PROPOSED STUDY & EVALUATION SCHEME
FOR
III YEAR B.TECH.
(CHEMICAL ENGINEERING)
ON
CHOICE BASED CREDIT SYSTEM (CBCS)

[EFFECTIVE FROM THE SESSION 2018-19]
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Subject Code</th>
<th>Subject Name</th>
<th>Department</th>
<th>L-T-P Marks</th>
<th>Th/Lab Marks</th>
<th>Sessional</th>
<th>Total</th>
<th>Credit</th>
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Deptt. Elective:

RCH051: Computational Fluid Dynamics
RCH052: Optimization Techniques
RCH053: Numerical Methods for Chemical Engineer
RCH054: Statistical Design of Experiments
### Sixth Semester

<table>
<thead>
<tr>
<th>SL. No.</th>
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**Deptt Elective:**

RCH061: Process Flow Sheet Simulation

RCH062: Process Integration

RCH063 Process Utility & Safety in Chemical Plants

RCH064: Intellectual Property Rights & Standardization
UNIT 1
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 2
Interpretation of variable volume batch reactions for zero, first and second order reactions, design equation for batch, continuous stirred tank, plug flow reactors for isothermal reaction.

UNIT 3
Optimum reactor size, plug flow/mixed flow reactors in series and parallel, recycle reactor.

UNIT 4
Design of reactors for multiple reactions, parallel and series reactions. Temperature and pressure effects for single reaction.

UNIT 5
Residence time distribution of fluids in vessels, E, F and C curves, Dispersion model, Tank in series model. Non Isothermal PFR and CSTR, Safety issues in Non Isothermal Reactors.

Text Books:

Reference Book:
UNIT 1

UNIT 2
Continuous Distillation of Binary Mixtures: Multistage contact operations, Characteristics of multistage tower, McCabe Thiele method, Ponchon Savarit method, Reflux, maximum, minimum and optimum reflux, Use of open steam, Tray efficiency, Determination of height and column diameter, Multistage batch distillation; Principles of azeotropic and extractive distillation, Introduction & Design of multicomponent distillation system.

UNIT 3
Liquid-Liquid Extraction: Ternary liquid equilibria, Triangular graphical representation concept of theoretical or ideal stage, Equipment used for single stage and multistage continuous operation; Analytical and graphical solution of single and multistage operation Super critical fluid extraction.

UNIT 4
Solid /Liquid Extraction: Leaching, Solid liquid equilibrium, Equipment used in solid–liquid extraction, Single and multistage cross current contact and counter current operations. Concept of an ideal stage, Overall stage efficiency, Determination of number of stages.

UNIT 5

Text Books:

Reference Books:
Transfer Analysis, 3rd Edition, Pearson
RCH 503: Chemical Technology (3:0:0)

Introduction of CPT 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.

UNIT 1

UNIT 2
Sugar, Glucose, Starch, Fermentation products such as Alcohol, Acetic acid, Citric acid and antibiotics

UNIT 3
Soap and Surfactants, Glycerin, Fatty acids, Hydrogenation of edible oils, paper and pulp

UNIT 4
Synthetic and natural fibers: Nylon, Dacron, Terylyne, Polyester and other new products, Viscose rayon, acetate rayon , synthetic rubber with special reference to manufacture, vulcanization and reclaiming of rubber, SBR, Plastics, Thermosetting and Thermo Plastics (PVC, Polyethylene, Polyurethane, Teflon )

UNIT 5
Crude oil distillation, Thermal conversion processes (visbreaking, coking), Catalytic conversion processes (fluid catalytic cracking, catalytic reforming, hydro cracking, alkylation, isomerisation, polymerization) Finishing processes, sulphur removal process, lub oil manufacture; Petrochemicals (ethylene, propylene, formaldehyde, methanol, ethylene oxide, ethanolamine, cumene, ethylene glycol, ethyl benzene)

Text Books:
UNIT 1
Basic Concepts of Fluid Flow: Philosophy of computational fluid dynamics, conservation principles of mass, energy, and momentum, simplified flow models such as incompressible, inviscid, potential and creeping flows, classification of flows.

UNIT 2
Turbulence and its Modelling: Transition from laminar to turbulent flow, Effect of turbulence on time- averaged Navier-Stokes equations, Characteristics of simple turbulent flows, Free turbulent flows, Flat plate boundary layer and pipe flow, Turbulence models, Mixing length model, The k-e model, Reynolds stress equation models, Algebraic stress equation models.

