Dr. Babasaheb Ambedkar Technological University, Lonere

(Established as a University of Technology in the State of Maharashtra)
(Under Maharashtra Act No. XXIX of 2014)
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Curriculum for Third Year
Undergraduate Degree Programme
B. Tech. in Chemical Engineering

With effect from AY 2025-2026

Course Structure for Chemical Engineering as per NEP-2020

Category	Course Code	Course Title	Evaluation Scheme							
			L	T	P	CA	MSE	ESE	Total	Credit
Semester V										
PCC	25UD1507PC501	Chemical Engineering Thermodynamics-II	3	-	-	20	20	60	100	**3**
PCC	25UD1507PC502	Chemical Reaction Engineering-I	3	-	-	20	20	60	100	**3**
PCC	25UD1507PC503	Mass Transfer Operations-I	3	-	-	20	20	60	100	**3**
PCC	25UD1507PC504	Chemical Technology	2	-	-	20	20	60	100	**2**
OE	24UD1MACOEM05H	Open Elective-III(Equity Stock market)	2	-	-	20	20	60	100	**2**
MDM	25UD1507MD506	Multidisciplinary minor-III(Heat Transfer Operations)	3	-	-	20	20	60	100	**3**
PCC	25UD1507PCL507	Chemical Engineering Lab I (CRE-I/MTO I)	-	-	2	60	-	40	100	**1**
PEC	25UD1507PE508	Program Elective-I A. Numerical methods B. Introduction to Bioprocess Engineering C. Mathematical Modeling in Chemical Engineering	3	1	-	20	20	60	100	**4**
ELC	25UD1507SE509	Seminar	-	-	2	60		40	100	**1**
		Total	19	1	4	260	140	500	900	**22**
Semester VI										
PCC	25UD1507PC601	Chemical Reaction	3	-	-	20	20	60	100	**3**

		Engineering-II								
PCC	25UD1507PC602	Mass Transfer Operations-II	3	-	-	20	20	60	100	**3**
PCC	25UD1507PC603	Process Dynamics and Control	3	-	-	20	20	60	100	**3**
PCC	25UD1507PCL604	PIC Lab	-	-	2	60	-	40	100	**1**
PEC	25UD1507PE605	Program Elective-II A. Energy Technology and Conservation B. Renewable Energy Resources C. Green Technology	4	-	-	20	20	60	100	**4**
MDM	25UD1507MD606	Multidisciplinary Minor-IV(Mass Transfer Operations)	3	-	-	20	20	60	100	3
PEC	25UD1507PE607	Program Elective-III A. Plant Utilities and Plant Safety B. Industrial Safety and Hazard Mitigation C. Disaster Management in Chemical Industries	4	-	-	20	20	60	100	4
VSEC	25UD1507PCL608	Chemical Engineering Lab-II (CRE + MTO)	-	-	4	60	-	40	100	2
ELC	25UD1507MP609	Mini-project 1	-	-	2	60	-	40	100	1
		Field Training / Internship /Industrial Training (about four weeks which can be completed partially in fifth semester and sixth semester or in at one								

		time) to be evaluated in seventh semester.								
		Total	20	-	8	300	120	480	900	**24**

Semester: V

Chemical Engineering Thermodynamics - II 3 Credit

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		**Chemical Engineering Thermodynamics – II**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Course Outcomes: At the end of the course, the student will be able to:

CO1	Calculate heat effects involved in industrial chemical processes
CO2	Determine thermodynamic properties of gaseous mixtures/solutions
CO3	Calculate Bubble-P &T, Dew-P&T for binary and multi-component systems
CO4	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems
CO5	Determine equilibrium constant and composition of product mixture at given temperature And pressure

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	✓	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

Unit I: Solution Thermodynamics Framework: Fundamental property relation, Chemical potential and phase equilibria, Partial properties, Ideal gas mixture, Fugacity and fugacity coefficient: Pure Species, Species in solution, Generalized correlations for the fugacity coefficient, The ideal solution, Excess properties.

Unit II: Phase Equilibrium Introduction: Property Changes of Mixing, Heat Effects of Mixing Processes, The nature of equilibrium, the Phase Rule, Duhem's Theorem, VLE: Qualitative behavior, Equilibrium and Phase Stability, Vapor/Liquid/Liquid Equilibrium.

Unit III: Thermodynamic Formulations for Vapor/Liquid Equilibrium: Excess Gibbs Energy and Activity Coefficients, The Gamma/Phi Formulation of VLE, Simplifications: Raoult's Law, Modified Raoult's Law, and Henry's Law, Correlations for Liquid-Phase Activity Coefficients, Fitting Activity Coefficient Models to VLE Data, Residual Properties by Cubic Equations of State, VLE from Cubic Equations of State, Flash Calculations.

Unit IV: Chemical Reaction Equilibria: The reaction coordinate, Application of equilibrium criteria to chemical reactions, The standard Gibbs energy change and equilibrium constant, Effect of temperature on the equilibrium constants, Evaluation of Equilibrium Constants.

Unit V: Chemical Reaction Equilibria: Relation of equilibrium constants to composition, Equilibrium conversions for single reactions, Phase rule and Duhem's theorem for reacting systems, Multi reaction equilibria, Fuel cells.

Text/Reference books:

1. J. M. Smith, H. C. Van Ness, and M.M. Abbott, Chemical Engineering Thermodynamics, 6thed, Tata McGraw Hill edition, 2003.
2. Y. V. C. Rao, "Chemical Engineering Thermodynamics", University Press1997
3. S. I. Sandler. "Chemical Engineering Thermodynamics", Wiley, NewYork, 1999.

Chemical Reaction Engineering - I 3 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		**Chemical Reaction Engineering - I**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity and knowledge of appropriate solution techniques related to:

1. Mole balances in chemical reactions, types of reactors and their performance equations along with rector sizing
2. Rate laws used in chemical kinetics and design equations
3. Reactor design in isothermal conditions and its applications to different types of reactors and problems.
4. Collection and analysis of data, integral and differential methods
5. Catalysts and catalysis, rate determining steps and applications

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand different types of chemical reactors.
CO2	Write rate law for chemical reactions of different orders.
CO3	Analyze the performance of different reactors to carry out isothermal processes
CO4	Analyze the reaction data by different analysis methods
CO5	Understand catalysis and analyze the rate determining step in catalytic reaction

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-

CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO5	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-

Detailed Syllabus:

Unit I: Mole Balances: Definition of the rate of reaction, General mole balance equation, Batch Reactors, Continuous-flow reactors, Industrial reactors

Conversion and Reactor Sizing: Definition of conversion, Design equations, Applications of the design equations for continuous-flow reactors, Reactors in series

Unit II: Rate Law: Basic definitions, Reaction order and rate law, reaction rate constant, theories of reaction rates.

Stoichiometry: Batch systems-Equations for concentrations, constant volume batch reaction systems; Flow systems - Equations for concentrations, liquid phase concentrations, Reactions with phase change

Unit III: Isothermal Reactor Design: Design structure for isothermal reactors, Scale up of liquid-phase batch reactor data to the design of a CSTR, Design of continuous stirred tank reactor-A single CSTR, CSTRs in series, CSTRs in parallel, A second-order reaction in a CSTR, Tubular reactors.

