Department of Chemical Engineering
University of Calcutta

Course structure & Syllabi (with Objectives & Outcomes) for Semesters I to IV of 2-Year 4-Semester M. Tech. Program in Chemical Engineering (CE – Code: 113), University of Calcutta

(with effect from: Academic Year 2024-2025)

Vide Notification No. CSR/108/2024

(The program structure is appended in continuation of the General Regulations for M. Tech. Degree from the University of Calcutta vide Notification No.: CSR/85/2024)

UNIVERSITY OF CALCUTTA

Notification No. CSR/108/2024

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of her powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 24.09.2024, approved the Course Structure & Syllabus of 2year M.Tech. Programme in Chemical Engineering (CE-code-113), as laid down in the accompanying pamphlet.

The matter was accepted and recommended for approval in the meeting of the Faculty Council in Engineering & Technology, CU, dated. 29.07.2024, Vide Item No.3(xiii)

The above shall take effect from session 2024-2025.

26/9/24

Prof.(Dr.) Debasis Das

Registrar

SENATE HOUSE

Kolkata-700073

26.09.2024

Course Structure and Syllabi of the 2-Year 4-Semester Master of Technology (M. Tech) Program in Chemical Engineering, University of Calcutta.

1. **The nomenclature and duration of the course and total credit of the Examination for M. Tech. Degree in Chemical Engineering shall be as follows:**

Name of Examination	Duration of Course	Total Credits
M. Tech 1st Semester	6 months	20
M. Tech 2nd Semester	6 months	20
M. Tech 3rd Semester	6 months	20
M. Tech 4th Semester	6 months	20

2. **Schedule of Papers and distribution of Credits for the 2-Year M. Tech Semester I, II, III & IV (final) Examination in Chemical Engineering are as follows:**

Semester I

Sr. No.	Course Type/Code	Course Name	Class per week				Credit	Marks
			L	**T**	**P**	Total		
1	Core 1 MChE 101	Mathematical and Statistical Methods in Chemical Engineering	3	1	0	4	4	100
2	Core 2 MChE 102	Advanced Separation Process	3	1	0	4	4	100
3	Program Specific Elective a) MChE 103 b) MChE 113	**Elective I:<u>Any one</u>** a) Chemical Reactor Analysis b) Process Design and Synthesis	3	1	0	4	4	100
4	Program Specific Elective a) MChE 104 b) MChE 114	**Elective II:<u>Any one</u>** a) Safety and Pollution Control in Chemical Industries b) Application of Nanotechnology in Chemical Engineering	3	1	0	4	4	100
5	Laboratory 1 MChE 105	Process Modeling and Simulation Laboratory	0	0	4	4	2	100
6	MChE 106	Research Methodology and Literature Review	2	0	0	2	2	100
7	Audit 1 MChE 107	English for Research Paper Writing	2	0	0	2	0	100*
		Total	16	4	4	24	20	600

*Marks of paper 'Audit 1'- not included in the total Credits/Marks.

Semester II

Sr. No.	Course Type/Code	Course Name	Class per week				Credit	Marks
			L	T	P	Total		
1	Core 3 MChE 201	Advanced Transport Phenomena	3	1	0	4	4	100
2	Core 4 MChE 202	Advanced Reaction Engineering	3	1	0	4	4	100
3	Program Specific Elective a) MChE 203 b) MChE 213	**Elective III: <u>Any one</u>** a) Computational Fluid Dynamics b) Bioprocess Engineering	3	1	0	4	4	100
4	Program Specific Elective a) MChE 204 b) MChE 214	**Elective IV: <u>Any one</u>** a) Process Plant Design & Flow Sheeting b) Refinery& Petrochemicals	3	1	0	4	4	100
5	Laboratory 2 MChE 205	Advanced Chemical Engineering Laboratory	0	0	4	4	2	100
6	MChE 206	Mini Project	0	0	4	4	2	100
7	Audit 2 MChE 207	Constitution of India	2	0	0	2	0	100**
		Total	14	4	8	26	20	600

** Marks of paper 'Audit 2'- not included in the Total Credits/Marks.

Semester III

Sr. No.	Course Type/Code	Course Name	Class per week				Credit	Marks
			L	T	P	Total		
1	Program Specific Elective a) MChE 301 b) MChE 311	**Elective V: <u>Any one</u>** a) Design of Experiments and Parameter Estimation b) Computer Aided Design	3	1	0	4	4	100
2	Open Elective a) MChE 302 b) MChE 312	**<u>Any one</u>** a) Composite Materials b) Waste to Energy	3	1	0	4	4	100
3	Dissertation MChE 303	Dissertation Phase – I	0	0	18	18	12	300
		Total	6	2	18	26	20	500

Semester IV

Sr. No.	Course Type/Code	Course Name	Class per week				Credit	Marks
			L	T	P	Total		
1	Dissertation MChE 401	Dissertation Phase – II	0	0	30	30	20	500

3. **Details of Course objectives, Course outcomes, Syllabi and References of the 2-Year M. Tech Semester I, II, III & IV (final) Examination in Chemical Engineering:**

SEMESTER # I

For conducting **- End Semester Examination**(applicable to all Theory papers, including Electives):

- The Examination will be of 3 hours duration.
- There will be at least 2 (two) paper-setters (internal) for each theoretical paper for End Semester Examination and the answer scripts will be examined by at least two Examiners (Internal).
- Each question paper shall consist of 4 (four) compulsory sections giving equal weightage to each individual module of the syllabus. Questions shall be set taking all the course outcomes specified for the paper.
- There will be no external paper setter or External Examiner for theoretical papers.

Papers

Paper Name: **Mathematical and Statistical Methods in Chemical Engineering**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 101 **(Core #1)**	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:

Engineering Mathematics, Thermodynamics, Mass Transfer, Heat Transfer, Fluid Flow

Course Objectives:

1. To give students an insight in various Chemical Engineering Processes using advanced Numerical and Statistical Methods.
2. To provide adequate background of Mathematics to deal with Chemical Engineering Problems
3. To understand research papers on relevant topics involving advanced Mathematics
4. To study correlation and regression of multivariate data.
5. To evaluate Experimental design methods and statistical quality control measures.

Course outcomes:

Students completing the course will be able to

CO1	Students should be able to solve system of linear algebraic equations	Understand
CO2	Students should be able to do numerical integrations of functions.	Understand
CO3	Students should be able to fit relationship between two data sets using linear, non-linear regression.	Apply
CO4	Students should be able to calculate maxima/minima and functions.	Apply

Course Contents:

Module I **(No. of classes: 13)**

Equation Forms in Process Modeling, Linear and Nonlinear Algebraic Equation, Optimization based Formulations, ODE-IVPs and Differential Algebraic Equations, ODE-BVPs and PDEs, Fundamentals of Vector Spaces, Generalized concepts of vector space, sub-space, linear dependence, Concept of basis, dimension, norms defined on general vector spaces, Examples of norms defined on different vector spaces, Cauchy sequence and convergence, introduction to concept of completeness and Banach spaces, Inner product in a general vector space, Inner-product spaces and their examples, Cauchy-Schwartz inequality and orthogonal sets, Gram-Schmidt process and generation of orthogonal basis, well known orthogonal basis Matrix norms.