UNIT 3
Grid Generation: Structured and unstructured grids, choice of grid, general transformation of equations, some modern developments in grid generation in solving the engineering problems.

Finite Difference Method: Discretization of ordinary and partial differential equations, approximation of first, second and mixed derivatives, implementation of boundary conditions, discretization errors, applications to the engineering problems.

UNIT 4

UNIT 5
Special Topics: Flow in a sudden pipe contraction / expansion, flow and heat transfer in a complex tubes and channels, reactive flow, multiphase flow, and turbulent flow processes.

Books:
Unit 1
Analytical Method Necessary and sufficient conditions for optimum in single and multi-variable unconstrained and constrained problems.

Unit 2
Unconstrained One Dimensional Search Newton, Quasi-Newton and Secant method for unidimensional search, Region elimination methods (Golden Section, Fibonacci, Dichotomous. etc.)

Unit 3
Linear Programming, Graphical simplex method, revised simplex method, duality and transportation problems. Unconstrained Multi Variable Search, Direct methods, Indirect method.

Unit 4
Finite difference approximation, Dynamic Programming.

Unit 5
Principle of optimality, Discrete and continuous dynamic programming.

Books:
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

UNIT III
Bessel’s equation, Bessel Functions $J_v(x)$, Bessel Functions $J_v(x)$ for any $v \geq 0$. 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:
UNIT 1
Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments;
Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means, randomized and paired comparison design.
Experiments with Single Factor: Analysis of variance, Covariance and analysis of covariance, analysis of fixed effects model, model adequacy analysis, non-parametric methods.

UNIT 2
Design of Experiments: Fundamental and types of Design of Experiment, Randomized blocks, latin squares, and related design, factorial design, two-factor factorial design, blocking in a factorial design, the $2^2$ & $2^3$ factorial design, the general $2^k$ factorial design, blocking and compounding in the $2^k$ factorial design, two-level, three level and mixed level factorial and fractional factorial designs.

UNIT 3
Parameter Estimation: Linear regression models, estimation of the parameters in linear regression models, hypothesis testing in multiple regression, non-linear regression, logistic and weighted regression, Chi-squared tests, confidence intervals in multiple regression, prediction of new response observations, regression model diagnostics, testing for lack of fit.

UNIT 4
Response Surface Methods: Central composite and Box-Behnken designs, method of steepest ascent, analysis of a second-order response surface, experimental designs for fitting response surfaces, mixture experiments, Simultaneous optimization of several responses, Simplex method, evolutionary operation, robust design.

UNIT 5
Experiments with Random Factors: Random effect model, two factor factorial with random factors, two-factor mixed model, sample size determination with random effects, approximate F tests.
Design and Analysis: Nested and split-plot design, non-normal responses and transformations, unbalanced data in a factorial design.

Books:
1. Find out kinetic constant and study conversion of a given reaction in a batch reactor
2. Find out kinetic constant and study conversion of a given reaction in a plug flow reactor
3. Find out kinetic constant and study conversion of a given reaction in a CSTR
4. Study and operation of an adiabatic batch reactor
5. Study of a reversible reaction in a batch reactor
6. To determine energy of activation of reaction of ethyl acetate with sodium hydroxide
7. Find out specific rate constant and activation energy of a reaction in a plug flow reactor
8. To determine reaction equilibrium constant of reaction of acetic acid with ethanol.
9. To determine changes in free energy, enthalpy and entropy for the reaction of potassium iodide with iodine.
10. Study and operation of a cascade CSTR

The reaction of disappearance of phenolphthalein in NaOH solutions may be used for experiments 1, 2 and
1. Determination of ternary curve for the system acetic acid-water-carbon tetrachloride.
2. Determination of distribution coefficient of a solute in two immiscible liquids.
3. Solid-Liquid extraction – Soxhlet’s experiment.
4. Liquid - liquid extraction in packed bed.
5. Determination of adsorption kinetics and isotherm at solid-liquid interface.
7. Estimation of efficiency of the fluidized bed dryer
Preparation and Quality evaluation of following items:

1. Cement Paint
2. Dry Distemper
3. Oil bound Distemper
4. Plastic Emulsion Paint
5. Polystyrene by Bulk Polymerization Technique
6. PMMA by Bulk Polymerization Technique
7. Transparent Soaps
8. Powdered Detergent
9. Liquid Detergent
Use of following Techniques in C/C++ Language