Unit IV: Collection and Analysis of Rate Data: Batch reactor data, Method of initial rates, Method of half-life, Differential reactors.

Unit V: Catalysis and Catalytic Reactors - Catalysts, Steps in a catalytic reaction, synthesizing a rate law, mechanism and rate - limiting step, Heterogeneous data analysis for reactor design, Catalyst deactivation-Types of catalyst deactivation

Texts/References:

1. H.S. Fogler,“Elements of Chemical Reaction Engineering”,3rdEd, New Delhi - Prenticea Hall, 2001
2. O. Levenspiel, “Chemical Reaction Engineering” WilleyEastern,3rdEd., 2000
3. J. M. Smith, “Chemical Engineering Kinetics”,3rd Ed., McGraw- Hill,1988.

Mass Transfer operations - I 3 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		**Mass Transfer Operations - I**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity and knowledge of appropriate solution techniques related to:

1. Diffusion in fluids and solids, mass transfer coefficients.
2. Material balances and co-current, counter-current operation and concept of stage.
3. Gas absorption and stripping, number of transfer units in plate towers and packed bed towers.
4. Liquid-liquid extraction and solid-liquid extraction, and calculation of amount of solvent needed and number of stages.
5. Adsorption and ion exchange, adsorption isotherms and their applications.
6. Equipment for majorly gas-liquid operations.

Course Outcomes:

On completion of course, students will be able to:

1. Understand Fick's law of diffusion
2. Determine mass transfer coefficients
3. Calculate rate of mass transfer in absorption and adsorption
4. Calculate rate of mass transfer in extraction and leaching
5. Select equipment for gas-liquid operation

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	-	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	-	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Unit I: Basics of mass transfer, molecular diffusion in fluids, Fick's Law of diffusion, different cases of mass transfer, diffusivity of gases and liquids, mass transfer coefficients**,** mass transfer from a gas into falling liquid film, eddy diffusion, different theories of mass transfer, momentum , heat and mass transfer analogies, diffusion in solids

Unit II: Interphase mass transfer - Mass transfer equilibrium, diffusion between two phases, Local and overall mass transfer coefficient, avarage overall coefficients, Simultaneous heat and mass transfer, material balances, Steady-state co-current and counter-current processes, stage wise and differential contacts, cocurrent, crosscurrent and countercurrent cascades, Number of theoretical stages, Stage efficiency, Height of mass transfer units.

Unit III: Gas Absorption: Equilibrium solubility of gases, choice of solvent, Material balance for transfer of one component, Counter-current multistage operations for binary and multi component systems, Minimum and actual solvent calculations, absorption factors, Tray towers and theoretical tray calculations, Continuous contact equipments, height of transfer units, dilute cases,absorption with chemical reaction.

Unit IV: Liquid - liquid extraction **:** different types of systems, choice of solvent, stagewise contact with calculations for different cases, equipments, Leaching : Steady state operation, methods of calculations, single and multistage operations , equipments

Unit V: Adsorption and ion-exchange: Types and nature of adsorption, adsorbents, adsorption equilibria, types of isotherms, Stage-wise and continuous adsorption, applications of Freundlich equation, breakthorgh curve, basics of ion-exchange, Equipments for Gas - liquid operations: Sparged vessels (bubble columns), mechanically agitated vessels, tray towers, liquid dispersed scrubbers, Venturi scrubbers, wetted wall towers, packed towers.

Texts/References:

1. R. E. Treybal, Mass transfer operations, 3eded.McGraw Hill,1980.
2. A. S. Foust et al, Principles of Unit Operations.
3. J. M. Coulson and J. F. Richardson,"Chemical Engineering",Vol.1 ELBS, Pergamanpress,1970.
4. J. M. Coulson and J.F. Richardson,"ChemicalEngineering"Vol.2 ELBS,Pergamanpress,1970.

Chemical Technology 2 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		Chemical Technology	2	-	-	20	20	60	100	2

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity, and knowledge of appropriate solution techniques related to:

1. Chemical industries in general, chlor-alkali industries, phosphorous industries
2. Nitrogen and sulphuric acid industries
3. Soaps and detergents, starch production
4. Fermentation industries and polymerization industries
5. Petroleum processing and allied industries

Course Outcomes:

On completion of the course, students will be able to:

1. Understand inorganic and organic chemical technologies

2. Draw process flow diagrams
3. Identify the effect of chemical technologies on health, safety, and the environment
4. Understand engineering problems in chemical processes and equipment
5. List chemical reactions and their mechanisms involved

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO3	✓	✓	✓	-	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Unit I: Introduction and Basic Chemical Industries: Chemical Industries: Facts and figures, unit operation and unit process concepts, chemical processing, and role of chemical engineers, Chloro-Alkali Industries: Soda ash, Solvay process, dual process, natural soda ash from deposits, electrolytic process, caustic soda, Phosphorus Industries: Phosphoric acid (wet process, electric furnace process), calcium phosphate, ammonium phosphates, nitro phosphates, sodium phosphate

Unit II: Nitrogen and Sulfur Industries: Nitrogen Industries: Ammonia, nitric acid, urea from ammonium carbonate, ammonium nitrate, Sulfur and Sulfuric Acid Industries: Elemental sulfur mining (Frasch process), Sulfur production by oxidation-reduction of H_2S, Sulfur and sulfur dioxide from pyrites, Sulfuric acid (contact process, chamber process)

Unit III: Soap and Detergents: Batch saponification production, Sugar and Starch Industries: Sucrose, Extraction of sugarcane to produce crystalline white sugar, Extraction of sugarcane to produce

sugar, Starch production from maize, Production of dextrin by starch hydrolysis in a fluidized bed. Fermentation Industries: Ethyl alcohol by fermentation,

Unit IV: Pulp and Paper Industries: Sulfate pulp process, Chemical recovery from sulfate pulp digestion liquor, Types of paper products, Raw materials, Methods of production, Plastic and Polymerization fundamentals, Polymer manufacturing processes, Polyethylene, polypropylene, PVC and polyester synthetic fibers, Rubber Polymers

Unit V: Petroleum Processing: Production of crude petroleum, Petroleum refinery products, Types of refineries, Design of refinery, Choice of crude petroleum, Refinery processes, desalting, atmospheric and vacuum distillation, cracking, coking and reforming, alkylation

Text/References:

1. Austin G.T., Shreve's Chemical Process Industries - International Student Edition, 5thEdition, Mc Graw HillInc.,1998.
2. Sittig M. and Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21stCentury,3rd Edition, WEP EastWestPress,2010

Chemical Engineering Lab I (CRE-I/MTO I) 1 Credit

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		Chemical Engineering Lab - I	-	-	2	60	-	40	100	1

1. Mass Transfer Laboratory – I

Course Outcomes: At the end of the course, students will be able to:

CO1	Determine diffusion coefficient for vapor in gas diffusion
CO2	Plot solubility curve for extraction
CO3	Determine mass transfer coefficient for gas absorption
CO4	Understand leaching operation for single stage process
CO5	Understand batch adsorption process

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	✓	-	✓	-
CO2	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO3	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO4	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO5	✓	-	✓	-	-	-	-	-	✓	-	✓	-

List of Practicals:

1. To determine the diffusivity of acetone in air
2. To study liquid-liquid diffusion.
3. To study solid in air diffusion.
4. To study wetted wall column for absorption
5. To study single stage/multistage leaching operation for calcium carbonate, sodium Hydroxide, water system or any suitable system
6. To study counter-current single stage extraction process for water(A), acetic acid(B) and benzene(C)/Toluene(C) system or any suitable system.
7. To study liquid-liquid extraction in packed bed for suitable ternary system.
8. To study batch adsorption.