Module II **(No. of classes: 13)**

Approximation Theory, Transformations and unified view of problems through the concept of transformations, classification of problems in numerical analysis, Weierstrass theorem and polynomial approximations, Taylor series approximation, Orthogonal Collocations method for solving ODE-BVPs, PDEs with examples, Least square approximations, Formulation and derivation of weighted linear least square estimation, Function approximations and normal equation in any inner product space, Model Parameter Estimation using linear least squares method, Gauss Newton Method, Gelarkin's method and generic equation forms arising in problem discretization, Errors in Discretization, Generic equation forms in transformed problems.

Module III **(No. of classes: 13)**

Classification of solution approaches as direct and iterative, review of Gaussian elimination, Introduction to methods for solving sparse linear systems: Thomas algorithm for tridiagonal and block tridiagonal matrices, Block-diagonal, triangular and block-triangular systems, solution by matrix decomposition, Iterative methods: Derivation of Jacobi, Gauss-Siedel and successive over-relaxation methods, Convergence of iterative solution schemes: analysis of asymptotic behavior of linear difference equations using Eigen values, Convergence of iterative solution schemes with examples, Convergence of iterative solution schemes, Optimization based solution of linear algebraic equations, Matrix conditioning, examples of well conditioned and ill-conditioned linear systems.

Module IV **(No. of classes: 13)**

Solving Nonlinear Algebraic Equations, Method of successive substitutions derivative free iterative solution approaches, Secant method, regulafalsi method and Wegsteine iterations, Modified Newton's method and qausi-Newton method with Broyden's update, Optimization based formulations and Leverberg-Marquardt method, Contraction mapping principle and introduction to convergence analysis. Multi-step (predictor-corrector) approaches: derivations and examples, Stability of ODE-IVP solvers, choice of step size and stability envelopes, Stability of ODE-IVP solvers (contd.), stiffness and variable step size implementation, Introduction to solution methods for differential algebraic equations (DAEs), Single shooting method for solving ODEBVPs.

Suggested Text/Reference Books:

1. Gilbert Strang, Linear Algebra and Its Applications (4th Ed.), Wellesley Cambridge Press (2009).
2. Philips, G. M.,Taylor, P. J. ; Theory and Applications of Numerical Analysis (2nd Ed.), Academic Press, 1996.
3. Gourdin, A. and M Boumhrat; Applied Numerical Methods. Prentice Hall India, New Delhi, (2000).
4. Gupta, S. K.; Numerical Methods for Engineers.Wiley Eastern, New Delhi, 1995.
5. Linz, P.; Theoretical Numerical Analysis, Dover, New York, (1979).
6. Gilbert Strang , Introduction to Applied Mathematics, Wellesley Cambridge Press (2009)

Paper Name: Advanced Separation Processes	L	T	P	Credit
Paper Code: MChE 102 (Core # 2)	3	1	0	4
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Class Test/ Assignments/Flipped-classroom technique	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			100

Pre-requisite:
Knowledge of Mass Transfer Operations, Thermodynamics, Particle & Fluid Technology.

Course Objectives:
1. To familiarize students with various advanced aspects of separation processes and the selection of separation processes.
2. To enable students to understand the principles and processes of adsorption, membrane separation and chromatography.
3. To introduce them to new trends used in the separation technologies.

Course outcomes:
Students completing the course will be able to:

CO1	Analyze multicomponent distillation and azeotropic distillation columns.	Apply
CO2	Analyze fixed bed adsorption and ion-exchange columns.	Apply
CO3	Apply bubble and foam fractionation as well as membrane based separation(UF & MF)	Apply
CO4	Demonstrate various chromatographic methods.	Understand

Course Contents:

Module I **(No. of classes: 13)**
Multicomponent Distillation – overview, application, rigorous stage-to-stage calculation using Lewis-Matheson technique;
Azeotropic Distillation – Heterogeneous Systems & Homogeneous Systems, selection of solvent, rigorous stage-to-stage calculation.

Module II **(No. of classes: 13)**
Transient Diffusion and Mass transfer with Chemical Reaction: Transient diffusion in three dimensions - Transient diffusion equations and solutions, Applications;
Adsorption in a fixed bed: Mass Transfer Zone and breakthrough, Detailed design calculation using length of unused bed; Details of Adsorption Dynamics: One dimensional model, Equilibrium model and velocity of the concentration front, Constant pattern behavior;
Ion-Exchange: Overview of ion-exchange resins, Basic mechanism of ion-exchange-cation and anion exchangers; Ion-exchange equilibria, Designing ion-exchanger columns.

Module III **(No. of classes: 13)**

Bubble and Foam Fractionation: Foam fractionation: Introduction, Theory; Morphology, Coalescence, and Size Distribution of Foam Bubbles – Introduction, Morphology and Structure of Foams, Gas Diffusion in Foams, Thinning and Rupture of Bubble , Stability of foams;

Foam Fractionation – Adsorption, Column Operation, Design, Batch and Continuous Separation of different compounds; Single stage and multi stage operations, Applications;

Bubble Fractionation – Introduction, Theory, Parameters, Applications;

Membrane based Separation: Various Types of membranes and various types of membrane modules (Plate and frame, spiral wound, Hollow-fiber); Pressure driven membrane processes for liquid separation: Micro filtration (applications, Theoretical principles), Ultrafiltration (Applications, Configuration), Concentration polarization and other resistances to solvent flow – Theoretical analysis of concentration polarization, Mass transfer correlations, Solvent flux, Membrane fouling and cleaning.

Module IV **(No. of classes: 13)**

Chromatographic Separations: Principles of chromatographic separation – Means of achieving differential migration, Distribution coefficients, Basic chromatographic theory;

Different types of chromatography; Column chromatography – Introduction, Principles, Analyte development and elution, Retention time, Retention factor, Plate height and resolution, Qualitative and quantitative analysis, Sample clean-up;

Principle, operation & applications – Gas Chromatography, Liquid Chromatography – High-performance liquid chromatography; Adsorption chromatography, Partition Chromatography, Ion-exchange chromatography, Affinity chromatography; Paper and Thin-Layer Chromatography, Polarization Chromatography, Supercritical fluid chromatography. .

Suggested Text/Reference Books:

1. King C.J., Separation Processes, Tata McGraw Hill. 1982.
2. Nakagawal O.V., Membrane Science and Technology, Marcel Dekker. 1992.
3. Humphrey J., Keller G., Separation Process Technology, McGraw-Hill. 1997.
4. Khoury F.M., Multistage Separation Processes, 3^{rd} Ed., CRC Press. 2004.
5. Wankat P.C., Separation Process Engineering, 3^{rd} Ed., Prentice Hall. 2012.
6. Seader J.D., Henley E.J., Separation Process Principles, 2^{nd} Ed., Wiley. 2006.
7. Basmadjian D., Mass Transfer and Separation Processes: Principles and Applications, 2^{nd} Ed., CRC Press. 2007
8. Lemlich R., Adsorptive Bubbles Separation Techniques, New York, Academic Press.1972.
9. Rousseau, R. W., Handbook of Separation Process Technology, John Wiley, New York. 2009.

