano-composites.

BOOKS:

1. Principles of Colloid and Surface Chemistry, Paul C. Hiemenz, Marcel Dekker, 2nd edition and onwards, 1986.
2. Physical Chemistry of Surfaces, Arthur W. Adamson, 5th edition, Wiley, 1990.
3. Foundations of Colloid Science, Robert J. Hunter, Clarendon, Oxford, Volume 1, 1989.
4. Colloidal Dispersions, W. B. Russel, D. A. Saville, and W. R. Schowalter, Cambridge University Press, 1989.
5. Intermolecular and Surface forces, Jacob N. Israelachvili, Academic Press, 1992 or later editions.
6. Interfacial Forces in Aqueous Media, Carel J. van Oss, Marcel Dekker or Taylor Francis, 1994.

UNIT I

Basic aspects introduction, classification, economics and cost of corrosion. Emf series, Galvanic series, corrosion theories derivation of potential-current relationship of activation controlled and diffusion corrosion processes. Potential-pH diagrams Fe-H₂O system, application and limitations. Passivation definition, anodic Passivation, theory of Passivation, oxidation laws, effects of oxygen and alloying on oxidation rates.

UNIT II

Forms of corrosion-definition, factors and control methods of various forms of corrosion such as pitting, inter granular, crevice, stress corrosion, corrosion fatigue, hydrogen embrittlement, corrosion processes and control methods in fertilizers, petrochemical and petroleum refineries

UNIT III

Environmental aspects: Atmospheric corrosion- classification, factors influencing atmospheric corrosion, temporary corrosion preventive methods, corrosion in immersed condition, effect of dissolved gases, salts, pH, temperature and flow rates on corrosion, Underground corrosion- corrosion process in the soil, factors influencing soil corrosion.

UNIT IV

Corrosion control aspects: Electrochemical methods of protection-theory of cathodic protection, design of cathodic protection, sacrificial anodes, anodic protection. Corrosion inhibitors for acidic, neutral and alkaline media, cooling water system-boiler water system. Organic coating-surface preparation, natural synthetic resin, paint formulation and applications. Design aspects in corrosion prevention, corrosion resistant materials.

UNIT V

Corrosion Testing, monitoring and inspection, laboratory corrosion tests, accelerated chemical tests for studying different forms of corrosion. Electrochemical methods of corrosion rate measurements by DC and AC methods, corrosion monitoring methods, chemical and electrochemical removal of corrosion products.

BOOKS:

1. S.N. Banerjee, An Introduction to Corrosion and Corrosion Inhibition, Oxonian Press Ltd., New Delhi.
2. LL Shrier Corrosion Vol. I & II George NownonsLtd., Southampton Street London Endn. II
3. M.G. Fontana & N.D. Greene, Corrosion Engineering, McGraw Hill, New York (3/e)
4. H.H. Uhlig, Corrosion and Corrosion Control. A Wiley- Inter Science. Publication John Wiley & Sons, New York.
5. C.T.Munger- Organic Coatings
6. Jain & Jain, Engineering Chemistry, Dhanpat Rai & Sons, New Delhi

1. Solve a non-linear algebraic equation using Newton-Raphson's method.
 2. Calculate pressure drop in pipe.
 3. Calculate minimum fluidization velocity.
 4. Calculate terminal velocity.
 5. Solve a system of non-linear equations,
 6. Calculate the molar volume of saturated liquid water and saturated water vapour using van der
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1. Waals, Redlich-Kwong and Peng-Robinson cubic equation of state.
 2. Solve system of simultaneous ordinary differential equations.
 3. Solve for outlet temperatures of series of stirred tanks with coil heater.
 4. Solve for non-isothermal PFR.
 5. Solve for concentration profiles of A, B and C in the series reaction $A \rightarrow B \rightarrow C$.