2. Chemical Reaction Engineering Laboratory - I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand and calculate activation energy for given reaction
CO2	Determine rate of reaction and parameter affecting the rate.
CO3	Understand kinetic of different reactions
CO4	Determine void volume of catalyst particle.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓			✓			-	-	-	-	-	-
CO2	✓	✓		✓			-	-	-	-	-	-
CO3	✓	✓		✓			-	-	-	-	-	-
CO4	✓	✓		✓			-	-	-	-	-	-

List of Practicals:

1. To determine Arrhenius rate constants for acid-catalyzed hydrolysis o f methyl acetate
2. To determine the rate constant and order of acid hydrolysis of methyl acetate using graphical method.
3. To study the saponification of ethyl acetate and sodium hydroxide for determination of conversion and reaction rate constant.
4. To study pseudo first order reaction for determination of order of reaction and reaction rate constant.
5. To study the effect of concentration of reactant and temperature on the rate of reaction.
6.To study hydrolysis of methyl acetate by strong acid
7.To determine void volume, solid density and porosity of a catalyst particle.

Program Elective-I 4 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PEC		Program Elective - I	3	1	-	20	20	60	100	4

A. Numerical Methods

Course Objectives:

After completion of the course, students will have adeq uate background, conceptual clarity, and knowledge of appropriate solution techniques related to:

1. Common numerical methods and how they are used to obtain approximate solutions
2. Numerical methods to obtain approximate solutions to mathematical problems
3. Numerical methods for various mathematical operations like interpolation, differentiation, etc.
4. Accuracy of common numerical methods

Course Outcomes:

At the end of the course, the student will be able to:

1. Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions
2. Apply numerical methods to obtain approximate solutions to mathematical problems
3. Derive numerical methods for various mathematical operations like interpolation, differentiation, etc.
4. Analyze and evaluate the accuracy of common numerical methods

Mapping of course outcomes with program outcome

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	✓	-	-	✓	-	✓	-	-	-
CO2	✓	-	-	✓	-	✓	-	-	-
CO3	✓	-	-	✓	-	✓	-	-	-
CO4	✓	-	-	✓	-	✓	-	-	-

Detailed syllabus

Unit I: Solutions of Linear Algebraic Equations: Gauss elimination and LU decomposition, Gauss-Jordan Elimination, Guass - Seidel and relaxation methods. Eigen values and Eigen Vectors of Matrices **-** Faddeev - Leverrier method, Power method, Householder's and Given's method.

Unit II: Nonlinear Algebraic Equations: Fixed point method, Multi variable successive substitutions, Single variable Newton – Raphson Technique, Multivariable Newton-Raphson Technique.

Unit III: Function Evaluation: Least-squares curve fit, Newton's Interpolation formulae, Newton's divided difference interpolation polynomial, Langrangian interpolation, Pade approximations, Cubic spline approximations.

Unit IV: Ordinary Differential Equations (Initial value problems): Runge Kutta Methods, Semi-implicit Runge Kutta Techniques, Step size control and estimates of error Ordinary Differential Equations (Boundary value problems) **-** Finite difference technique, Orthogonal collocation technique, Orthogonal collocation on finite elements.

Unit V: Partial Differential Equations: Introduction to finite difference technique

Texts / References:

1. S. K. Gupta, "Numerical Methods for Engineers", Wiley Eastern,1995.
2. M. E. Davis, "Numerical Methods & Modeling for Chemical Engineers", Wiley, 1984.

B. Introduction to Bio-process Engineering

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity and knowledge of appropriate solution techniques related to :

1. Cell and enzyme kinetics
2. Basics of biology, structure of cells
3. Material and energy balances in bioprocesses
4. Kinetics and manufacture and application of enzyme-catalyzed reactions,
5. Design of bioreactors

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand cell and enzyme kinetics
2. Understand basics of biology, structure
3. Understand material and energy balances in bioprocesses
4. Understand kinetics and manufacture and application of enzyme-catalyzed reactions,
5. Study design of bioreactor

Detailed Syllabus:

Unit I: Bioprocess engineering and related fields, basics of biology, structure and function of microbial, plant and animal cells, introduction to chemicals of life such as lipids, carbohydrates, nucleic acids and proteins. Metabolism and central metabolic pathways, central dogma, transcription and translation processes, material and energy balances in bioprocesses with examples.

Unit II: Unstructured and structured growth models of bioprocesses, growth kinetics, estimation of process parameters, logistic equation, effect of substrate and product inhibition.

Unit III: Enzymes, kinetics of enzyme-catalyzed reactions, inhibited enzyme kinetics, immobilized enzymes, manufacture and application of enzymes.

Unit IV: Design of biological reactors, continuous, batch and fed batch processes and their comparison, multistage chemist at systems, introduction to transport phenomena in bioprocesses. Non - ideal effects. Scale-up and scale-down criteria.

Unit V: Recovery and purification of bioprocesses, recent advances and applications of bioprocess engineering, genetic engineering and recombinant DNA technology, mixed cultures, application to biological wastewater treatment. Introduction to control strategies in bioprocesses.

References:

1. Shuler and Kargi, "Bioprocess Engineering : Basic Concepts" Prentice Hall of India,2002
2. J.E. Bailey & D.F. Ollis (eds) : `Biochemical Engineering Fundamentals', McGraw Hill Inc., 1986.

C. Mathematical Methods in Chemical Engineering

Course Objective:

1. To introduce the student to analytical methods of solving linear algebraic, ordinary differential, and partial differential equations
2. To cover numerical methods to solve algebraic and differential equations
3. To learn the methods used to solve chemical engineering mathematical problems

Course Outcomes:

At the end of the course, the student will be able to:

1. Formulate lumped and distributed parameter mathematical models for chemical processes
2. Calculate degrees of freedom for the developed mathematical models
3. Solve the model equations describing chemical processes and equipment
4. Analyze the results of the solution methods

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus

UNIT I:

Mathematical Formulation of the Physical Problems- Introduction, Representation of the problem, blending process, continuous stirred tank reactor, Unsteady state operation, heat exchangers, distillation columns, biochemical reactors.

