

# M.Tech (CHEMICAL ENGINEERING)

## **Scheme of Instruction** And **Syllabus**

Under Choice Based Credit System  
Effective from 2016-17

DEPARTMENT OF CHEMICAL ENGINEERING  
S V U COLLEGE OF ENGINEERING  
TIRUPATI – 517 502

SRI VENKATESWARA UNIVERSITY COLLEGE OF ENGINEERING (Autonomous) : TIRUPATI  
M.Tech (Chemical Engineering) - Scheme of Instruction under Choice Based Credit System  
(with effect from 2016 – 2017)

**I Semester**

	Course Name	Instruction		Credits	Test I	Test II	Continuous Assessment	End Sem. Exam		Total Marks
		L/T	P/S					Time	Marks	
MACHT01	Probability & Statistics for Chem Engg	4	--	4	20	20	--	3 hr	60	100
CHCHT01	Advanced Transport Phenomena	4	--	4	20	20	--	3 hr	60	100
CHCHT02	Process Plant Simulation	4	--	4	20	20	--	3 hr	60	100
CHCHT03	Separation Process	4	--	4	20	20	--	3 hr	60	100
	Elective I	4	--	4	20	20	--	3 hr	60	100
	Elective II	4	--	4	20	20	--	3 hr	60	100
CHCHP01	Computational Techniques lab	--	3/0	2	--	--	40	3 hr	60	100
CHCHS01	Seminar – I	--	0/2	1	--	--	100	--	--	100
		24	5	27	--	--	--	--	--	800

SRI VENKATESWARA UNIVERSITY COLLEGE OF ENGINEERING (Autonomous) : TIRUPATI  
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**II Semester**

Course No	Course Name	Instruction		Credits	Test I	Test II	Continuous Assessment	End Sem. Exam		Total Marks
		L/T	P/S					Time	Marks	
CHCHT04	Optimization Theory & Practice	4	--	4	20	20	--	3 hr	60	100
CHCHT05	Chemical Reactor Theory	4	--	4	20	20	--	3 hr	60	100
CHCHT06	Advanced Control Systems	4	--	4	20	20	--	3 hr	60	100
CHCHT07	Process Synthesis & Analysis	4	--	4	20	20	--	3 hr	60	100
	Elective –III	4	--	4	20	20	--	3 hr	60	100
	Elective – IV / Open Elective	4	--	4	20	20	--	3 hr	60	100
CHCHP02	Advanced Chem Engg Lab	--	3/0	2	--	--	40	3 hr	60	100
CHCHS02	Seminar – II	--	0/2	1	--	--	100	--	--	100
CHCHV01	Comprehensive Viva Voce	--	--	2	--	--	--	--	100	100
		24	5	29	--	--	--	--	--	900

**CHCHJ : III & IV Semesters – Dissertation - 24 credits**

### **LIST OF ELECTIVES – I, II , III & IV from**

CHCHE11	Pollution Control Systems
CHCHE12	Fluidization Engineering
CHCHE13	Polymer Science
CHCHE14	Polymer Engineering
CHCHE15	Fuel Cell Systems
CHCHE16	Computational Fluid Dynamics
CHCHE17	Reactive Separations
CHCHE18	Advanced Heat Transfer
CHCHE19	Enzyme Science & Engineering
CHCHE20	Bioprocess Engineering
CHCHE21	Membrane Separations
CHCHE 22	Energy Conservation and Audit in Process Industries

A student will have the option to choose elective IV from the Department list or any core or elective subject offered by other Departments.

Permission of the Heads of the Departments and the Course Coordinator is necessary.

## **MACHT01      PROBABILITY & STATISTICS FOR CHEMICAL ENGINEERING**

**Instruction : 4 hr/week**

**Credits : 4**

**Evaluation : 40 + 60**

### **UNIT I :**

Introduction to Probability – Sample space – axioms of probability.

Random variables – Discrete and continuous expectations – Moment Generating functions.

Conditional probability – Baye's theorem – independent events.

### **UNIT II :**

Discrete distributions – Binomial, Hyper geometric, Gamma, Students t, chi-square, Weibell distributions.

Bivariate random variables and their distributions (with specific reference to bivariate normal distributions only). Conditional distributions – covariance, correlation coefficient – regression of the mean.

### **UNIT III :**

Functions of random variables – Probability distribution of functions of random variables – their joint probability distributions.

Sampling – sampling distribution – law of large numbers – central limit theorem.

Estimation – point estimation, interval estimation and confidence intervals. (Maximum likelihood estimation). Bayesians estimation.

### **UNIT IV :**

Testing of Hypothesis – Simple hypothesis and the Neyman – Pearson lemma – Composite hypothesis – goodness of fit tests

Non-parametric statistics – Ranking Tests, Spearman rank correlations – Willcoxon sign test.

### **UNIT V :**

Analysis of variance – One way classification – Randomized, complete block designs.

Factorial design of experiments. Sequential Analysis.

### **Reference Books :**

1. Fundamental of Applied Statistics by S.C.Gupta and V.K. Kapoor, Sultan Chand & Sons.
2. Mathematical Statistics by John E.Freund and Ronald E.Walpole, Prentice Hall of India.
3. Applied Statistics for Engineering by William Volk, McGraw Hill.
4. Statistics for Scientists and Engineers by R.L.Wine, Prentice Hall

**UNIT – I:**

Introduction to Transport phenomena: The conservation laws- mechanism of transport of momentum, energy and mass. Shell momentum balances and boundary conditions, Shell energy balances and boundary conditions, Shell mass balances and boundary conditions.