Paper Name: **Chemical Reactor Analysis**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 103 (Program Specific Elective - I)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:
Reaction Engineering, Thermodynamics, Mass Transfer, Heat Transfer, Mathematics

Course Objectives:
1. To learn the heterogeneous catalyzed reactions and the models involved in reactor design
2. To study mass and heat transfer mechanisms in the different reactors
3. To appreciate the importance of both external and internal transport effects in gas-solid andliquid-solid systems
4. To design isothermal and non-isothermal reactors for heterogeneous catalytic reactions.

Course outcomes:
Students completing the course will be able to

CO1	Estimate optimum parameters for operation and kinetic parameters
CO2	Evaluate heterogeneous reactor performance considering mass transfer limitations.
CO3	Perform the energy balance and obtain concentration profiles in multiphase reactors.
CO4	Estimate the performance of multiphase reactors under non-isothermal conditions.

Course Contents:

Module I **(No. of classes: 13)**
Chemical factor affecting the choice of the reactor, fundamental mass, energy and momentum balance. Model for a semi-batch reactor, optimum operation policies and control strategies, optimal batch operation time, optimal temperature policies. Temperature effects in reactor: introduction, well mixed system with steady feed, the limit cycles and oscillatory reactions, PFR, diffusion control, prorogation of reaction zone. Stability of operation and transient analysis for CSTR.Hot spot equation; optimization using Lagrange multiplier, Pontryagin's Maximum Principle.

Module II **(No. of classes: 13)**
Fixed bed catalytic reactor: The importance and scale of fixed bed catalytic processes, factors in preliminary design, modeling: one dimensional and two dimensional model equations. Pseudo-homogeneous models, heterogeneous models. Themultibed adiabatic reactor, auto-thermal operation, non-steady-state model with axial mixing, global and intrinsic rates. Mechanism of catalytic reactions. Engineering properties of catalysts - BET surface area, pore volume, pore size, pore size distribution.

Module III **(No. of classes: 13)**
Multiphase flow reactor: types of multiphase flow reactors, packed columns, plate columns, empty columns, stirred vessel reactors. Development of rate equations for solid catalyzed fluid phase reactions, estimation of kinetic parameters, external mass and heat transfer in catalyst particles, stability and selectivity. Packed bed reactor, slurry reactor, trickle bed reactor and fluidized bed reactor. Intra-particle heat and mass transfer - Wheelers parallel pore model, random pore model of Wakao and Smith, deactivation of catalyst, ideal and non-ideal flow in reactors.

Module IV **(No. of classes: 13)**
Design model for multiphase flow reactors: gas and liquid phase in completely mixed and plug flow, gas phase in plug flow and liquid phase in completely mixed flow. Effective diffusion model, two zone model, specific design aspects. Packed absorber, two-phase fixed bed reactor. Plate column, spray tower, bubble reactor.

Suggested Text/Reference Books:

1. G.F. Froment, K.B. Bischoff and J. De Wilde, Chemical Reactor Analysis and Design, Wiley, Third Edition, 2010.
2. K.G. Denbigh and J.C. Turner, Chemical Reactor Theory: An Introduction, Cambridge University Press, Thirdedition, 1984.
3. E.B. Nauman, Chemical Reactor Design, Wiley, 1987.
4. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall of India, Third Edition, 1998.
5. J.M. Smith, Chemical Engineering Kinetics, McGraw Hill, Third Edition, 1981.
6. Chemical Reactor Design and Operation by K. R. Westerterp, W. P. M. Van Swaaij and A. A. C. M. Beenackers, Wiley, Second Edition, 1991.

Paper Name: Process Design and Synthesis	**L**	**T**	**P**	**Credit**
Paper Code: MChE 113 (Program Specific Elective - I)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:

Thermodynamics, Reaction Engineering, Mass Transfer, Heat Transfer, Mathematics

Course Objectives:

1. To understand the systematic approaches for the development of conceptual chemical process designs
2. To learn the advances in problem formulation and software capabilities which offer the promise of a new generation of practical process synthesis techniques
3. Learning chemical process synthesis, analysis, and optimization principles
4. Product design and development procedure

Course outcomes:

Students completing the course will be able to

CO1	Understanding different processes and equipment
CO2	Application of chemical process parameter to produce industrial process
CO3	Design best chemical process flow sheet for a given product
CO4	Perform economic analysis related to process design and evaluate project profitability

Course Contents:

Module I **(No. of classes: 13)**

Introduction to fundamental concepts and principles of process synthesis and design and use of flow-sheet simulators to assist process design. Process Flow Sheet Models: An Introduction to Design, Chemical process synthesis, analysis and optimization. Introduction to commercial process design software such as HYSYS, Aspen plus etc., Chemical Process (reactor, heat exchanger, distillation etc) analysis using commercial software. Engineering Economic Analysis of Chemical Processes, Project costing and performance analysis, Environmental concerns, Green engineering, Engineering ethics, Health and safety

Module II **(No. of classes: 13)**

Reactor Networks-Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR in higher dimensions & for other processes, Reactive Separation processes, Fundamental behavior and problems, Separation through reactions. Reactive Residue Curve Maps, Criteria for selection of separation methods, select ion of equipment: Absorption, Liquid-liquid extraction Membrane separation, adsorption, leaching, drying, crystallization, Ideal distillation Column and sequence fundamentals, Sharp splits & sequencing Phase diagrams for 2, 3 and 4 components.

Module III **(No. of classes: 13)**

Feasibility and vapour flow rates for single columns, Residue curve basics, Non-ideal Distillation - Azeotropic systems; detecting binary azeotropes, Residue curve maps for azeotropic systems, Topological analysis, Feasibility for single azeotropic columns ,Binary VLLE and pressure swing separation, Non-ideal distillation synthesis. Equipment sequencing: VLE + VLLE, Detailed Residue Curve Maps, Residue curve maps: Interior structure

Module IV **(No. of classes: 13)**

Minimum heating and cooling requirements, Minimum Energy Heat Exchanger Network, Loops and Paths, Reducing Number of Exchangers, HENS basics & graphics, The pinch point approach, Stream Splitting, Performance targets, trade-off & utilities, Heat & power integration, HENS as mathematical programming

Suggested Text/Reference Books:

1. Douglas, J. “Conceptual Design of Chemical Processes”, New York, NY: McGraw-Hill Science/Engineering/Math, 1988. ISBN: 0070177627.
2. Seider, W. D., J. D. Seader, and D. R. Lewin. “Product and Process Design Principles:Synthesis, Analysis, and Evaluation”, 2nd ed. New York, NY: Wiley, 2004.
3. Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., “Analysis, Synthesis, and Design of Chemical Processes”, 2nd Edition, 2002, Prentice Hall ISBN-10: 0-13-064792-6
4. Biegler L.T., Grossmann I.E. and Westerberg A.W., “Systematic Methods of Chemical Process Design”, Prentice Hall, 1997.

Paper Name: **Safety and Pollution Control in Process Industries**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 104 **(Program Specific Elective - II)**	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments/Flipped-classroom technique	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisite:
Particle and Fluid Processing Technology, Mass Transfer, Chemical Reaction Engineering, Chemical Process Technology, Environmental Science

Course Objectives:
1. To understand the importance of industrial pollution and its abatement.
2. To study the underlying principles of industrial pollution control.
3. To acquaint the students with case studies.
4. Student should be able to design complete treatment system.