UNIT II: Analytical (Explicit) Solution of Ordinary Differential Equations Encountered in Chemical Engineering Problems: Introduction, Order and degree of differential equations, First-order differential equations, Second-order differential equations, Linear differential equations, Simultaneous differential equations

UNIT III: Formulation of partial differential equations: Introduction, Interpretation of partial derivatives, Formulation partial differential equations, particular solutions of partial differential equations, Orthogonal functions, Method of separation of variables, The Laplace Transform method, Other transforms.

UNIT IV: Unsteady state heat conduction in one dimension: Mass Transfer with Axial Symmetry, Continuity equations, Boundary conditions - Iterative solution of algebraic equations - The difference operator - Properties of the difference operator - Linear finite difference equations.

UNIT V: Non-linear finite difference equations: Simultaneous linear differential equations - analytical solutions - Application of Statistical Methods.

Text Books/References:

1. Rice R. G. and D. Do Duong, 'Applied mathematics and modeling for chemical engineers' John Wiley &Sons,1995.
2. Jenson J F and G. V. Jeffereys, 'Mathematical Methods in Chemical Engineering', Academic Press, 1977.
3. B. A. Finlayson, 'Introduction to Chemical Engineering Computing', Wiley India Edition, 2010
4. Singaresu S. Rao, 'Applied Numerical Methods for Engineers and Scientists', Prentice Hall, 2002.
5. Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall India, 2nd Edition, 2011.

MDM 3 Heat Transfer Operations

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit

MDM		**Heat Transfer Operations**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Course Objectives:

Upon successful completion of the course, students will gain a strong foundation, conceptual understanding, and practical knowledge of methods and techniques associated with:

1. Different modes of heat transfer.
2. Evaluation of heat transfer coefficients under forced and free (natural) convection.
3. Heat transfer processes involving phase change phenomena.
4. Performance analysis of heat exchangers operating in parallel-flow and counter-flow arrangements.

Course Outcomes: At the end of the course, the student will be able to:

1. Understand different modes of heat transfer.
2. Calculate heat transfer coefficients in forced and natural convection scenarios.
3. Evaluate the performance of heat exchangers in both parallel and counter-flow operations.
4. Develop and design double-pipe and shell-and-tube type heat exchangers

Detailed syllabus

Unit I:

Conduction through a single homogeneous solid, thermal conductivity of solids, liquids and gases, Conduction through several bodies in series, Contact resistances, Unsteady state heat conduction, lumped heat capacity system, transient heat flow in a semi-infinite solid, Concept of critical insulation thickness.

Unit II:

Heat transfer by Convection: Forced convection, Laminar heat transfer on a flat plate Laminar and turbulent flow heat transfer inside and outside tubes. Film and overall heat transfer coefficients. Resistance concept, Coefficients for scale deposits, L.M.T.D. in heat exchangers with co and counter current flow. Heat exchanger design, Effectiveness – N T U method in finned tube heat exchangers.

Unit III:

Natural convection: Heat transfer from plates and cylinders in verticals and horizontal configuration, natural convection to spheres. **Heat transfer with phase change,** heat transfer in condensing vapour, types of condensation. Nusselt Theory, Heat transfer to Boiling liquid, Pool boiling. Evaporation , Single and multiple effect evaporators, Types of evaporators, Performance of evaporator, Calculations of single and multiple effect evaporator.

Unit IV:

Heat Transfer by Radiation: Black and gray body radiations, emissivity, laws of radiation, view factor, luminous and non-luminous gases. Radiation between surfaces, Combined heat transfer, i.e. conduction, convection and radiation together. .

Unit V:

Introductory Concepts of Heat exchanger design: Design of single and multi pass shell and tube type exchangers using LMTD and effectiveness - NTU methods. Spiral coil and plate type heat exchangers. Single and multi phase condenser. Design of Reboilers, vaporisers, Kettle type and Thermosiphon reboilers, forced circulation vaporizers. Heat transfer in agitated vessels both, jacketed and with coil, Determination of overall heat transfer coefficient, transient heating or cooling..

Texts / References:

1. J. M. Coulson and J. F. Richardson, "Chemical Engineering", Vol. 1 ELBS, Pergamon press, 1970
2. J. M. Coulson and J. F. Richardson, "Chemical Engineering" Vol. 2 ELBS, Pergamon press, 1970
3. W. L. McCabe J. C. Smith and P. Harriot, "Unit Operations of Chemical Engineering", 4th ed. McGraw Hill 1985.
4. John H. Lienhard V, John H. Lienhard IV, "A Heat Transfer Textbook" January 1, 1981.

Open Elective III Equity Stock market

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
OL		Equity Stock market	2	**-**	**-**	**20**	**20**	**60**	**100**	2

Detailed syllabus

Unit 1

Financial markets : An overview, Equity stock market : an overview, Estimating the price of Equity stock, market mechanism of equity stock market, Indices and regulatory mechanisms

Unit 2

Fundamental analysis, technical analysis, moving averages, Dow theory, Elliot Wave theory

Unit 3

Overview of Equity risks, Portfolio theory, CAL ,CML, SML, CAPM, evaluation of Equity portfolio using different theories

Unit 4

Derivatives in Equity market, Hedging using stock futures, index futures and single option, Multiple options and trading strategies

Unit 5

Private Equity market, venture capital, value at risk, computing and enforcing margins

References

1. Guide to Indian Stock market by Jitendra Gala

2. Fundamental analysis of Shares by Ankit Gala and Khushboo gala

3. Equity Stock market by P. C. Narayan (NPTEL course)

Seminar

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
		Seminar	**-**	**-**	**2**	**60**	**-**	**40**	**100**	**1**

Course Outcomes: At the end of the course, the student will be able to:

CO1	Acquire knowledge on topics outside the scope of curriculum.
CO2	Communicate with group of people on different topic
CO3	Collect and consolidate required information on a topic
CO4	Prepare a seminar report

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	✓
CO2	✓	✓	-	-	✓	✓	-	-	✓	✓	✓	✓

CO3	√	√	√	√	√	-	√	-	-	-	√	√
CO4	√	√	-	√	-	√	√	-	-	-	√	√

Each student is expected to collect information on recent advances in Chemical Engineering by regularly referring to national and international journals (research / review articles) and reference books. At the end of the semester, he/she is required prepare a report as per the guide lines prescribed by the Department. Each student will be assigned a guide for this seminar course. Every student shall give a power point presentation on his Seminar topic before a panel of examiners.

SEMESTER VI

Chemical Reaction Engineering - II 3 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		**Chemical Reaction Engineering - II**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Course Outcomes: At the end of the course, students will be able to:

CO1	Compare the performance of ideal and non-ideal reactors using E- and F-curves.
CO2	CO_2 determines the mean residence time and standard deviation using residence time distribution (RTD).
CO3	Analyze the performance of non-ideal reactors using segregation model, tanks-in-series model, and dispersion model.
CO4	Understand the effect of velocity, particle size, and fluid properties on the rate of reactions controlled by mass transfer.
CO5	Design fixed bed reactors involving chemical reactions with mass transfer
CO6	Determine internal and overall effectiveness factors

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO6	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: Multiple Reactions: Types of reactions, maximizing desired product in parallel reactions, maximizing desired product in series reactions, stoichiometry and rate laws for multiple reactions, multiple reactions in PFR and CSTR

UNIT II: Non elementary Reaction Kinetics: Fundamentals, Searching for a mechanism, enzyme reaction fundamentals, Bioreactors.