Equations of Change for Isothermal Systems: Equation of Continuity, Equation of Motion, Equation of Mechanical Energy, Equations of Change in terms of the Substantial Derivative, Use of the Equations to solve Flow Problems, viz., flow through a circular pipe, falling film with variable viscosity, operation of coquette viscometer, flow near slowly rotating sphere. Dimensional Analysis of the Equations of Change, pressure drop for creeping flow in a packed tube.

**UNIT- II:** Velocity Distributions with more than one Independent Variable: Time Dependent Flow of Newtonian Fluids with examples like flow near a wall suddenly set in motion, unsteady laminar flow between two parallel plates and unsteady laminar flow near an oscillating plate. Velocity Distributions in Turbulent Flow -Comparisons of Laminar and Turbulent Flows, Time Smoothed Equations of Change for Incompressible Fluids, Empirical Expressions for the Turbulent Momentum Flux.

Macroscopic Balances for Isothermal Systems: The Macroscopic Mass Balance, The Macroscopic Momentum Balance, The Macroscopic Mechanical Energy Balance, Estimation of the viscous loss, Use of the Macroscopic Balances for Steady-State Problems viz., pressure rise and friction loss in a sudden enlargement, liquid-liquid ejector, thrust on a pipe bend, the impinging jet. Derivation of the macroscopic mechanical energy balance.

**UNIT – III :**Equations of Change for Non-Isothermal Systems: The Energy Equation, Special forms of the Energy Equation, The Boussinesq Equation of Motion for Forced and Free Convection, Use of the Equations of change to Solve Steady-State Problems viz., tangential flow in an annulus with viscous heat source, steady flow in a non isothermal film, Transpiration cooling, free convection heat transfer from a vertical plate and adiabatic frictionless processes in an ideal gas. Dimensional analysis of the equations of change for non-isothermal systems.

Temperature Distribution with more than One Independent Variable - Unsteady Heat Conduction in Solids viz., heating of semi infinite and finite slabs, unsteady heat conduction near a wall with sinusoidal heat flux, cooling of sphere in contact with a well stirred fluid.

Temperature Distributions in Turbulent Flow - Time-Smoothed Equations of Change for Incompressible Non-Isothermal Flow, Time-Smoothed Temperature Profile near a Wall, Empirical Expressions for the turbulent heat flux eg., an approximate relation for the wall heat flux for turbulent flow in a tube.

**UNIT – IV:** Macroscopic Balances For Non-Isothermal Systems: Macroscopic Energy Balance, Macroscopic Mechanical Energy Balance, Use Of The Macroscopic Balances To Solve Steady State Problems With Flat Velocity Profiles viz., the cooling of an ideal gas, mixing of two ideal gas streams, the d-forms of macroscopic balances eg., parallel and counter flow heat exchangers.

Equation of change for multi component systems: The equation of continuity for a multi component mixture, Fick's second law of diffusion, Use of equation of change for mixtures with examples like simultaneous heat and mass transfer, concentration profile in a tubular reactor and catalytic oxidation of carbon monoxide.

**UNIT – V:** Concentration Distributions in Turbulent Flow - Concentration Fluctuations and the Time-Smoothed Concentration, Time-Smoothing of the Equation of Continuity of A, Semi-Empirical Expressions for the Turbulent Mass Flux.

Inter phase Transport in Multi-Component Systems: Definition of Transfer Coefficients in One Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Definition of Transfer Coefficients in Two Phases, Mass Transfer and Chemical Reactions.

**Text Books:**

1. Bird R. B., Stewart W. E. and Light Foot E. N., Transport Phenomena, Revised 2<sup>nd</sup> Edition, John Wiley & Sons, 2007.
2. Geankopolis C. J., Transport Processes and Unit Operations, 4<sup>th</sup> Ed., Prentice Hall (India) Pvt. Ltd., New Delhi. 2004.
3. Thomson W. J., Transport Phenomena, Pearson education, Asia, 2001.

Instruction : 4 hr/week

Credits : 4

Evaluation : 40 + 60

**UNIT I**

**Modeling Aspects:** Deterministic vs. Stochastic Processes, Physical modeling, Mathematical modeling, Chemical Systems Modeling, Cybernetics, Controlled System, Principles of Similarity

**Classification of Mathematical Modeling:** Independent and Dependent variables, Classification based on variation of independent variables, Classification based on state of the process, Classification based on type of the process, Boundary Conditions, The black Box Principle, Artificial Neural Networks

**UNIT II - Process Modeling - I**

**Models from mass transfer:** steady state single stage solvent extraction, steady state two stage solvent extraction, steady state two stage cross current solvent extraction, , steady state N- stage solvent counter current extraction, unsteady state single stage solvent extraction, unsteady state mass balance in a stirred tank and in a mixing tank.

**Models from Heat Transfer :** steady state heat conduction through a hollow cylindrical pipe, unsteady state steam heating of a liquid, unsteady state heat loss through a measuring tank, heat transfer through extended surfaces, unsteady state heat transfer in a tubular gas pre heater

**UNIT III – Process Modeling -II**

**Models from fluid flow:** flow through a packed bed column, flow of a film on the outside of a circular tube, annular flow with inner cylinder moving axially, flow between coaxial cylinders and concentric spheres

**Models from Reaction Engineering :** chemical reaction with diffusion in a tubular reactor, chemical reactor with heat transfer in a packed bed reactor, gas absorption accompanied by chemical reaction

**UNIT IV**

**Error Propagation & Data Regression :** Propagation of errors through addition, subtraction, multiplication and division, Errors of measurement, Precision errors, errors method

**Data Regression :** Theoretical properties, data regression methods, Problems in data regression

**Process Simulation :** Modular Approach, The equation solving approach

**UNIT V**

**Decomposition of Networks :** Tearing Algorithms, Algorithms based on signal flow graph and reduced digraph

**Convergence Promotion:** Newton's method, direct substitution method, Wegstein's method, dominant Eigen value method, quasi Newton method, Criterion for acceleration, Physical and Thermodynamic Properties

**TEXTBOOKS:**

1. Process Plant Simulation, B.V.Babu, Oxford University press, 2004
2. Process Modeling, Simulation and Control for Chemical Engineers, 2<sup>nd</sup> ed., W. L. Luyben, McGraw-Hill, New York, 1990

**REFERENCE:**

1. Introduction to Numerical Methods in Chemical Engineering, P. Ahuja, PHI learning Pvt. Ltd., New Delhi, 2010
2. Process Modeling and Simulation, Amiya K. Jana, 2012.