Course outcomes:
Students completing the course will be able to:

CO1	Analyze the performance of air pollution control devices for industrial applications under Indian regulatory regimes.
CO2	Analyze the performance of waste water treatment systems for industrial applications under Indian regulatory regimes.
CO3	Analyze fire and explosion followed by Hazard Identification studies for industrial applications under Indian regulatory regimes.
CO4	Analyze hazardous waste minimization methods for industrial applications under Indian regulatory regimes.

Course Contents:
Module I **(No. of classes: 13)**
Air Pollution Control: Introduction to industrial air pollution; Selection, Design, Operation, Advantages and Disadvantages of Industrial Air Pollution Control Devices -
(a) Gravity Settling Chamber, Cyclone Separator, Fabric Filter
(b) Electrostatic Precipitator, Wet Scrubber,
(c) Absorber, Adsorber, Incinerator,
Indian regulatory requirements for controlling industrial air emission with permit giving procedure; Air pollution control systems in Indian industries to meet the emission standards: Coal fired Thermal Power Plant, Integrated Iron & Steel Industry, Fertilizer, Petroleum Oil Refinery & Petrochemicals, Cement Industry, Sponge Iron, Cupola, Induction Furnace, Ferro alloys manufacturing units etc.
Dispersion of air pollutants: Lapse rate and stability, plume behavior, Application of Gaussian plume dispersion model for air pollutants from point stationary sources (relevant to dispersion of stack emission).

Module II **(No. of classes: 13)**
Wastewater Treatment: Introduction to industrial wastewater; Primary treatment system: grit chamber, equalization, primary clarifier, coagulation, flocculation.
Secondary, tertiary and advanced treatment systems.
Biological treatment: Kinetics of biological growth, Design of activated sludge process, trickling filter, Rotating Biological Contactor, Oxidation Ponds.
Indian regulatory requirements for controlling industrial discharge of wastewater with permit giving procedure; Wastewater treatment systems to meet the wastewater discharge standards in Indian industries such as Distillery, Integrated Iron & Steel, Pulp and Paper, Inorganic acids, Petroleum Oil Refinery, Petrochemical, Fertilizer, Pesticide, Textile, Coal fired Thermal Power Plant etc.

Module III **(No. of classes: 13)**

Process Plant Safety: Introduction to industrial hazard, Classification of chemical plant accidents, Case Studies. Fundamentals of Toxicology, Dose-response relationships, Threshold limit values. Industrial Hygiene: Material safety data sheets (MSDS),

Fire: Fire Triangle; Flammability Characteristics of Liquids and Vapours -Flammability limit dependence on temperature and pressure, Autoignition, Auto-Oxidation,

Explosions: Detonation and Deflagration, Vapour Cloud Explosions, Boiling-Liquid Expanding-Vapor Explosions (BLEVE); TNT Equivalency.

Hazard Identification: Fire and Explosion index, HAZOP Study, Safety Reviews;

Applicable Indian Regulations for Chemical Plant Safety with special reference to Petroleum Oil Refinery and Petrochemical plants.

Module IV **(No. of classes: 13)**

Hazardous waste management: Hazardous Waste Fundamentals: Definition, Classification, TCLP.

Hazardous Waste Management: Waste Minimization, Waste Audit, Waste Exchange and Recycling

Treatment Methods: (a) Biological Treatment, Chemical Treatment, Physical Treatment,

(b) Incineration, Stabilization and solidification

(c) Land Disposal including secured landfill with leachate collection/treatment facility,

Risk Assessment.

Indian regulatory requirements for industries**:** Hazardous and other Wastes (Management & Transboundary Movement) Rules, 2016as amended and related international regulations like Basal Convention.

Suggested Texts/Reference Books:

1. deNevers N., Air Pollution Control Engineering, 2nd Ed. McGraw-Hill. 2000.
2. Masters G.M., Ela W.P., Introduction to Environmental Engineering and Science, 3rd Ed. Prentice Hall of India Private Limited. 2008.
3. Davis M.L., Cornwell D.A., Introduction to Environmental Engineering, 5th Ed. McGraw-Hill, 2013.
4. Sincero A.P.,Sincero G.A., Environmental Engineering: A Design Approach. Prentice Hall of India Private Limited. 1999.
5. Metcalf & Eddy. AECOM. Wastewater Engineering: Treatment and Resource Recovery, 5th Ed. McGraw-Hill Education. 2014.
6. Nemerow N.L., Liquid waste of industry- theories, Practices and Treatment, Addison Wesley, New York. 1971.
7. Mahajan S.P., Pollution Control in Process Industries, Tata McGraw Hill Publishing Company. 1985.
8. Crowl D.A., Louvar J.F., Chemical Process Safety: Fundamentals with Applications, 2nd Ed. Prentice Hall Inc. 2002.
9. Lees' Loss Prevention in the Process Industries, 4th Ed. Volume 1, Volume 2, Volume 3. Butterworth-Heinemann, Elsevier. 2012.
10. Central Pollution Control Board, CPCB, Ministry of Environment, Forest & Climate Change, Government of India for Environmental (Protection) Acts & Environmental (Protection) Rules. https://cpcb.nic.in/

Paper Name: Application of Nanotechnology in Chemical Engineering	L	T	P	Credit
Paper Code: MChE 114 (Program Specific Elective - II)	3	1	0	4
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite:
Physics and Chemistry, Basic Electronics

Course Objectives:
1. To provide basic and advanced knowledge regarding nanomaterial preparation and properties
2. To gain knowledge of structure, properties, manufacturing, of various nanomaterials and characterization methods in nanotechnology
3. To give a survey of the key processes, principles, and techniques used to build novel nanomaterials and assemblies of nanomaterials
4. To familiarize the student with the use and application of nanotechnology and to make the students industry-ready by exposing them to real-life challenges.

Course outcomes:
Students completing the course will be able to

CO1	Provides an introductory exploration of nanotechnology, elucidating its background, evolution, and significance.	Understand
CO2	Understanding with nanofabrication/growth techniques and characterization tools, encompassing fabrication processes, integration, and nano-dimensional materials	Understand
CO3	Explores diverse synthesis techniques for nanoscale materials, encompassing self-assembly, bottom-up, and top-down methods	Apply
CO4	Acquire the concept of semiconductors and quantum dots, examining their properties and applications spanning various fields.	Apply

Course Contents:

Module I **(No. of classes: 13)**
Introduction to nanotechnology, Background, Evolution, Significance. Classification of nanostructures, Nanoscale architecture, Chemical interactions at nanoscale, Types of carbon-based nanomaterials, One, two and multidimensional structures, Crystallography. Polymer-based and Polymer-filled Nanocomposites.

Module II **(No. of classes: 13)**
Self-Assembly and Overview on Synthesis of Nanomaterials (Bottom up and top down), Sol gel technique, Arc discharge, Laser ablation, RF sputtering; Bottom-up: Chemical Vapor Deposition (CVD), Metal Oxide Chemical Vapor Deposition (MOCVD), Atomic layer deposition (ALD), Molecular beam Molecular self-assembly; Ultrasound assisted, microwave assisted, Mini, micro and

nanoemulsion. Wet grinding method, Spray pyrolysis, Ultrasound assisted pyrolysis, atomization techniques. Surfactant based synthesis procedures,

Module III **(No. of classes: 13)**

Fabrication Processes and Integration, Nano Dimensional Materials (Carbon Nanotubes, Graphene, Dendrimer, Metal Organic Frameworks, Quantum dots, Conjugated Polymers).Analysis using X-ray imaging, Transmission Electron Microscopy, HRTEM, Scanning Electron Microscopy, SPM, AFM, STM, PSD, Zeta potential, DSC and TGA.