UNIT III: External Diffusion Effects on Heterogeneous Reactions: Mass transfer fundamentals, Binary diffusion, External resistance to mass transfer, the shrinking core model.

UNIT IV: Distribution of Residence times for Chemical Reactors - General Characteristics, Measurement of RTD, Characteristics of RTD, RTD in ideal reactors, Reactor modeling with RTD, Zero-parameter models,

UNIT V: Models for non - ideal reactors: One parameter models- tank-in-series model, dispersion model, Tank-in-series model versus dispersion model

Texts/References:

1. H. S. Fogler, "Elements of Chemical Reaction Engineering", 3rd Ed, New Delhi- Prentice Hall, 2001.
2. O. Levenspiel," Chemical Reaction Engineering" Willey Eastern, 3rd Ed.,2000
3. J. M. Smith, "Chemical Engineering Kinetics", 3rdEd.,McGraw-Hill, 1988

Mass Transfer Operations – II 3 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		**Mass Transfer Operation - II**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand vapor liquid equilibria for distillation
CO2	Determine number of stages in distillation
CO3	Determine the height of cooling tower
CO4	Calculate drying rates and moisture content for batch and continuous drying

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: Distillation - Vapour liquid equilibria, flash vapourisation, batch distillation, differential distillation.

UNIT II: Continuous fractionation **-** Binary systems, Mc-Cabe.Thiele and Ponchon Savarit method calculations , multiple feeds and withdrawal.

UNIT III: Humidification **-** Vapour liquid equilibrium, enthalpy for pure substances, vapour gas contact operation. Psychrometric charts and measurement of humidity, adiabatic saturation temperature and wet bulb temperature

Cooling Tower Design**:** Adiabatic and non-adiabatic operations evaporative cooling, cooling tower design and dehumidification methods.

UNIT IV: Drying **-** Drying equilibrium and rate of drying, types of moisture, time of drying, drying operation : batch and continuous , number of transfer units.

UNIT V: Crystallization **-** Theories of crystallisation, nucleation and crystal growth. principles of supersaturation. different types of crystallizers, Special topics in separation: Membrane separation processes basics, Types of membranes , reverse osmosis and dialysis; Mechanism of solute/solvent rejection in the process; Design of R.O. and dialysis units; applications.

Texts / References:

1. R. E. Treybal, Mass transfer operations, 3ed ed. McGraw Hill, 1980.
2. J. M. Coulson and J. F. Richardson, “Chemical Engineering”, Vol. 1 ELBS, Pergamon press, 1970
3.J. M. Coulson and J. F. Richardson, “Chemical Engineering” Vol. 2 ELBS, Pergamon press, 1970

Process Dynamics and Control 3 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		Process Dynamic Control	3	-	-	20	20	60	100	3

Pre-Requisites: mathematics and process instrument knowledge

Course Outcomes: At the end of the course, students will be able to:

CO 1	Understand the dynamic behavior of different processes
CO2	Analyze different components of a control loop
CO3	Analyze stability of feedback control system
CO4	Design controllers for first and second order processes
CO5	Analyze frequency response for controllers and processes

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus

UNIT I: Introduction to Process Control: Need of process control, control system, steady and dynamic system, Basic control actions, Types of variables in process control process variable, controlled variable, manipulated variable, measured variable.

Laplace Transforms: Definition, transforms of simple functions, ramp functions, sine functions, inversions of transform function by partial fractions, final value and initial value theorems, transforms of unit impulse functions, transforms of integral.

UNIT II: Open loop response of simple systems: Dynamics of first order systems using transfer functions; Various first order response such as, a thermometer bulb, liquid level, mixing process, pure capacitive system definition time constant. General response to step, ramp, impulse, and sinusoidal inputs; Concentration and temperature responses of a stirred tank.

Linearization of liquid level systems; Response of a pressure system, second order systems, the manometer; Response of interacting and non-interacting systems.

UNIT III: The Control Systems: Block diagram symbols, negative and positive feedback, Block diagram reduction, closed loop and open loop control systems, and Servo and regulated operation,

Controller: Classification and mechanism of controllers: Proportional control (P), Proportional Integral control (PI), Proportional Derivative control (PD), Proportional Integral Derivative control (PID), transfer function of P, PI, PD, PID control and On-Off controller.

Transient response of control systems: Proportional control for set point and load change, Proportional Integral control for set point and load change, Proportional Derivative control for set point and load change, Proportional Integral Derivative control for set point and load change.

UNIT IV: Stability: Concept of stability, Stability criterion, The characteristic equation, Routh-Hurwitz stability criterion, root locus and its applications

Frequency response analysis: First order systems, Second order systems, Phase margin and gain margin, Bode diagram.

UNIT V:

Complex numbers to get frequency response, Ziegler- Nichols method.

Controller selection and tuning: Control valve characteristics and sizing, cascade control, Ratio control, Feed forward control, PID controller design and tuning. Introduction of digital control principles.

Text / References:

D. R. Coughanowr, Process system analysis and control, 2nd ed, McGraw Hill, 1991.

P. Harriott, Process Control, Reprint of text, ed. Tata McGraw Hill, 1983.

G. Stephanopoulos, Chemical Process Control: An introduction to theory and practice,Prentice Hall, New Jersey, 1984.

Process Instrumentation and Control Lab — Credits 1

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
VSEC	PCC	Process Instrumentation and Control Lab	-	-	2	60	-	40	100	1

Course Objective:

1. To make students aware of working of Different process control instruments throughhands-on training.
2. To make students to correlate theory and practical process control through principles, fundamental concepts and by experimentation.

Course Outcomes:

At the end of the course, the student will be able to:

1. Calculate the characteristics of control valves.
2. Determine the dynamics of level and temperature measurement process.
3. Determine the dynamics of two capacity liquid level process without interaction and with interaction, U-tube manometer.
4. Determine the performance of controllers for a flow process, pressure process,level process, temperature process.
5. Evaluate the performance of PID control.

List of Experiments:

1. To determine the time constant of given thermometer with positive and negative step change.
2. To determine the time constant and valve properties of single tank system.

3. To study the step response of two tank non-interacting liquid level system andcompare the observed transient response with the theoretical transient response.
4. To study the step response of two tank interacting liquid level system and compare the observed transient response with the theoretical transient response.
5. To study the impulse response of a tank.
6. To study coupled three or four tanks system.
7. To study any inherently second order system, such as U tube manometer.
8. To study different types of controllers.
9. To study characteristics of PID controller.
10. To study characteristics of control valves.

Program Elective-II 4 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PEC		Program Elective - II	4	-	-	20	20	60	100	4

A. Energy Technology and Conservation

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity and knowledge of appropriate solution techniques related to:

1. Energy conversion processes for solid fuels.
2. Energy utilization systems for heat recovery.
3. Properties of fuel samples
4. Energy audit.