**UNIT I**

**Use and Characteristics of Separation Processes** – Importance and variety of Separations – Characteristics of separation Processes- Inherent separation factors for equilibrium and rate Governed Processes

**Simple equilibrium processes:** Equilibrium calculations- Checking phase conditions for a mixture- Analysis of simple equilibrium separation-processes for binary and multi component systems - Computational and Graphical Approaches.

**Unit II**

**Additional Factors Influencing Product Purities** – Incomplete Mechanical Separation of Product Phases – Flow Configuration and Mixing Effects – Batch Operations – Methods of Regeneration – Mass and Heat Transfer Limitations – Stage Efficiencies

**Multistage Separation Processes:** Increasing product purity - Reducing consumption of separating agent - co-current, crosscurrent and countercurrent flow - Other separation processes - Fixed bed processes.

Unit-III:

**Binary Multistage Separations - Distillation:** Binary Systems - Equilibrium stages and McCabe-Thiele Diagram - design and other problems – Multistage batch distillation - Straight operating lines and curved operating lines.

**UNIT IV**

**Patterns of Change:** Binary and Multi component multistage separations

**Group Methods** - Linear stage-exit relationships and constant flow rates- non linear stage –Exit Relationships and varying flow rates.

**Capacity of contacting devices:** factors limiting capacity and factors influencing efficiency.

**UNIT V**

**Energy Requirements of separations processes:**

Thermodynamic efficiency - single stage and multistage separation processes - reduction of energy consumption.

**Selection of Separation processes:** Factors influencing the choice of separation Process - solvent extraction and Illustrative examples

**TEXT BOOKS:**

1. Separation Processes - C.Judson King,, McGraw – Hill, 1982

**REFERENCE BOOKS**

1. Separation Process Principles - J.D.Seader and E.J.Henley, , John Wiley, 1998.
2. Mass Transfer Operation - R.E. Treybal, , 3<sup>rd</sup> edition - McGraw – Hill 1980
3. Transport Processes and Unit Operations – Geankopolis C.J. 4<sup>th</sup> ed – PHI Pvt. Ltd

## CHCHT 04                    OPTIMIZATION THEORY AND PRACTICE

**INSTRUCTION : 4 Hr/week**

**Credits : 4**

**Assessment : 40 + 60**

### **Unit-I: Introduction**

Basic concepts of optimization, applications of optimization, general procedure for solving optimization problem, formulation of the objective function, fitting models to data, classification of functions.

### **Unit-II: Single Variable unconstrained optimization methods**

Direct search methods-Interval halving method, Fibonacci method, Golden section method;

Direct root methods-Newton method and Quasi Newton method;

Polynomial approximation methods - Quadratic interpolation and cubic interpolation.

### **Unit-III: Optimization of unconstrained multivariable functions**

Direct search methods-random search, grid search, uni-variate search and pattern search methods. ; Indirect search methods - steepest descent, conjugate gradient methods, Newton's method and secant method.

### **Unit-IV: Linear and non-linear programming**

Linear programming: Basic concepts in linear programming, Standard LP form, Graphical solution and Simplex method.

Non-linear programming: Lagrange multiplier method, Quadratic programming, Penalty function and augmented Lagrangian methods.

### **Unit -V: Applications of optimization**

Optimizing recovery of waste heat, optimal design and operation of a conventional staged-distillation column, optimal pipe diameter, optimal residence time for maximum yield in chemostat and optimization of a thermal cracker using linear programming.

### **Text Book:**

1. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill, New York.

### **Reference Books :**

1. Diwaker, U. W. "Introduction to Applied Optimization", Kluwer.

2. Joshi, M. C. and Moudgalya, K. M., "Optimization, Theory and Practice", Narosa, New Delhi, 2004.

3. Rao, S. S., Engineering Optimization: Theory and Practice, New Age Publishers.

**UNIT I**

**Isothermal Reactor design:** Design structure for isothermal reactors - Scale-up of liquid phase batch reactor data to the design of a CSTR - Tubular reactors - Pressure drop in Reactors - Reversible reactions - unsteady state operation of reactors - Simultaneous reaction and Separation.

**UNIT-II**

**Analysis of Non ideal Reactors** - RTD - Measurement and characteristics of RTD- RTD in ideal reactors - Reactor modeling with the RTD - Zero and One parameter models - Two- Parameter model - Modeling real reactors with combinations of ideal reactors - Testing a model and determining its parameters - Other models of non ideal reactors using CSTRs and PFRs

**UNIT-III**

**External diffusion Effect on Heterogeneous Reactions** - Binary diffusion - External resistance to mass transfer - the shrinking core model.

**Diffusion and reaction in Porous Catalyst** – Diffusion and reaction in spherical pellets - Internal Effectiveness factor - Falsified Kinetics - Overall effectiveness factor - Estimation of diffusion and reaction limited regimes - Mass transfer and reaction in a packed bed

**UNIT-IV**

**Internal Transport Processes-Reaction and Diffusion in porous catalysts:**

Intra pellet mass transfer and intra pellet heat transfer, Mass transfer with reaction, Mass and Heat transfer with reaction, effect of internal transport on selectivity and poisoning.