Module IV **(No. of classes: 13)**

Intrinsic semiconductors, Extrinsic semiconductors, Review of classical mechanics, Quantum Theory of Nano-dimensional Materials, de Broglie's hypothesis, Heisenberg uncertainty principle Pauli exclusion principle Schrödinger's equation Properties of the wave function, Applications: quantum well, wire, dot, Quantum cryptography, Chemical and Biosensors- Classification and Main Parameters of Chemical and Biosensors, Nanostructured Materials for Sensing, Waste Water Treatment, Nano-biotechnology, Drug Delivery.

Suggested Text/Reference Books:

1. Louis Hornyak G., DuttaJoydeep, Tibbals Harry F. and Rao Anil K., "Introduction toNanoscience", (CRC Press of Taylor and Francis Group LLC), May 2008.5
2. K.K. Chattopadhyay and A.N. Banerjee, Introduction to Nanoscience and Nonotechnology, PHI, 2010.
3. Charles Poole and Frank Owens, Introduction to Nanomaterials, Wiley 2007
4. T. Pradeep, Nano: The Essentials, Understanding Nanoscience and Nano Technology, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2007.
5. Nanotechnology: Principles & Practices; Sulabh K. Kulkarni, Capital Publishing Company, Kolkata
6. Ranganathan Sharma, "Nanostructuring Operations in Nanoscale Science and Engineering", McGraw-Hill Companies, Inc., 2010.
7. H. Singh Nalwa (Ed.), Handbook of Nanostructured Materials and Nanotechnology, Elsevier.
8. Principles of nanotechnology: N. Phanikumar; Scitech, Kolkata Introduction to nanotechnology: Charles P. Poole & Frank Li Owens, Wiley India (p) Ltd, New Delhi

Paper Name: **Process Modeling and Simulation laboratory**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 105 **(Laboratory – I)**	**0**	**0**	**4**	**2**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation			**Marks**
Continuous Assessment	Assessment of all Practical sessions	50	60
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 4 (four) hours duration and shall jointly be conducted by two Internal Examiners.		40
	Practical Notebook	10	
	Experimental Study	20	
	Viva-Voce	10	
Total			**100**

Pre-requisite:
Mass Transfer, Heat Transfer, Reaction Engineering, Process Thermodynamics

Course Objectives:
Objectives:
1. To learn Process Modeling and Simulation of Chemical operations and processes.
2. To understand Dynamic Behavior of processes.
3. To understand Close loop control of processes.
4. To learn Dynamic simulation of chemical processes.
5. To get acquainted with Controllability Analysis of chemical processes.

Course outcomes:
Students completing the course will be able to:

CO1	Carry out thermodynamic property estimations using property estimation and property analysis in Aspen.
CO2	Simulate Mixer, splitter, heat exchangers, reactors, distillation columns.
CO3	Apply sensitivity, design specification and case study tools in Aspen.
CO4	Solve linear and non-linear programming problems.

Course Contents:
List of Experiments:
[At least six experiments shall be conducted]

1. Thermodynamic property estimations using property estimation and property analysis in Aspen.
2. Simulate Mixer, splitter, heat exchangers, and reactive distillation column.
3. Apply sensitivity, design specification and case study tools in Aspen
4. Apply sensitivity, design specification and case study tools in Aspen.
5. Solve linear and non-linear programming problems.
6. Controller tuning by Ziegler- Nichol's & Cohen- Coon methods
7. Simulation of Ideal Binary Distillation Column
8. Modeling and Simulation of cyclone separator

Note: Simulation can be done using C/C++ / MATLAB/ ASPEN PLUS/ CHEMCAD

Suggested Text/Reference Books:
1. Heat& Mass transfer Text/Reference books
2. Reaction Engineering books
3. Simulation Software(s)
4. Laboratory Manual

Paper Name: Research Methodology and Literature Review	L	T	P	Credit
Paper Code: MChE 106	**2**	**0**	**0**	**2**
Total Contact Hour = 28				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments throughClass Test/ Assignments/Flipped-classroom technique	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisite:

Completed Project Work at undergraduate level.

Course Objectives:

1. To familiarize students on various aspects of the research including the technique of formulating a research problem
2. To teach students on various aspects of the literature review in research.
3. To enable students to learn the technique in writing Research Report, Thesis and Research proposal
4. To familiarize students on research ethics, plagiarism and AI based publications as well as to enable students as to how to comply with the Indian Plagiarism Rules.

Course outcomes:

Students completing the course will be able to:

CO1	Assess issues relating to the research process in formulating a research problem.
CO2	Develop Literature Review.
CO3	Prepare Research Report, Thesis and Research proposal.
CO4	Analyze the issues on Research Ethics to comply with the Plagiarism Rules.

Course Contents:

Module I **(No. of classes: 7)**

Research: Meaning of research, Applications; The research process: characteristics and requirements; Types of research, Research approaches, Research Methods versus Methodology, Criteria of Good Research.

The research process: Deciding what to research, Planning a research study, Conducting a research study.

Research Problem: Meaning, Importance of formulating a research problem, Sources, Considerations in selecting a research problem, Steps in formulating a research problem, Research objectives and motivation.

Module II **(No. of classes: 7)**

Reviewing the literature: Meaning of review of literature, Literature review in research– Bringing clarity and focus to the research problem, Improving research methodology, Broadening the knowledge-base in research area, Enabling to contextualise findings; Objective of review of literature.

Sources of review of literature, Functions of review of literature; How to review the literature – Searching for the existing literature, Reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework; Writing about the literature that is reviewed, Suggestions for reporting Review of literature.

Module III **(No. of classes: 7)**

Research Report/Thesis: Introduction, Need of Research Report, Detailed format,Report writing, Ethical issues.

Research Proposal: Introduction, research proposal in quantitative and qualitative research; Detailed contents of a research proposal, structure of the report, problems and limitations, ethical issues.

Evaluation of research report/proposal: Introduction, Need, Intervention–development–evaluation process, Perspectives in the classification of evaluation studies, Types of evaluation, Undertaking an evaluation, Ethics in evaluation. Format of Research proposal.

Elements of technical article for publication in peer reviewed journals.

Module IV **(No. of classes: 7)**

Ethics in Research & Publication: Research, Publication Ethics and Malpractice, Authorship, Authorship Disputes and its preventive measures, Competing interests, Plagiarism – Definition, Detection and Prevention, Word-for-word copying, Paraphrasing, Tools for detecting similarity index value (e.g., iThenticate, Turnitin) and reporting, Duplicate Submission/Publication, Research Fraud, Salami Slicing, Citation Trading, False citation, Fraud and Ghost Reviewer and its prevention.

Regulatory Measures for Plagiarism: International Standards for Authors in responsible research publication. UGC Regulations for preventing Plagiarism. Journal Reporting of Academic Misconducts-Case studies.

Generative AI and AI-assisted technologies for research publications: Chatbots, Generative AI and Scholarly Manuscripts, AI and Authorship.