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand energy conversion processes for solid fuels.
2. Design energy utilization systems for heat recovery.
3. Estimate the properties of fuel samples
4. Perform energy audit.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	-	-	-	-	-

Detailed syllabus

Unit I: Energy scenario: Introduction and classification of energy, renewable and non- renewable energy, Indian energy scenario, energy pricing in India, energy and environment. Solid fuels: Introduction, Biomass, Peat, Light and brown coal, Black Lignite, Bituminous coal, Semi anthracite, Anthracite, Natural coke/SLV fuel, Origin of coal, composition of coal, classification of coal, Sampling and analysis of solid fuels, oxidation of coal, Hydrogenation of coal,storage of coal.

Unit II: Carbonization and gasification processes: Introduction, carbonization of coal, the gasification of solid fuels, the gasification of oil and hydrocarbon gas reforming, carbureted water gas. Energy conversion with combustion: Introduction, Combustion, Burner design, Combustion plant, direct conversion of energy.

Unit III: Fuel testing: Introduction, Calorific value, tests on liquid fuels, Fuel and flue gas analysis.

Energy auditing: Introduction, Energy conservation schemes Industrial energy use, energy conversion, energy index, energy costs. Energy sources: Energy consumption, world energy reserves, energy prices, fuel production and processing, energy policies, choice of fuels, cycle efficiency.

Unit IV: Heat transfer media: Water, Steam, Thermal fluids, Air-water vapor mixtures, Heat transfer equipment: Heat exchangers, Combustion and thermal efficiency, Steam plant, pressure hot water and thermal fluids plant, thermal fluids plant.

Unit V: Energy utilization and conversion systems: Furnaces, Hydraulic power systems, Compressed air, steam turbines, combined power and heating systems, Energy conversion, District heating, Heat recovery: Sources of waste heat and its applications, Heat recovery systems, Incinerators, Regenerators and recuperators, waste heat boilers.

Text / Reference:

1. Samir Sarkar, Fuels and Combustion, Universities Press, 2009.
2. Murphy W. R and Mckay G., Energy Management, Elsevier, 2007.
3. Harker J.H. and J. R. Backhurst, Fuel and Energy, Academic Press, London, 1981.

B. Renewable Energy Sources

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarityand knowledge of appropriate solution techniques related to:

1. Challenges and problems associated with the use of energy sources.
2. Renewable energy resources and technologies
3. Conversion technologies for solar, wind, biomass and hydrogen energies
4. Performance of energy conversion technologies

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand the challenges and problems associated with the use of energy sources.
2. List renewable energy resources and technologies
3. Design conversion technologies for solar, wind, biomass and hydrogen energies
4. Evaluate the performance of energy conversion technologies

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	-	-	-	-	-

Detailed syllabus

Unit I: Sources of energy: Energy sources and their availability, renewable energy sources. Energy from Biomass: Introduction, Biomass as a source of energy, Biomass conversion technologies, Biogas generation, classification of biogas plants, Biomass gasification.

Unit II: Solar Energy: Sun and solar energy, solar radiation and its measurement, solar energy collectors, solar energy storage, Photovoltaic systems, Application ofsolar energy.

Unit III: Wind Energy: Wind as an Energy source, Basic principles of wind energy conversion, Types of Wind machines, Components of wind energy conversion system, Performance of wind machines, application of windenergy.

Unit IV: Energy from the Oceans: Introduction, Ocean Thermal Electric Conversion (OTEC), Energy from Tides, Ocean Waves.

Unit V: Hydrogen energy: Introduction, Hydrogen production, Hydrogen storage, Hydrogen transportation. Chemical Energy Sources: Introduction, Fuel cells, Batteries.

Text / Reference:

1. Rai, G.D, Non-Conventional Energy Sources, Khanna Publishers, New Delhi, 2010.
2. Rajesh Kumar Prasad, T.P. Ojha, Non-Conventional Energy Sources, Jain Brothers,2012.
3. Sukhatme S.P and J. Nayak, Solar energy – Thermal Collection and storage, 3rd Edition, Tata McGraw Hill Education Pvt Ltd., 2008.
4. MM. EI – Wakil, Power Plant Technology, Tata McGraw Hill, NewYork, 1999.

C. Green Technology

Course Objectives:

After completion of the course, students will have adequate background, conceptualclarity and knowledge of appropriate solution techniques related to :

1. Principles and concepts of green chemistry
2. Manufacturing processes to reduce wastage and energy consumption
3. Technologies to reduce the level of emissions from buildings and core infrastructure
4. Effects of pollutants on the environment

Course Outcomes:

At the end of the course, the student will be able to:

1. Understand principles and concepts of green chemistry
2. Develop manufacturing processes to reduce wastage and energy consumption
3. Design the technologies to reduce the level of emissions from buildings and coreinfrastructure
4. Analyze the effects of pollutants on the environment

Detailed Syllabus

Unit I: Principles and concepts of Green Chemistry: Introduction, Sustainable Development and Green Chemistry, Atom Economy, Atom Economic Reactions, Rearrangement Reactions, Addition Reactions, Atom Un-economic Reactions, Substitution Reactions, EliminationReactions, Wittig Reactions, Reducing Toxicity, Measuring Toxicity.

Unit II: Waste- Production, Problems and Prevention: Introduction, Some Problems Caused by Waste, Sources of Waste from the Chemical Industry, The Cost of Waste, Waste Minimization Techniques, The Team Approach to Waste Minimization, Process Design for Waste Minimization, Minimizing Waste from Existing Processes, On-site Waste Treatment, Physical Treatment, Chemical Treatment, Bio-treatment Plants, Design for Degradation, Degradation and Surfactants, DDT, Polymers, Some Rules for Degradation, Polymer Recycling, Separation and Sorting, Incineration, Mechanical Recycling, Chemical Recycling to Monomers.[6 hrs]

Unit III: Measuring and controlling environmental performance: The Importance of Measurement, Lactic Acid Production, Safer Gasoline, Introduction to Life Cycle Assessment, Green Process Metrics, Environmental Management Systems, The European Eco-management and Audit Scheme, Eco-labels, Legislation, Integrated Pollution Prevention and Control. Catalysis and green chemistry: Introduction to Catalysis, Comparison of Catalyst Types, Heterogeneous Catalysts, Basics of Heterogeneous Catalysis, Zeolites and the Bulk Chemical Industry, Heterogeneous Catalysis in the Fine Chemical and Pharmaceutical Industries, Catalytic Converters, Homogeneous Catalysis, Transition Metal Catalysts with Phosphine Ligands, Greener Lewis Acids, Asymmetric Catalysis, Phase Transfer Catalysis, Hazard Reduction, C - C Bond Formation, Oxidation Using Hydrogen Peroxide, Bio-catalysis, Photocatalysis.

Unit IV: Organic solvents, environmentally benign solutions: Organic Solvents and Volatile Organic Compounds, Solvent-free Systems, Supercritical Fluids, Supercritical Carbon Dioxide, Supercritical Water, Water as a Reaction Solvent, Water-based Coatings, Ionic Liquids, Ionic Liquids as Catalysts, Ionic Liquids as Solvents, Fluorous Biphase Solvents.