**UNIT-V**

**Design of heterogeneous Catalytic Reactors:** Fixed bed reactors and isothermal and adiabatic fixed-bed reactors, non isothermal, non adiabatic fixed bed reactors, Two phase model, Fluidized-Bed reactors, Operating characteristics of FBRs. Mass Transfer in Fluidized Beds: Gas-Solid Mass Transfer, Mass Transfer between the Fluidized-Bed Phases, Reaction in Fluidized Bed. *Trickle bed reactor Models, Slurry reactor models.*

**Text Books**

1. J.M.Smith "Chemical Engineering Kinetics" 3<sup>rd</sup> ED., Mc Graw Hill, New York 1980
2. Fogler H. S., Elements of Chemical Reaction Eng.", 3<sup>rd</sup> Ed., Prentice Hall, 1999
3. Levenspiel, O., "Chemical Reaction Eng." John Wiley & Sons 1972.

Instruction : 4 hr/week

Credits : 4

Evaluation : 40 + 60

**Unit I :**

**Feed Forward and Ratio Control** – Introduction, Feed forward controller design based on steady state and dynamic models, tuning and configuration of feed forward control

**Advanced Control Strategies** – Cascade control, time delay compensation and inferential control, selective and override systems, adaptive control, statistical process control

**Unit II :**

**Control of Multi Input, Multi-Output Systems** – Process interactions and control loop interactions, pairing of controlled and manipulated variables, strategy for reducing interactions, decoupling, multivariable control techniques

**Supervisory Control** – Basic requirements, applications, formulation and solution of optimization problems, unconstrained and constrained optimization

**Unit III :**

**Digital Computer Control** – Digital control systems in process control, distributed instrumentation and control systems, general purpose digital data acquisition, digital control hardware and software, table driven PID controller, Programmable logic controllers and batch process control

**Sampling and Filtering of Continuous Measurements** – Sampling and signal reconstruction, selection of sampling period, signal processing and data filtering, comparison of analog and digital filters, effect of filter selection on control system performance

**Unit IV :**

**Development of Discrete Time Models** – Finite difference models, exact discretization for linear systems, higher order systems, fitting discrete time equations to process data

**Dynamic Response of Discrete –Time Systems** – The z-Transform, inversion, pulse transfer function, relating pulse transfer functions to difference equations, effect of pole and zero locations, conversion between laplace and z- transforms

**Unit V :**

**Analysis of Sampled – Data Control Systems** – Open loop block diagram analysis, development of closed loop transfer functions, stability of sampled data control systems

**Design of Digital Controllers** – Digital PID controller, selection of controller parameters, direct synthesis methods, digital feed forward control, combined load estimation and time delay compensation

**Text Books:**

1. Process Dynamics and Control – D.E.Seborg, T.F.Edgar and D.A.Mellichamp, John Wiley & Sons
2. Chemical Process control – An Introduction to Theory and Practice - George Stephanopoulos, Prentice hall 1990.

## CHCHT 07            PROCESS SYNTHESIS AND ANALYSIS

**INSTRUCTION : 4 Hr/week**

**Credits : 4**

**Assessment : 40 + 60**

### **UNIT-I :**

**Nature of Process Synthesis & Analysis :** Creative aspects – A hierarchical approach

**Engineering Economics :** Cost Information – Estimation of Capital and Operating Costs – Total Capital Investment- Total Product Cost - Time Value of Money – Measures of Process Profitability – Simplifying the Economic Analysis for Conceptual Design

### **UNIT II :**

**Economic Decision Making :** Solvent Recovery System – Problem Definition & General Considerations – Design of a Gas Absorber – Equipment Design Consideration – Rules of Thumb

**Input Information & Batch- Continuous:** Input Information – Level 1 Decision – Batch Vs. Continuous

### **UNIT III :**

**Input-Output Structure of the Flow Sheet :** Decisions for the I/O structure – Design Variables – Over all Material Balances – Stream Costs – Process Alternatives

**Recycle Structure of the Flow Sheet :** Decisions determining the recycle Structure – Recycle Material balances – reactor Heat Effects – Equilibrium Limitations – Compress Design & Costs – Reactor Design – recycle Economic Evaluation

### **Unit IV :**

**Heat Exchanger Networks** – Minimum Heating & Cooling Requirements – Minimum Number of Exchangers – Area Estimates – Design of Minimum Energy Heat Exchanger Networks – Loops and Paths – Reducing the Number of Exchanger – Stream Splitting – Heat and Power Integration – Heat Distillation – HAD Process

### **UNIT V :**

**Separation System :** General Structure – Vapor Recovery System – Liquid Separation System – Azeotropic Systems – Rigorous Material Balances

**Cost Diagrams and Quick Screening of Process Alternatives** - Cost Diagrams for simple and complex process – Quick Screening of Process Alternatives – HAD Process

### **Text Book :**

1. Conceptual Design of Chemical Processes, Douglas, J.M., McGraw Hill,

### **Reference Books :**

1. Chemical Process Design, Robin Smith, McGraw Hill,
2. Chemical Process Design, Dimian A.C, & Bidea,C.S., Wiley – VCH,2008
3. Chemical Process Synthesis & Engineering Design, Kumar,A, Tata McGraw Hill,1982
4. Systematic Methods of Chemical Process Design, Biegler, L.T., Grossman, E.I and Westerberg, A.W. Prentice Hall Inc.
5. Product and Process Design Principles, Seider, W.D., Seider,J.D & Lewin, D.R. Wiley,2005