Suggested Texts/Reference Books:

1. Melville S., Goddard W., Research methodology: An introduction for science &engineering students, Juta & Co. Ltd. Kenwyn, South Africa, 1996.
2. Goddard W., Melville S., Research Methodology: An Introduction, 2nd Ed. Juta& Co. Ltd. Kenwyn, South Africa, 2007.
3. Kumar R., Research Methodology: A Step by Step Guide for beginners, 3rdEd. SAGE Publications India Private Ltd. 2011.
4. Kothari, C.R. Research Methodology: Methods and Techniques, 2nd Ed. New Age International (P) Ltd., Publishers. 2004.
5. Singh Y.K., Fundamental of Research Methodology and Statistics. New Age International (P) Ltd., Publishers. 2006.
6. Useful resources for Ethics, Plagiarism, AI tools in Research: www.ethics.elsevier.com
7. Novikov A.M., Novikov D.A., Research Methodology: From Philosophy of Science to Research Design, CRC Press, Taylor & Francis Group. 2013.
8. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations, 2018.Notified in Extraordinary Gazette of India. New Delhi, Tuesday, July31, 2018.

Paper Name: **English for Research Paper Writing**	L	T	P	Credit
Paper Code: MChE 107 (Audit # 1)	**2**	**0**	**0**	**0**
Total Contact Hour = 28				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments/Flipped-classroom technique	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination • The students only need to pass this paper, however no Grade will be awarded. To pass this paper, a student has to obtain either 50 marks or above out of 100. In the Mark/Grade-Sheet, only QUALIFIED (Q)/ FAIL (F) will be mentioned against this paper. In case of FAIL (F), the student has to be re-evaluated as in the Regulations for 2-year 4-semester M. Tech. Program.			70
Total			**100**

Pre-requisite:
Basic knowledge of reading research papers.

Course Objectives:
1. To give an overview to the students in planning for preparing a research paper for submitting in a Journal for the broad interests of the readers.
2. To elaborately teach the students on various sections of a research paper (from writing title to conclusions).
3. To make students alert and provide guidance for final check prior to submission.

Course outcomes:
Students completing the course will be able to:

CO1	Developfundamentalunderstanding for preparing a research paper.
CO2	Apply the English usage in writing Title, Abstract and Introduction.
CO3	Apply the English usage in writing Review of the Literature, Methods and Results.
CO4	Apply the English usage in writing Discussion and Conclusions followed by assessing the research paper for Final Check prior to submission.

Course Contents:

Module I **(No. of classes: 7)**
Planning and preparation;Basic word order for English and length of sentence; Structuring paragraphs and sentences; Being concise and avoiding redundancy; Avoiding ambiguity and vagueness; Clarifying and highlighting the research paper; Noting and describing the limitations; Readability.

Module II **(No. of classes: 7)**
Sections of a Research Paper: Elaborate discussion on writing Title, Abstract and Introduction for a research paper.

Module III **(No. of classes: 7)**

Sections of a Research Paper: Elaborate discussion on writing Review of Literature, Methods and Results for a research paper.

Module IV **(No. of classes: 7)**

Sections of a Research Paper: Elaborate discussion on writing Discussion, Conclusions for a research paper and the Final Check prior to submission (meeting the author's guidelines for the Journal selected for submission of the research paper).

Suggested Texts/Reference Books:

1. Wallwork A., English for Writing Research Papers, 3rd Ed. Springer. 2023.
2. Goldbort R., Writing for Science, Yale University Press. 2006.
3. Gastel B., Day R.A., How to Write and Publish a Scientific Paper, 8th Ed. Greenwood - An Imprint of ABC- CLIO, LLC. 2016.
4. Higham N.J., Handbook of Writing for the Mathematical Sciences, 3rd Ed. Society for Industrial and Applied Mathematics (SIAM). 2020.

SEMESTER # II

For conducting **-End Semester Examination** (applicable to all Theory papers, including Electives)**:**

- The Examination will be of 3 hours duration.
- There will be at least 2 (two) paper-setters (internal) for each theoretical paper for End Semester Examination and the answer scripts will be examined by at least two Examiners (Internal).
- Each question paper shall consist of 4 (four) compulsory sections giving equal weightage to each individual module of the syllabus. Questions shall be set taking all the course outcomes specified for the paper.
- There will be no external paper setter or External Examiner for theoretical papers.

Papers

Paper Name: Advanced Transport Phenomena	**L**	**T**	**P**	**Credit**
Paper Code: MChE 201 (Core #III)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td rowspan="3">Internal Assessment</td><td>Sessional Assessments through Class Test/ Assignments</td><td>20</td><td rowspan="3">30</td></tr>
<tr><td>Active participation in routine classes</td><td>05</td></tr>
<tr><td>Overall conduct, attendance, manners, skills etc.</td><td>05</td></tr>
<tr><td colspan="3">End Semester Examination</td><td>70</td></tr>
<tr><td colspan="3">Total</td><td>100</td></tr>
</table>

Pre-requisite:

Fluid Mechanics, Mass Transfer, Heat Transfer, Mathematics

Course Objectives:

1. To understand the transport of energy, mass, and momentum for rational design of engineering systems involving Newtonian and non-Newtonian fluids, solid-state heat conduction, forced and free convection, binary diffusion with or without chemical reaction based on generalized and reformulated basic principles.
2. To place emphasis on the use of fundamental laws and a judicious blend of experimental, analytical, and numerical methods to develop the required understanding and necessary models for essential portions of engineering problems involving transport processes.

Course outcomes:

Students completing the course will be able to

CO1	Explain conservation Principles (momentum, energy and mass)
CO2	Identify the various analogies between momentum, heat, and mass transfer for industrial applications
CO3	Develop generalized and reformulated basic equations to obtain the desired changes in the velocity, temperature and concentration profiles for industrial application.
CO4	Examine the data from the balancing equation solutions using mathematical methods to create the models required for the key components of the Engineering quantities of interest application.

Course Contents:

Module I **(No. of classes: 13)**

Introduction to Transport Phenomenon: Classification of Transport Processes, Conservation Laws, Vector and Tensor Calculus, Principles of Transport, Shell Balance**,** 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, Dimensional Analysis of the Equations of Change. Velocity distributions with more than one Independent Variable.

Module II **(No. of classes: 13)**

Velocity Distributions in Turbulent Flow -Comparisons of Laminar and Turbulent Flows, Time Smoothed Equations of Change for Incompressible Fluids, Time Smoothed Velocity Profile near a wall, Empirical Expressions for the Turbulent Momentum Flux, Turbulent Flow in Ducts, Turbulent Flow in Jets.

Module III **(No. of classes: 13)**

Energy Transport: 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, Dimensional Analysis of the Equations of Change for Non-Isothermal Systems. Temperature Distributions in Solids and in Laminar Flow: Heat Conduction with an Electrical Heat Source, Heat Conduction with a Viscous Heat Source. Temperature Distributions with more than One Independent Variable - Unsteady Heat Conduction in Solids, Steady Heat Conduction in Laminar, Incompressible Flow. Temperature Distributions in Turbulent Flow - Time-Smoothed Equations of Change for Incompressible Flow.