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
MDM IV	**25UD1507MD606**	**Mass Transfer Operation**	**3**	**-**	**-**	**20**	**20**	**60**	**100**	**3**

Renewable resources: Biomass as a Renewable Resource, Energy, Fossil Fuels, Energy from Biomass, Solar Power, Other Forms of Renewable Energy, Fuel Cells, Chemicals from Renewable Feedstocks, Chemicals from Fatty Acids, Polymers from Renewable Resources, Some Other Chemicals from Natural Resources, Alternative Economies, The Syngas Economy, The Biorefinery, Chemicals from renewable feed stocks.

Unit V: Emerging Greener technologies and Alternative energy solutions: Design for Energy Efficiency, Photochemical Reactions, Advantages of and Challenges Faced by Photochemical, Processes, Examples of Photochemical Reactions, Chemistry Using Microwaves, Microwave Heating, Microwave-assisted Reactions, Sonochemistry, Sonochemistry and Green Chemistry, Electrochemical Synthesis, Examples of Electrochemical Synthesis. Designing greener processes: Conventional Reactors, Batch Reactors, Continuous Reactors, Inherently SaferDesign, Minimization, Simplification, Substitution, Moderation, Limitation, Process Intensification, Some PI Equipment, Examples of Intensified Processes, In-process Monitoring, Near-infrared Spectroscopy.

Industrial case studies: A Brighter Shade of Green, Greening of Acetic Acid Manufacture, EPDM Rubbers, Vitamin C, Leather Manufacture, Tanning, Fatliquoring, Dyeing to be Green, Some Manufacturing and Products Improvements, Dye Application, Polyethene, Radical Process, Ziegler–Natta Catalysis, Metallocene Catalysis, Eco-friendlyPesticides, Insecticides. An integrated approach to a greener chemical industry: Society and Sustainability, Barriers and Drivers, The Role of Legislation, EU White Paper on Chemicals Policy, Green Chemical Supply Strategies.

Text / Reference:

1. Mike Lancaster, Green Chemistry, Royal Society of Chemistry, 2010.
2. Paul T. Anastas John C. Warner, Green Chemistry: Theory and Practice, OxfordUniversity Press, 2000.
3. Jay Warmke, Annie Warmke, Green Technology, Educational Technologies Group,2009.

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MDM IV: Mass Transfer Operations 3 Credits

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand Fick's law of diffusion, Determine diffusivity coefficient in gases and liquid, Stage-wise and continuous adsorption.
CO2	Understand Stage-wise and continuous adsorption, Determine number of stages in distillation, Mc-Cabe.Thiele method.
CO3	Understand humidification and dehumidification operation, cooling tower design
CO4	Understand batch and continuous drying operation crystallization and membrane separation

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

UNIT I: Diffusion in fluids: Fick's Law of diffusion, equimolecular counter diffusion, diffusion in stationary gas, **Maxwell's law of diffusion**, **Interphase mass transfer** - Mass transfer equilibrium, diffusion between two phases, Local mass transfer coefficient, local and average overall mass transfer coefficients.

UNIT II: Adsorption and ion-exchange: Types and nature of adsorption, Freundlich equation, Stage-wise and continuous adsorption, Theory of ion-exchange and its application to removal of ionic impurities. **Gas - liquid operations:** Sparged vessels (bubble columns), Venturi scrubbers, wetted towers, packed

UNIT III: Distillation, Continuous fractionation - Vapour liquid equilibria, flash vaporization, batch distillation, **Binary** systems, Mc-Cabe.Thiele method calculations with multiple feeds and withdrawal.

UNIT IV: Humidification - Vapour liquid equilibrium, enthalpy for pure substances, vapour gas contact operation. Psychrometric charts and measurement of humidity **Dehumidification and Cooling Tower Design:** Adiabatic and non-adiabatic operations evaporative cooling, cooling tower design and dehumidification methods.

UNIT V: Drying and Crystallization - drying operation batch and continuous, theories of crystallization nucleation and crystal growth. different types of crystallizers, **Special topics in separation:** Types of membranes for osmosis and dialysis, Reverse Osmosis. and dialysis units; applications.

Program Elective - III 4 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PEC		Program Elective - III	4	-	-	20	20	60	100	4

A. Plant Utilities and Plant Safety

Course Outcomes: At the end of the course, the student will be able to:

CO1	List utilities in a plant.
CO2	Understand properties of steam and operation of boilers for steam generation
CO3	Understand refrigeration methods used in industry
CO4	Compare power generation methods
CO5	Classify and describe the types of water, water treatment methods, storage and distribution techniques

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO4	✓	-	✓	✓	-	✓	-	-	-	-	-	-
CO5	✓	-	✓	✓	-	✓	✓	-	-	-	-	-

Detailed Syllabus:

UNIT I: Identification of common plant utilities: water, compressed air, steam, vacuum, refrigeration, venting, flaring and pollution abating. Water and its quality, storage and distribution for cooling and firefighting.

UNIT II: Steam generation by boilers: Types of boilers and their operation, Steam generation by utilizing process waste heat using thermic fluids, Distribution of steam in a plant.

UNIT III: Principles of refrigeration: Creation of low temperature using various refrigerants. Creation of low pressure/vacuum by pumps and ejectors.

UNIT IV: Safety in Chemical Processes: Introduction, Chemical Process classification, Process design and safety parameters. Safety parameters in the process design of phenol from cumene, safety in polyvinyl chloride plant. Chemicals and their Hazards: Introduction, Acetonitrile, acetyl chloride, butyl amine, acrylamide, acrylonitrile, allyl alcohol, benzene, bromine, isopropyl alcohol, acetaldehyde, ethylene oxide, butane, n-hexane, anhydrous ammonia, acetone, toluene, p-xylene, acetic acid, monochloro benzene, oleum, carbon mon.

UNIT V: Hazards in Chemical Process plants: Introduction, Hazards, Hazard code and explosive limit, electrical safety in chemical process plants, static electricity hazards, pressure vessel hazards, LEL and UEL of various compounds, explosive hazard, flammable liquid hazards, protection to storage tanks, fire zone location, fireball, fireball hazard. Safety in handling gases, liquids and solids: Introduction, safety in handling of gases, chlorine hazards, chlorine leakage management, safety in handling of fluorine, important safety considerations in ammonia storage, flammable solids storage, flammable liquid storage, handling of LNG, requirements to be fulfilled for storing hydrocarbons or chemicals, fail safe concept, transportation of hazardous chemicals, Hazardous in plastics processing. **Combating Chemical Fires:** Classification of fires, control of high vaour pressure fire, fire fighting foams, foam for fire protection, Foam characteristics, gaseous agent extinguishing system, automatic sprinkler system, chemical extinguishing powders, natural gas fire control. Portable fire extinguishers: Soda-acid extinguishers, carbon dioxide extinguisher, dry chemical fire extinguisher, general safety precautions for maintenance of fire extinguishers. Safety Checklist: safety studies for chemical plants, safety checklist during startup, safety checklist during shutdown mode, safety checklist for installation, safety needs during construction. Protective devices.