2. Solution of single non-linear equations by Regulafalsi method.
3. Solution of system of linear simultaneous by Gauss Elimination method.
4. Solution of system of linear simultaneous equation by gauss seidel method and successive over relaxation method.
5. Solution of single first order ordinary differential equations by fourth order Runge-Kutta method.
7. Solution of Laplace equations (elliptic equation) by finite difference method.
8. Solution of wave equations (Hyperbolic equation) by finite difference method.
10. Finding Newton’s interpolatory polynomial based on finite difference table for n points.
UNIT 1
Vectors/Tensors, Newton’s law of viscosity, Temperature, pressure and composition dependence of viscosity, Kinetic theory of viscosity, Fourier’s law of heat conduction, Temperature, pressure and composition dependence of thermal conductivity, Kinetic theory of thermal conductivity, Fick’s law of diffusion, Temperature, pressure and composition dependence of diffusivity, Kinetic theory of diffusivity.

UNIT 2
Shell Momentum balances, velocity profiles, average velocity, momentum flux at the surfaces, Equations of Change (Isothermal), equation of continuity, equation of motion, equation of energy (isothermal).

UNIT 3
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 4
Shell mass balances, concentration profiles, average concentration, mass flux at surfaces, Equations of change (multi-component), equations of continuity for each species, equation of energy (multi-component).

UNIT 5
Introduction to the concept of heat and mass transfer coefficients. Interphase mass transfer, various coefficient of mass transfer and their determination, resistance concept, controlling phase concept, Mass transfer in turbulent flow, Analogies of mass transfer, Empirical equations. Theories of mass transfer, two film theory, Higbies penetration theory, Derivation of flux equation, surface renewal theory.

Text Book:
UNIT 1
Dynamic modeling of first and second-order process; Interacting and non-interacting processes; Nonlinear and integrating processes; introduction to non-minimum phase processes; Distributed parameter processes and MIMO processes; Response of first and second order processes with respect to different types of forcing functions.

UNIT 2
Experimental estimation of dynamic process parameters and identification. Modes of control action: Classification of controllers and control strategy.

UNIT 3
Closed loop feedback control: Servo and regulator problems; Offset; Selection of mode of control action; Closed loop response;

UNIT 4
Routh stability criterion; Controller tuning and design; Online tuning- closed loop and open loop methods. Frequency response technique: Phase margin and gain margin; Bode stability criterion; Nyquist stability criterion; Controller design. Root locus plot and stability analysis.

UNIT 5
Cascade and feed forward control: Design of controller and analysis of control system. Ratio, Adaptive, Model-based, Multivariable, Selective and Split range control. Computer process control

Text Book:

Reference Books:
UNIT 1
Introduction to heterogeneous reactions, rate equation for surface kinetics, pore diffusion resistance combined with surface kinetics, Fluid-fluid reactions: kinetics and design.

UNIT 2
Fluid-solid reactions, experimental methods for finding rates, selection of a model, shrinking-core model for spherical particles of unchanging size, rate of reaction for shrinking spherical particles, determination of rate controlling step, kinetic and design, Design of packed bed and fluidized bed reactors.

UNIT 3
Nature of catalysis, Determination of surface area, void volume and solid density, pore-volume distribution, physical and chemical adsorption, adsorption isotherms, Physical properties of catalysts, preparation, testing and characterization of solid catalysts, catalyst selection, catalyst preparation, promoters and inhibitors, catalyst poisoning and mechanisms of catalytic reactions, catalyst deactivation.

UNIT 4
Reaction and diffusion within porous catalysts, effectiveness factor, various resistances to transfer of reactants to the catalyst site, intrinsic and global rate of reaction, kinetic regimes, heat effects during reaction, Performance equations for reactors containing porous catalyst particles, design of solid catalytic reactors.

UNIT 5
Biochemical reactors, polymerization reactors.