Module IV **(No. of classes: 13)**

Mass Transport: 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, Derivation of the

Macroscopic Mechanical Energy Balance. Concentration Distributions in Solids and in Laminar Flow: Shell Mass Balances Boundary Conditions, Diffusion through a Stagnant Gas Film, Diffusion with a Heterogeneous Chemical Reaction. Concentration Distributions with more than One Independent Variable. Concentration Distributions in Turbulent Flow - Time-Smoothed Equations of Change for Incompressible Flow.

Suggested Text/Reference Books:

1. R.B.Bird,W.E.Stewart,E.N.Lightfoot,D.J.Klingenberg,IntroductoryTransportPhenomena, Wiley,2013.
2. Thomson W. J., Transport Phenomena, Pearson education, Asia, 2001.
3. Geankopolis C. J., Transport Processes and Unit Operations, 4th Ed., Prentice Hall (India) Pvt. Ltd.,New Delhi. 2004.
4. J.C.Slattery,AdvancedTransportPhenomena,CambridgeUniversityPress,1999.
5. P.K.Kunduand, I.M.Cohen, Fluid Mechanics, Academic Press
6. W.M.Deen, Analysis of Transport Phenomena (Topics in Chemical Engineering), Oxford University Press.

Paper Name: Advanced Reaction Engineering	**L**	**T**	**P**	**Credit**
Paper Code: MChE 202 (Core #IV)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:
Reaction Engineering, Thermodynamics, Mathematics

Course Objectives:

1. To understand heterogeneous reactions, its energy balance, temperature and concentration profiles
2. To understand advance design aspects of multiple reactors, insight of importance of population balance of particles
3. To apply the role of Reaction Engineering in mitigation of Global warming.

Course outcomes:
Students completing the course will be able to

CO1	Understand modern reactor technologies	Understand
CO2	Evaluate heterogeneous reactor performance considering mass transfer limitations	Understand
CO3	Estimate the performance of reactors under non-isothermal conditions.	Apply
CO4	Perform the energy balance and obtain concentration profiles in multiphase reactors	Apply

Course Contents:

Module I **(No. of classes: 13)**

Non-elementary kinetics importance: approximations for formulations of rate laws, formulations of kinetic model. Semibatch reactors: material balance, effect of flow on conversions, importance and applications, multiple reaction in semibatch reactors, conversion vs rate. Non-isothermal reaction modeling in CSTR, PFR and semi-batch reactor: energy balance equations. Unsteady state in non-isothermal energy balance, calculations of volumes for non-isothermal reactors. Adiabatic operations: temperature conversion profiles in PFR, CSTR, semibatch and steady state tubular reactor with heat exchange.

Module II **(No. of classes: 13)**

Need for multi-staging, CSTR with multiple stages: exothermic and endothermic reactions with examples, multiple reactions in CSTR and PFR with heat effects. Design of PFR and packed bed tubular reactors: radial and/or axial mixing. Optimal reactor design for reversible exothermic reactions: unsteady state non-isothermal reactor design, adiabatic operation in batch, shift of energy and material balance lines in CSTR. Auto-thermal PFR and packed tubular reactors, PFR with inter stage cooling. Examples of optimal design of PFR, Semi-batch reactor and CSTR.

Module III **(No. of classes: 13)**

Catalysis: theory and modeling of catalytic reactions, different steps in catalytic reactions, global rate of reaction. Heterogeneous catalysis: theory, types of reactions. Steady state approximation, formulations of rate law, rate laws derived from the pseudo steady state hypothesis, rate controlling steps, Eley-Rideal model, reforming catalyst. Packed bed reactor: transport and reactions, temperature gradient. Porous media reactor: mass transfer coefficients, flow effects on sphere, tube and cylinder, external mass transfer, pore diffusion, structure and concentration gradients, internal effectiveness factor.Catalytic wall reactor: limiting steps reactions, mass transfer limitedreactions, design of packed bed porous catalytic reactors: mass transfer limited reactions.

Module IV **(No. of classes: 13)**

Fluidized bed reactor and its modeling: comparison of fixed bed and fluidized bed reactor, advantage of fluidized bed reactor, important parameters, Geldart classification of powders. Class I chemical reactor model: arbitrary two region flow models. Class II chemical reactor model: Plug Flow or Mixed Flow Model. Class III chemical reactor model: the bubbling fluidized bed reactor (BFB), The Kunii-Levenspiel bubbling bed model, gas flow around and within a rising gas bubble in a fine particle BFB, performance of BFB. Application of population balance equations for reactor modeling: particle size distribution, distribution functions in particle measuring techniques, particle distribution model during colloidal particle synthesis in batch reactor.

Suggested Text/Reference Books:

1. K.G. Denbigh and J.C. Turner, Chemical Reactor Theory: An Introduction, Cambridge University Press, Third edition, 1984.
2. J.M. Smith, Chemical Engineering Kinetics, McGraw Hill, Third Edition, 1981.
3. O. Levenspiel, Chemical Reaction Engineering, Wiley, Third Edition, 2005.
4. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall of India, Third Edition, 1998.
5. G.F. Froment, K.B. Bischoff and J. De Wilde, Chemical Reactor Analysis and Design, Wiley, Third Edition, 2010.

Paper Name: Computational Fluid Dynamics	L	T	P	Credit
Paper Code: MChE 203 (Program Specific Elective - III)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:
Fluid Mechanics, Transport phenomena, Mathematics-III, Computer programming

Course Objectives:
1. To make students understand the governing equations of fluid dynamics and their derivation from laws of conservation
2. To develop a good understanding in computational skills, including discretisation, accuracy and stability
3. To acquaint the students with a process of developing a mathematical and geometrical model of flow, applying appropriate boundary conditions and solving system of equations.

Course outcomes:
Students completing the course will be able to

CO1	Explain the complexity and non-availability of analytical solution method	Understand
CO2	Explain different governing equation in conservative and non-conservative forms	Understand
CO3	Able to characterize and visualize transfer process in equipment or pipeline	Apply
CO4	Interested to use software of CFD to understand and present the transfer process	Apply

Course Contents:

Module I **(No. of classes: 13)**
Introduction to Computational Fluid Dynamics, Conservation Equations, Classification of different partial differential equations and their physical behaviour, Discretisation, Grid generation: Structured Grid generation Unstructured Grid generation Adaptive Grid generation, Approximate Solutions of Differential Equations

Module II **(No. of classes: 13)**
Different Numerical methods and their comparison; Finite Difference Method, Finite Volume Method, Finite Element Method, etc. Source terms and their linearization, Solution of discretized equations. Solution of diffusive problems: Steady 1D,Steady 2D and steady 3D problems

Module III **(No. of classes: 13)**
Steady convective-diffusion problems: 1D, 2D and 3 D, Different schemes: Central different scheme, Upwind and downwind schemes, Hybrid schematic, Unsteady diffusive and convective-diffusive type problems (Implicit, Crank Nicolson and explicit methods): 1D, 2D and 3D

Module IV **(No. of classes: 13)**

Fluid Flow, Pressure distribution in fluids, SIMPLE algorithms, SIMPLER algorithms, Transition from laminar to turbulent flow, Effect of turbulence on time-averaged Navier-Stokes equations, Characteristics of simple turbulent flows, Free turbulent flows, Flat plate boundary layer and pipe flow, Turbulence models, Mixing length model, The k-e model, Reynolds stress equation models, Algebraic stress equation models