INSTRUCTION : 4 Hr/week

Credits : 4

Assessment : 40 + 60

**UNIT-I :****Pollution and Its Measurement-** Introduction-Types of pollution—pollution Control aspects**Industrial pollution Emissions and Indian Standards-**Industrial Emissions-Liquids and Gases—Environmental Legislation—Water quality Management in India—Air Act 1981**Analysis of pollutants-**Industrial Waste Water Analysis-Industrial Gaseous Effluent Analysis**UNIT-II :****Removal of BOD**—Biological oxidation—Activated Sludge Process—Trickling Filters—Fluidized bed contactors—Anaerobic Treatment**Removal of Chromium**—Reduction Precipitation-Ion Exchange-Reverse Osmosis-Lime Coagulation and Adsorption**Removal of Mercury**—From Gaseous Streams and Liquid Streams**UNIT-III :****Removal of Ammonia/Urea**—Sources —Methods for Removal of Nitrogen — Physico —Chemical Processes—Biological Methods—Algal Bacterial Flocculating Systems—Miscellaneous Methods**Treatment of Phenolic Effluents**—Sources—Treatment Methods**Removal of Particulate Matter**— Introduction—Separation of Particulate Matter From Effluent Gases**UNIT-IV :****Removal of Sulphur Dioxide**—introduction—Methods of Sulphur Dioxide Control -- Process Changes—Reduction of Sulphur Dioxide Concentration—Wet And Dry Processes**Removal of Oxides of Nitrogen**—Introduction—Control Measures**Removal of Organic Vapour from Effluent Gases**—Absorption- Condensation- Adsorption of Vapour—Incineration of Vapour**UNIT-V :****Pollution control in Chemical Industries**—Pollution Control Aspects of Fertilizer Industries—Pollution Control in Petroleum Refineries and Petrochemical Units- Pollution Control in Pulp and Paper Industries**Pollution Control in Miscellaneous Process Industries****Text Book:**

1. Pollution Control In Process Industries SP Mahajan

**UNIT- I :**

**Introduction:** The Phenomenon of fluidization, Liquid like Behavior of a fluidized Bed, Comparison with other Contacting Methods, Advantages and Disadvantages of Fluidized beds for Industrial Operations, Fluidization Quality, Selection of a Contacting Mode for a given Application, Overall Plan.

**Industrial Applications Of Fluidized Beds:** Historical Highlights – Physical Operations – Synthesis Reactions – Cracking of Hydrocarbons –; Combustion and Incineration – Carbonization and gasification – Cacination - Reactions Involving Solids – Biofluidization

**UNIT-II :**

**Fluidization And Mapping Of Regimes.:** Fixed beds of particles: Fluidization without Carryover of particles, Types of Gas Fluidization without carryover – The Geldart classification of particles - Fluidization With Carryover Of Particles – The Mapping of Fluidization Regimes.

**The Dense Bed Distributors, Gas Jets and Pumping Power:** Distributor Types – Gas Entry Region of a Bed; Gas Jets in Fluidized Beds; Pressure Drop Requirements across distributors; Design of Gas Distributors, Power Consumption.

**UNIT – III**

**Bubbles in Dense Beds:** Single rising bubbles, Rise rate - Davidson model - Other Models - Comparison of Models with experiment - Evaluation of models - wake region and the movement of solids at bubbles -solids with in bubbles - coalescence and splitting of bubbles- Bubble formation above a distributor - slug flow.

**Bubbling Fluidized bed:** Experimental findings, Estimation of bed properties, physical models, Scale up and scale down, Flow models for bubbling beds.

**UNIT – IV**

**Entrainment And Elutriation From Fluidized Beds:** Freeboard Behavior –; Location of the Gas Outlet of a Vessel – Entrainment from Tall Vessels - Entrainment from Short Vessels

**High – Velocity Fluidization:** Turbulent Fluidized Beds – Experimental Findings; Fast Fluidization - Experimental Findings; The Freeboard – Entrainment Model Applied to Fast Fluidization – Design Considerations; Pressure Drop in Turbulent and Fast Fluidization

**Circulation Systems** - Classification – Pressure Balance in a circulation loop

**UNIT – V**

**Solid Movement Mixing- segregation and staging** - Vertical Movement of Solids – Horizontal movement of particles – Segregation of Particles – Large solids in beds of smaller particles – staging of fluidized beds – leakage of solids

**Particle-to-Gas Mass & Heat Transfer** – Mass Transfer – Interpretation of mass transfer coefficient - Heat Transfer – Interpretation of Heat transfer coefficient

**Text Book :**

1. Fluidization Engineering by Diazo Kunii & O.Levenspiel, John Wiley

**References :**

1. Fluidization by Davidson JF & Harrison B, Academic Press.
2. Fluidization and Fluid Particle systems Zenz PA & Othmer D F, Reinhold Pub. Co

**UNIT-I**

Introduction – Classification of Polymers – Polymer Structure – Molecular Weight – Chemical Structure and Thermal Transitions

Polymer Degradation and the Environment – Polymer Degradation and the Environment -

Management of Plastics in the Environment

**UNIT-II**

Polymer Synthesis – Step Growth Polymerization – Chain Growth Polymerization – Polymerization Techniques – Reactions of Synthetic Polymers – Special Topics in Polymer Synthesis – Chemical Structure Determination

**UNIT-III**

Conformational Solutions and Molecular Weight – Polymer Conformation and Chain Dimensions – Thermodynamics of Polymer Solutions – Measurement of Molecular Weight

**Unit –IV**

Viscoelasticity and Rubber Plasticity – Introduction to Viscoelasticity – Introduction to Rubber Plasticity

**UNIT-V**

Solid State Properties – The Amorphous State – The Crystalline State – Thermal Transitions and Properties – Mechanical Properties