Text / Reference:

1. A.Wangham, Theory and practice of Heat engines, ELBS cambridge University press, 1970.
2. J. L. Threlkeld, Thermal Environmental Engineering, Prentic Hall 1970.
3. S.D.Dawande, Chemical Hazards and safety, Dennet& Co publishers, 2007.

B. Industrial Safety and Hazard Mitigation

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity and knowledge of appropriate solution techniques related to:

1. Safety programs, engineering ethics and public perceptions
2. Fire and explosions with flammability characteristics
3. Prevention of fire and explosion
4. Operated reliefs in liquids, vapors, gases
5. Hazard identification, safety procedures and designs

Course Outcomes:

At the end of the course, the student will be able to: Know Safety programs, engineering ethics and public perceptions

1. Understand the principles of fire and explosions, flammability characteristics
2. Know about the methods for prevention of fire and explosion
3. Know about Operated reliefs in liquids, vapors, gases
4. Know about process hazard checklist, how to do hazard surveys
5. Know safety procedures and best safety practices

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-

Detailed syllabus

Unit I: Introduction: Safety Programs, Engineering Ethics, Accident and Loss Statistics, Acceptable Risk, Public Perceptions, Nature of the Accident Process, Inherent Safety. Industrial Hygiene: Anticipation and Identification, Hygiene Evaluation, Hygiene Control.

Unit II: Fires and Explosions: Fire Triangle, Distinction between Fires and Explosions, Flammability Characteristics of Liquids and Vapors, Limiting Oxygen Concentration and Inerting, Flammability Diagram

Unit III: Concepts to Prevent Fires and Explosions: Inerting, Controlling Static Electricity, Explosion- Proof Equipment and Instruments, Ventilation, Sprinkler Systems. Introduction to Reliefs: Relief Concepts, Location of Reliefs, Relief Types, Relief Scenarios, Data for Sizing Reliefs, Relief Systems.

Unit IV: Relief Sizing- Conventional Spring: Operated Reliefs in Liquid Service, Conventional Spring- Operated Reliefs in Vapor or Gas Service, Rupture Disc Reliefs in

Liquid Service, Rupture Disc Reliefs in Vapor or Gas Service. Hazards Identification: Process Hazards Checklists, Hazards Surveys, Hazards and Operability Studies, Safety Reviews.

Unit V: Safety Procedures and Designs: Process Safety Hierarchy, Managing Safety, Best Practices, Procedures - Operating, Procedures - Permits, Procedures - Safety Reviews and Accident Investigations, Designs for Process Safety.

Text / References:

1. D.A. Crowl and J.F. Louvar, Chemical Process Safety (Fundamentals with Applications),Prentice Hall,2011.
2. R.K. Sinnott, Coulson & Richardson's Chemical Engineering, Vol. 6, Elsevier India,2006.

C. Disaster Management in Chemical Industries

Course Objectives:

After completion of the course, students will have adequate background, conceptual clarity and knowledge of appropriate solution techniques related to :

1. General aspects of industrial disaster due to fire, explosion etc.
2. Classification of chemical hazards, occupational diseases
3. Hazard analysis and health management
4. Pressure vessels, its storage and handling
5. Safety practices, protection devices

Course Outcomes:

At the end of the course, the student will be able to:

1. Analyze the effects of release of toxic substances
2. Select the methods of prevention of fires and explosions
3. Understand the methods of hazard identification and preventive measures

4. Assess the risks using fault tree diagram

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-

Detailed Syllabus:

Unit I: General aspects of industrial disaster: Due to fire, explosion, toxicity and radiation; Chemicalhazards.

Unit II: Classification of chemical hazards, Chemical as cause of occupational diseases - dust, fumes,gases and vapors.

Unit III: Hazard analysis and health management; Engineering control of chemical plant hazards – Plant layout, ventilation and lighting.

Unit IV: Pressure vessels, Storage, Handling, Transportation, Electrical systems, Instrumentation.

Unit V: Emergency planning, Personal protective devices, Maintenance procedure; Emergency safety and laboratory safety, Legal aspects of safety. Management information system and its application in monitoring disaster, safety and health, Hazop Analysis.

Reference Books:

1. R. V. Betrabet and T. P. S. Rajan in CHEMTECH-I, Safety in Chemical Industry,Chemical

2. Engineering Development Centre, Madras, 1975.
3. Wells, Safety in Process Plant Design.
4. Less, P. Frank, Loss Prevention in Process Industries.
5. J. Lolb & S. Roy Sterm, Product Safety and Liability

Chemical Engineering Lab-II (CRE + MTO) 2 Credits

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
PCC		**Chemical Engineering Lab - II**	**-**	**-**	**4**	**60**	**-**	**40**	**100**	**2**

1. Mass Transfer Laboratory – II

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Perform experiment related to VLE and draw conclusion
CO2	Design equipment for separation purposes
CO3	Evaluate the performance of given technique and compare with other techniques.
CO4	Analyze performance of unit operation.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓			✓			✓					
CO2	✓			✓								
CO3	✓			✓			✓					
CO4	✓			✓								

List of Practical's:

1. To study vapor liquid equilibria for a suitable system
2. To prove Rayleigh equation by carrying out simple distillation of methanol-water system
3. To study flash distillation
4. To study sieve plate distillation column
5. To study crystallization of given salt in batch crystallizer
6. To determine rate of drying of given sample in natural draft tray dryer
7. Study of Rotary/fluidized bed dryer.
8. Study of Humidification/dehumidification system
9. Study of Cooling Tower

2. Chemical Reaction Engineering Laboratory – II

Course Outcomes: At the end of the course, students will be able to:

CO1	Determine the kinetics of chemical reaction in Batch reactor, CSTR, PFR
CO2	Determine the kinetics using Dilatometer
CO3	Determine the temperature dependency of reaction rate constant
CO4	Analyze the performance of reactors through RTD studies
CO5	Compare the performance of CSTR-PFR with PFR-CSTR reactor systems
CO6	Compare the performance of single CSTR with series of CSTRs

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO2	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO3	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO4	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO5	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-

CO6	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-

List of experiments:

1. Study of Isothermal continuous stirred tank reactor.
2. Study of RTD in packed bed.
3. Study of RTD studies in continuous stirred tank reactor.
4. Study of non- catalytic homogenous reaction in a isothermal tubular flow reactor.
5. Study of non- catalytic homogenous reaction in a batch reactor.
6. Study of non- catalytic homogenous reaction in a continuous stirred tank reactor.
7. Study of non- catalytic homogenous reaction in plug flow reactor.

Mini Project

Category	Code	Subject Name	L	T	P	CA	MSE	ESE	Total	Credit
		Mini Project	**-**	**-**	**2**	**60**		**40**	**100**	**1**

The purpose behind the mini project is that the student should be exposed to more hands-on rather than merely theory. It is expected that the student (or a small group say, not more than two in a group, to be confirmed) will undertake to make a working model, a program, critics on technology evolution, experimental work, survey etc. which he will benefit from since he /she will be doing it first-hand. It should be related to chemical engineering field.