Books:

Reference Books:
2. Coulson and Richardson's Chemical Engineering Volume 3 - Chemical and Biochemical Reactors and Process Control (3rd Edition)
DEPARTMENT ELECTIVE 2:
RCH-061: Process Flow Sheet Simulation (3:1:0)

UNIT 1
Introduction to Process Simulation: Background and history of process simulation; Steady State and Dynamic Simulation; Different approaches to process simulation; modules and components in a process simulation package, integration of simulation tools, structure and functionality of commercial simulation tools, selection of flowsheet and simulation software.
Process Flow sheeting: Approaches to flowsheeting, collection and estimation of thermo-physical properties for the chemical species of the system, thermo-physical properties banks, Flow sheet presentation, manual flow sheet calculations, computer aided flow-sheeting, manual calculations with recycle streams, partitioning and tearing a flowsheet.

UNIT 2
Fundamentals of systems engineering: system definition, system properties, aggregation/decomposition, hierarchies of systems; introduction of canonical modeling concepts: devices, connections, equations, variables; formalizing the modeling process: methods of structuring complex chemical processes, procedures for process modeling; degrees of freedom in a flow sheet. numerical properties of the model equations, numerical methods for steady-state and dynamic systems, Differential Algebraic Equations; Synthesis of reaction systems and synthesis of azeotropic separation systems.

UNIT 3
Processing Simulation with software’s such as : ASPEN PLUS/Hysis/PRO II/Design II/UniSim/OLI Pro/Aspen Custom Modeler/TK-Solver: Introduction to the Simulation Package; Features of simulation packages; Introduction to the simulation package Graphical User Interface; Example-1: Flashing of Light Hydrocarbons; Survey of unit operation models; Example-2: Vinyl chloride monomer (VCM) flowsheet.

UNIT 4
Flowsheet Calculations and Model Analysis Tools: Sensitivity and case-study runs; Design specifications and calculator blocks; Example-3: VCM flowsheet sensitivity run / design-spec run. Inorganic chemicals and electrolyte modeling; Example-4: sour water systems (CO2 and H2S removal for example)

UNIT 5
Physical Properties: Overview of physical property system; Property model specifications; Property data requirements and input; Physical property analysis; Example-1: Introducing a non-databank component. Multistage Separation: RADFRAC: Rigorous rating and design fractionation model; Example-2: Using RADFRAC in the VCM flowsheet. Introduction to ICARUS ( an economic evaluation package inside ASPEN PLUS), Flowsheet Convergence: Example-3: VCM flowsheet convergence, Introduction to overall Plant automation through simulation, molecular modeling and how it will compliment standard simulators and dynamic simulation.
Case Study: Design and simulation of some of the inorganic and organic process plants such as sulphuric acid, ammonia.

Books and Resources:

Resources:
SCILAB, available at http://www.scilab.org, is an open-source simulation package, quite similar to MATLAB.

Netlib online repository for numerical and scientific computing: http://www.netlib.org/

Numerical Recipes: The art of scientific computing website: http://www.nr.com/

CANTERA, Object-Oriented Software for Reacting Flows: http://www.cantera.org/

Practice problems: http://www.che.eng.kmutt.ac.th/cheps/ChE656.htm
UNIT 1
Process Integration and its Building Blocks: Definition of Process Integration (PI), Areas of application and Techniques available for Process Integration, Role of thermodynamic laws.

UNIT 2
Basic Elements of Pinch Technology: Data extraction, Targeting, Designing. Grid diagram, Composite curve, Problem table algorithm, Grand composite curve.

UNIT 3
Targeting of Heat Exchanger Network (HEN): Energy targeting, Area targeting, Number of units targeting, Shell targeting, cost targeting.

UNIT 4
Designing of HEN: Pinch design methods, Heuristic rules, Stream splitting, Design of maximum energy recovery (MER), Design of multiple utilities and pinches.

UNIT 5

Books:
2. V. Uday Sheno, Heat Exchanger network synthesis, Gulf Publishing Co, USA, 1995
RCH-063 PROCESS UTILITY & SAFETY IN CHEMICAL PLANTS (3:0:0)

Unit 1
Various process utilities, their role and importance in chemical plants. Water Sources of water and their characteristics: Treatment storage and distribution of water; water for use in boilers, cooling purposes, drinking and process; Reuse and conservation of water: Water resource management.

Unit 2
Steam Generation and Utilization
Steam Generation and its application in chemical process plants, distribution and utilization: Design of efficient steam heating systems: steam economy, steam condensers and condensate utilization Expansion joints, flash tank design, steam traps their characteristics, selection and application, waste heat utilisation; Lagging, selection and thickness. Selection and sizing of boilers; waste heat boilers.