Additives, Blends and Composites – Additives – Polymer Blends and Interpenetrating Networks – Introduction to Polymer Composites

**Text Book :**

1. Polymer Science & Technology - John R.Fried – 2 nd edition – PHI Learning Pvt Ltd- 2010

**Reference Books :**

1. Polymer Science : A Text Book – V K Ahluwalia & Anuradha Mishra - Ane Books India 2008
2. Plastics Engineering – R J Crawford – Elsevier ( Butterworth-Heinemann) – 3 rd edition - 2011



**UNIT-I**

Biopolymers, natural Polymers and Fibers – Biopolymers and other Naturally Occurring Polymers – Fibers -

**UNIT-II**

Thermoplastics, Elastomers and Thermosets – Commodity Thermoplastics – Elastomers - Thermosets

**UNIT-III**

Engineering and Speciality Polymers – Engineering Thermoplastics – Speciality Polymers

**Unit –IV**

Polymer Processing and Rheology – Basic Processing Operations – Introduction to Polymer Rheology – Analysis of Simple Flows – Rheometry – Modeling of Polymer Processing Operations

**UNIT-V**

Polymers for Advanced Technologies – Membrane Science and Technology – Biomedical Engineering and Drug Delivery – Applications Electronics – Photonic Polymers

**Text Book :**

1. Polymer Science & Technology - John R.Fried – 2 nd edition – PHI Learning Pvt Ltd- 2010

**Reference Books :**

1. Polymer Science : A Text Book – V K Ahluwalia & Anuradha Mishra - Ane Books India 2008
2. Plastics Engineering – R J Crawford – Elsevier ( Butterworth-Heinemann) – 3 rd edition - 2011

**UNIT-I**

**Introduction – Fuel Cells-** Relevance and Importance – Historical Highlights - Difference from Batteries – Fuel Choice – Classification  
Electrochemistry – Thermodynamic Aspects of Electrochemical(EC) Energy Conversion – Theoretical Efficiency of Heat of a Reaction to Mechanical Energy – Efficiency of EC Energy Conversion – Factors Affecting Efficiency of EC Energy Conversion  
Electrode Kinetics of EC Energy Conversion

**UNIT-II**

**Alkaline Fuel Cells** – Description – Working Principle – Components - Modules – Fuel Cell Stacks – General Performance Characteristics – Advancements – System Issues – Ammonia as AFC Fuel  
Molten Carbonate Fuel Cells – General Principle – Cell Components – Mechanisms of Electrode Reactions- Status

**UNIT-III**

**Phosphorus Acid Fuel Cells-** Technology- Electrode Materials and Manufacturing – Stacks and Systems

**Solid Oxide Fuel Cells** – History – Advantages and Limitations- Cell Components – Electrode Materials – Interconnects – Fuel – Configuration and Performance – Environmental Impact – Applications

**UNIT-IV**

**Direct Methanol Fuel Cells** – Technology Evolution – The Noble Metal Issue- The Catalyst – Electro-oxidation of Methanol – The Electrolyte – Non Catalytic Aspects – Methanol Cross over to DMFC – catalyst Optimization and Scale up – Engineering Aspects

**UNIT-V**

**Proton Exchange Membrane Fuel Cells** – Basic Scientific aspects- Challenges – Technology Development – Fuel Processing – Modeling Studies of PEMFC Performance – Applications – Challenges to High Temperature Operations – Technological and Economic Challenges

**Text Book :**

1. Fuel Cell : Principles and Applications – B.Viswanathan and M. Aulice Scibioh – Universities Press - 2006

Instruction : 4 hr/week

Credits : 4

Assessment : 40 + 60

**Unit I :**

**Philosophy of CFD** – CFD - CFD as a research tool – CFD as a design tool – Examples

**Governing Equations of Fluid Dynamics** – Introduction – Models of Flow – The sustainable derivative- Divergence of Velocity – Continuity Equation – Momentum Equation – Energy Equation – Physical boundary conditions – Forms of Governing equations suited to CFD

**Unit II :**

**Mathematical Behaviour of Partial Differential Equations (PDEs)** – Classification of quasi linear PDEs – General Method of determining the classification of PDEs – General Behavior of different classes of PDEs

**Unit III :**

**Discretization** – Basic aspects – Finite Differences – Difference equations – Explicit and Implicit approaches – Errors and analysis of stability

**Unit IV :**

**Grids with appropriate transformations** – General transformation of equations – Metrics and Jacobians – Form of governing equations suited to CFD – Stretched grids – boundary fitted coordinate systems – adaptive grids – modern developments in grid generation, finite volume mesh

**Unit V :**

**Simple CFD Techniques** - The Lax – Wendroff Technique – MacCormack's technique - Viscous Flows, Conservation form and space marching – Relaxation Technique – Aspects of numerical dissipation and dispersion – Alternating – Direction- Implicit technique – Pressure correction technique

## Text Book :

1. CFD : The Basics with Applications – John D. Anderson Jr. TMH Publication

## Reference

1) Introduction to CFD – Pradip Niyogi, S K Chakrabarthy, M K Laha , Pearson Edu.:

**UNIT – I :**

**Reactive Distillation:** Definition, introduction to reactive distillation process - Thermodynamic and kinetic effects on the feasible products of RD - Azeotropes, arheotropes, kinetics arheotropes in reactive membrane separation.

Equilibrium theory and nonlinear waves for reaction separation processes: Introduction, Theoretical background, Analysis of reaction separation processes.

**UNIT – II :**

**Reactive stripping** in structured catalytic reactors: introduction, hydrodynamics, Reactive experiments, comparison of different internals.

**Reactive Absorption:** introduction, reactive absorption equipment, modeling concept, model parameters, case studies.

**UNIT – III :**

**Reactive Extraction:** introductions, phase equilibria, reactive mass transfer, hydrodynamics.

**Development of reactive crystallization process:** introduction, work flow in process development, process synthesis, reactive phase diagrams, kinetic effects, asymmetric transformation of enantiomers.

**UNIT – IV :**

**Reactive extrusion for solvent free processing:** introduction, advantages & disadvantages, main reactions in extruders, extruder types, kinetic considerations, heat transfer and thermal instabilities.

**Reactive comminution:** introduction, mechanical comminution of solids, equipment and processes, applications.

**UNIT – V :**

**Reactive filtration:** introduction, separation of particulates and catalytic reaction of volatiles, separation of particles and reaction of solids.

**Reactive assisted granulation in fluidized beds:** introduction, modeling, experiments.

**Text Books:**

1. Sundmacher K., Kienle A., Siedel A., Integrated Chemical Processes, Wiley VCH, 2005.
2. Kulprathipanja, Reactive Separation Processes, Taylor and Francis, 2002.
3. LuybenW. L. and Cheng-Ching Yu, Reactive Distillation Design and Control, John Wiley and Sons, 2008.

**CHCHE 18**

**ADVANCED HEAT TRANSFER**

**Instruction : 4 hr/week**

**Credits : 4**

**Assessment : 40 + 60**

**UNIT I :**

Process heat transfer: Introduction, Steady state conduction in multiple dimensions, Principles of convection, Radiation Heat Transfer-Physical mechanism, radiation properties, radiation shape factor and relations between shape factors.

**Unit II :**

**Heat-Transfer Equipment:**Introduction, Basic design procedure and theory, Overall heat-transfer coefficient, Fouling factors, Shell and tube exchangers: construction details, Mean temperature difference (temperature driving force).

**Unit III:**

**Shell and Tube Exchangers:** general design considerations, Tube-side heat-transfer coefficient and pressure drop (single phase), 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 IV:**

Design of Condensers, Reboilers and Vaporizers.

**Unit V:**

**Design of Plate heat exchangers:** Gasketed plate heat exchangers, Welded plate, Plate-fin, Spiral heat exchangers, Direct-contact heat Exchangers, finned tubes, Double-pipe heat exchangers, Air-cooled exchangers, Fired heaters (furnaces and boilers), Heat transfer to vessels.

**References:**

1. Chemical Engineering Design by Coulson & Richardson's, Volume 6 Fourth Edition.
2. Heat Transfer" by J.P.Holman, Ninth Edition.
- 3.Process Heat Transfer by Donald Q. Kern.

Instruction : 4 hr/week

Credits : 4

Assessment : 40 + 60

**UNIT I :**

**Enzymes** : Classification – Protein Structure –Extraction, Purification and characterization from natural sources – Development of enzymatic assays, Comparison of chemical and enzyme catalysis

**UNIT II :**

**Mechanisms and Kinetics of Enzyme Action** : Mechanisms of enzyme action – concept of active site and energetics of enzyme-substrate complex formation – Specificity of enzyme action – Kinetics of single substrate reactions (irreversible & reversible), estimation of Michaelis-Menten Parameters – Multi substrate mechanisms and kinetics

Types of inhibition – kinetic Models – substrate and product inhibition – temperature and pH effects on enzyme activity – deactivation kinetics

**UNIT-III:**

**Enzyme Immobilization** – Physical and Chemical methods – Comparison of different methods –

**Immobilized Enzyme Kinetics** - Analysis of Film and Pore Diffusion effects on immobilized enzyme systems – Formulation of dimensionless groups and calculation of effectiveness factors

**UNIT-IV :**

**Enzyme Reactors** - Immobilized Enzyme Reactors – Packed bed, Fluidized bed, membrane reactors – Bioconversion calculations in free enzyme CSTRs and immobilized enzyme reactors

**UNIT V :**

**Applications** : Applications of free and immobilized enzymes

**Biosensors** : Applications of enzymes in analysis; Design of enzyme electrodes and their applications as biosensors in industry, health care and environment

**Text Books**

1. Enzymes-Palmer;T,(Affiliated East West Press Pvt.Ltd.), 2004
2. Biochemical Engineering Fundamentals – Bailey, J.E. & Ollis,D.F., McGraw Hill

**References**

1. Biochemistry- Stryer,Berg, 6thEdition, (W.H.Freeman and Co.), 2007.
2. Enzyme Biotechnology- Tripathi;G, (ABD Publishers), 2003.
3. Enzyme Technology, M.F. Chaplin and C. Bucke. Cambridge University Press
4. Industrial Enzymes & their applications, H. Uhlig, (John Wiley and Sons Inc.)

**UNIT I :**

**Introduction** - Biotechnology & Bioprocess Engineering - Role of a Bioprocess Engineer – Engineering Approach to Biosynthesis - **Bioprocesses: Regulatory Constraints** - Steps in Bioprocess development - Major products of biological processing – A case study of Penicillin

**Biology Basics** - Microbial diversity – Cell Construction – Cell Nutrients

**UNIT II :**

**Sterilization** - Methods of Sterilization – Radiation & Chemical Sterilization - Batch Thermal Sterilization – Continuous Thermal Sterilization – Thermal death Kinetics – Calculation of Sterilization Time - Sterilization of Air and Filter Design - Indices to assess effectiveness of sterilization

**UNIT III :**

**Cell Growth** – Complexity of Growth Process – Batch Growth – Quantifying Growth Kinetics – Cell Growth in Continuous Cultures

**Stoichiometry of Microbial Growth and Product Formation** – Introduction – Stoichiometric Calculations- Theoretical Predictions of Yield Coefficients