Unit 3
Compressors, blowers and Vacuum Pumps
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 gas leakage. Inert gas systems. Compressed air for process, Instrument air.

Insulation
Importance of insulation for meeting the process requirements, installation 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 4
Elements of safety
Elements of safety, safety and site selection; Plant and unit plot planning; Definition of risk and hazard Identification and assessment of the hazard and risk, Industrial between hazards and risk, Industrial hygiene, toxicological studies, Hazard operability (HAZOP) hazard analysis (HAZAN); Assessment of the risk, fault tree, event tree, scope of risk assessment; control of hazards, controlling toxic chemicals and controlling flammable materials. Prevention of losses Prevention of losses, Pressure relief, fire & explosions, Provision of fire fighting equipments, Technology selection and transfer, choosing the right process.

Unit 5
Control of Process
Control of process, Prevention of hazardous deviation in process variable, e.g. pressure, temperature flow by Provision of automatic control systems-interlocks, alarms, trips together with good operating practices and management. Accidental analysis, Regulations and legislation, Role of government role, risk management routines and tackling disaster.case studies.

Text Books:
Unit I
Introduction: Introduction, types of intellectual property, international organizations, agencies and treaties, importance of intellectual property rights.

Unit II
Law of copy rights: Fundamental of copy right law, originality of material, rights of reproduction, rights to perform the work publicly, copy right ownership issues, copy right registration, notice of copy right, international copy right law.
**Law of patents:** Foundation of patent law, patent searching process, Patent and kind of inventions protected by a patent, ownership rights and transfer. Case studies of patents.

Unit III
Industrial Designs: Introduction, need to protect industrial design, **industrial designs protection law.**
Trade Marks: Purpose and function of trademarks, acquisition of trade mark rights, protectable matter, selecting, and evaluating trade mark, trade mark registration processes.

Unit IV
**Trade Secrets:** Trade secrete law, determination of trade secrete status, liability for misappropriations of trade secrets, protection for submission, trade secrete litigation. Unfair competition: Misappropriation right of publicity, false advertising.

Unit V
**New developments:** New developments in trade mark law; copy right law, patent law, intellectual property audits. International overview on intellectual property, international – trade mark law, copy right law, international patent law, and international development in trade secrets law.

TEXT BOOKS
2. B.L.Wadehra; Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India 2000

REFERENCE BOOKS
1. P. Narayanan; Law of Copyright and Industrial Designs; Eastern law House, Delhi, 2010
3. Ajit Parulekar and Sarita D’ Souza, Indian Patents Law – Legal & Business Implications; Macmillan India ltd, 2006
1. Flowsheet preparation and drawing
2. Equipment selection, Equipment numbering, stream designation
3. Preparation of plant layouts
4. Piping layouts
5. Steady state flowsheeting using propositional logic in process synthesis
6. Steady state flowsheeting using resolution based synthesis procedure
7. Steady state flowsheeting of processes with recycle (recycle calculation sequence)
8. Network of heat exchangers
9. Sequencing of distillation columns
10. Development of process flowsheet for a specific chemical plan

Recommended to be done using a simulation package/ programming environment
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. Study the principle of operation & working of pneumatic servo system with various input functions.
6. Transient response of a CSTR System to step change.
7. Controlling a batch reactor using digital PID controller.
8. Study the dynamics of parallel & counter flow shell & tube heat exchanger.
9. Controlling of Parallel Flow & counter flow STHE using digital PI controller to have desired output.
10. Dynamics characteristics of mercury & water manometers.
11. Study of control value characteristics.
1. Study the performance of cascade control system & to maintain desired level in a tank, with flow.
2. Study the dynamics of bubble cap distillation column.
3. Control of a bubble cap distillation column using digital PID controller.
4. Study of effect of PID controller on pressure process trainer.
5. 16 Calibration of thermocouple/Bimetallic thermocouple/Resistance thermocouple.
1. Study and operation Trickle bed reactor
2. Study and operation Condensation polymerization reactor
3. Study and operation Emulsion polymerization reactor
4. RTD study in a CSTR
5. RTD study in a plug flow reactor
6. Study and operation of a coiled tubular reactor
7. Study of heterogeneous catalytic reactor
8. Determination of porosity and pore volume of a substance. (kieselguhr, alkaline earth or alumina may be used as substance)
9. To study toluene hydrogenation over Raney nickel catalyst
10. To study acetaldehyde decomposition over copper gauze catalyst