**UNIT IV :**

**Operating Considerations for Bioreactors** - Choosing the cultivation method – Modifying batch and Continuous Reactors -

**Immobilization of Cells** - Active immobilization - Passive Immobilization – Diffusional Limitations – Bioreactor Considerations in Immobilized Cell Systems

**Solid State Fermentation**

**Scale up of Bioreactors** - Reactor Types – Aeration – Agitation – Heat Transfer – Scale up- Scale Down

**Bioreactor Instrumentation and Control**

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**UNIT V :**

**Recovery and Purification of Products** - Strategy - Separation of Insoluble Products – Cell Disruption – Separation of Soluble Products – Finishing Steps – Integration of Reaction and Separation

**Traditional Industrial Bioprocess** - Anaerobic Bioprocesses ( ethanol, Lactic Acid, Acetone-Butanol) – Aerobic Processes ( Citric Acid ,Yeast , High Fructose Corn Syrup)

**Text Books**

1. Bioprocess Engineering Basic Concepts – Michael L Schler & Fikret Kargi – Prentice – Hall second Edition, 2002
2. Biochemical Engineering Fundamentals – Bailey, J.E. & Ollis, D.F., McGraw Hill

**CHCHE 21**

**Membrane Separations**

**Instruction : 4 hr/week**

**Credits : 4**

**Assessment : 40 + 60**

**UNIT I :**

**OverView of Membrane Separations**

**Membrane Types, Materials, Preparation and Characterization** - Types of Synthetic Membranes – Membrane Modules – Typical Flow patterns – Membrane materials – Pore Characteristics – Membrane Manufacture – Measurement of Pore size and Solute rejection Properties – surface Properties measurement and interpretation

**UNIT II :**

**Nano Filtration** – principles – nano-filtration membranes – Mass Transfer – Process Limitations – Industrial application

**Ultrafiltration** - Basic Principles – Membranes – Configuration – Types of Devices – Factors affecting performance – Flux – Models for Solvent Flux – Fouling and Flux decline – Methods to reduce Concentration Polarization – Energy Considerations – Micellar enhanced UF – Affinity UF – Applications

**Microfiltration** – Basic Principles – Membranes – Transport Mechanism – retention characteristics – Flow Characteristics – Membrane Plugging and Throughput – Fouling – energy Considerations – Applications

**UNIT III :**

**Reverse Osmosis** - Concepts – Phenomenon of RO – Models for RO transport – Design and Operating parameters – Concentration Polarization – Membrane plugging – Equivalent work requirement – Design of an RO module – RO of non-aqueous systems – Osmotic pinch effect – Forward osmosis – Applications

**Dialysis** – Principles – Dialysis systems – Membranes – Mass transfer – Applications – Diffusion dialysis

**UNIT IV :**

**Gas Separation** - Basic Principles – Membranes – Membrane Modules – Fundamental Mechanisms of Gas Transport - Factors affecting Gas Permeation – Complete Mixing Model – Cross and Countercurrent models – Applications

**Pervaporation** - Basic Principles – Advantages – Membrane characteristics – Thermodynamic Considerations – Mass transfer – Thermodynamic Considerations – Design of a Module – Concentration Polarization – factors affecting pervaporation – Temperature drop at the interface – Applications

**UNIT V :**

**Ion Exchange Membrane Process** - Basic Principles – Ion exchange Membranes – Energy requirement, Efficiency- Concentration Polarization and limiting current density – Other operating parameters – applications

**Liquid Membranes** - Types of liquid membranes – Mechanism of Mass transfer – Applications

**Other Membrane Processes** – Membrane contactor and applications – Membrane distillation – Membrane reactors – PEM Hydrogen Fuel Cell



### **Text Book**

1. Membrane Separation Processes – Kaushik nath – Prentice Hall, 2008

### **References**

1. Reverse Osmosis and Synthetic Membranes Theory, Technology and Engineering, Sourirajan,S National Research Council, Canada.
2. Reverse Osmosis/ Ultrafiltration Process Principles, Sourirajan,S. and Matsuura, T., National Research Council, Canada. Separation Processes, Elsevier Scientific Publication.
3. Industrial Membrane Separation Technology, Scott,K., and Hughes, R. (Eds.), Blackie Academic & Professional London.
4. Separation Processes, King, C.J, Tata McGraw Hill, New Delhi.
5. Membrane Processes, Rautenbatch, R., and Albrecht, R John Wiley & Sons, New York.
6. Membrane Separation Processes, Baum,B., Halley, W. and White, R.A, Elsevier Scientific Publication

## **CHCHE 22 Energy Conservation and Audit in Process Industries**

**Instruction : 4 hr/week**

**Credits : 4**

**Assessment : 40 + 60**

### **UNIT I :**

Energy out-look - The second law of thermodynamics - Thermodynamics and economics part-I

### **UNIT II :**

Characterising energy use (energy-audit) - Optimum performance of existing facilities - Facilities improvement

### **UNIT III**

Methodology of thermodynamic analysis - Detailed thermodynamic analysis of common unit operations

### **UNIT IV**

Use of Thermodynamic analysis to improve energy efficiency - Thermodynamic and economics

### **UNIT V :**

Systematic design methods - Guidelines and recommendations for improving process operation

### **TEXT BOOK:**

1. Energy Conservation in Process Industries - W.F.Kenney, Academic Press, Inc., (London) Ltd., 1984.

### **References :**

1. Practical Techniques for Saving Energy in Chemical, Petroleum and Metal industries, Noys Data Corp. 197
2. Hand Book of Industrial Energy Analysis, Boustead, I and Hancock, G.F. Ellis Horwood Ltd., Chichester, U.K. (1979).
3. Hand Book of Energy Audit, Albert Thuman., P.E. The Fairmount Press Inc., (1979)

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