Suggested Text/Reference Books:

1. An Introduction to Computational Fluid Dynamics - H K Versteeg and W Malalasekera
2. Anderson John D., "Computational Fluid Dynamics: The Basics with Applications", Mc-Graw Hill, 1995
3. Ranade V.V., "Computational Flow Modeling for Chemical Reactor Engineering", Process Engineering Science, Volume 5, 2001
4. Knupp Patrick and Steinberg Stanly, "Fundamentals of Grid Generation", CRC Press, 1994
5. Wilcox D.C., "Turbulence Modelling for CFD", 1993
6. Wesseling Pieter, "An Introduction to Multigrid Methods", John Wiley & Sons, 1992
7. Thompson J.F., Warsi Z.U.A. and Mastin C.W., "Numerical Grid Generation: Foundations and Applications", North Holland, 1985
8. Patankar S.V., "Numerical Heat Transfer and Fluid Flow", McGraw-Hill,1981
9. Gatski Thomas B., Hussaini M. Yousuff and Lumley John L., "Simulation and Modelling ofTurbulent Flows", Oxford University Press, 1996
10. Laney, C. B., "Computational Gas Dynamics", Cambridge Uni. Press, 1998.

Paper Name: **Bioprocess Engineering**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 213 (Program Specific Elective – III)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisite: Mass & Heat Transfer, Chemical Reaction Engineering, Particle and Fluid Processing Technology, Instrumentation & Process Control, Biotechnology

Course Objectives:

1. To teach students on the principles of bioprocessing for traditional chemical engineering in the design and development of processes involving biocatalyst.
2. To learn and develop quantitative models and approaches related to bioprocesses.
3. To learn mechanisitic models for enzyme catalyzed reactions for large scale production of bioproducts.
4. To familiarize students on the applications of bioprocess engineering in different areas.

Course outcomes:

Students completing the course will be able to:

CO1	Demonstrate advanced enzyme kinetics in bioprocess engineering.	Understand
CO2	Apply bioreactors in production of bio-products.	Apply
CO3	Applyhomogeneous and heterogeneous kinetics in biochemical reactions.	Apply
CO4	Apply bioprocess engineering in industrial applications of bioprocesses along with recovery and purification of biological products	Apply

Course Contents:

Module I **(No. of classes: 13)**

Introduction: Role of chemical engineers in bioprocess engineering, An overview of biological basics. Advanced Enzyme Kinetics**:** Models for complex enzyme kinetics, Enzyme deactivation kineticsmodeling of effect of pH and temperature, models for insoluble substrate, models for immobilized enzyme systems, diffusion limitations in immobilized enzyme system, electrostatic and steric effects.

Module II **(No. of classes: 13)**

Operating considerations for bioreactors: Choosing the cultivation method; Modifying batch and continuous reactors- chemostat with recycle, multistage chemostat systems, fed-batch operation, perfusion systems. Active and passive immobilization of cells; Bioreactor considerations in immobilized cell systems, Solid-state fermentations. Selection, design, operation and control of bioreactors, Sparger design, Scale-up and its difficulties, Bioreactor instrumentation and control, Fermentation monitoring, Sterilization of process fluids.

Module III **(No. of classes: 13)**

Homogeneous reactions in bioprocesses: Cell Yield, Cell growth kinetics, influence of substrate concentration, growth kinetics with plasmid instability; Production kinetics in cell culture, Substrate uptake kinetics with respect to extracellular product formation, Cell death kinetics. Heterogeneous reactions in bioprocesses: Concentration gradients and reaction rates in solid catalysts. Internal mass transfer and reaction considering spherical geometries, The Thiele Modulus and effectiveness factor. External mass transfer, experimental aspects.

Module IV **(No. of classes: 13)**

Recovery and purification of biological products: Strategies to recover and purify products, Recovery and purification of biological products – Separation for insoluble products, Mechanical andnon-mechanical cell disruption methods, Separation of soluble products, Finishing steps for purification. Industrial bioprocesses: Anaerobic process– Ethanol and Lactic Acid production; Aerobic process– Bakers'Yeast and Penicillin production.

Suggested Text/Reference Books:

1. Shuler M.L., Kargi F., Bioprocess Engineering: Basic Concepts, 2ndEd. Prentice Hall.2002
2. Doran P.M., Bioprocess Engineering Principles, 2nd Ed. Academic Press. 2015.
3. Bailey J.E., Ollis D.F., Biochemical Engineering Fundamentals, 2nd Ed. McGraw-Hill Book Co. 1986.

Paper Name: Process Plant Design and Flowsheeting	L	T	P	Credit
Paper Code: MChE 204 (Program Specific Elective - IV)	3	1	0	4
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite:

Materials & Energy Balance, Fluid Flow, Heat & Mass Transfer, Plant Design, Project Engineering, Economics, Management

Course Objectives:

1. To understand the scope, limits and exclusions of Process Plant design
2. To apply basic principles of chemical engineering to solve complex chemical engineering problems
3. To apply systematic and standard processes to design and operation of chemical process plants

Course outcomes:

Students completing the course will be able to

CO1	Understand the basic concepts of process flow sheet construction	Understand
CO2	Evaluate the detailed process design.	Apply
CO3	Know the economic and management aspects of the overall process with cost optimization	Apply
CO4	Correlate the design with equipment cost	Apply

Course Contents:

Module I **(No. of classes: 13)**

Concept of Process plant design: Basic concepts of process plant design; Role of Engineering and Environmental ethicsin plant design; Codes, standards and design basis; Site selection; Application of plant safety in plant design; Environmental aspects of designing and flowsheets-EIA, HAZOP.

Plant operation and control: Instrumentation, maintenance, utilities, structural design, storage, material handling.

Module II **(No. of classes: 13)**

Flowsheets: Development of PFD from basic data, P&ID and equipment layout in a process plant.

Process flow sheet synthesis and development: Hierarchy of chemical process design; synthesis of flowsheets; Combination of reaction-separation system; Distillation sequencing; Heat integration of process equipment like distillation columns, reactors and heat exchangers; Algorithmic flowsheet generation, Comparison of hierarchical and algorithmic results.

Module III **(No. of classes: 13)**

Economic aspects of design: Feasibility study report; Break-even analysis, Factors affecting Investment and production costs, Estimation of capital investment and total product costs, Cost indices, Interest, Time value of money, Taxes and Fixed charges, Salvage value, Methods of calculating depreciation, Profitability, Alternative investments and Replacements.

Module IV **(No. of classes: 13)**

Optimization in design: Optimum production rate, optimum batch cycle time, optimum insulation thickness, optimum cooling water flow rate.

Management aspects of process design: Degrees of freedom, Network analysis – Bar chart, Gantt chart, PERT, CPM; Project crashing;

Suggested Text/Reference Books:

1. Peters, M.A. and Timmerhaus, K.D., Plant Design and Economics for Chemical Engineers, McGraw Hill (2003).
2. Kumar, A. ,Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1982).
3. Sinnot,R.K., Chemical Engineering Design, Coulson and Richardson's Chemical Engineering Series, Volume 6, Elsevier (Butterworth-Heinemann).
4. Chakrabarti, S. Project Engineering Primer for Chemical Engineers; Springer Nature Singapore Pte Ltd, 2022
5. Ludwig, E.D., Applied Process Design for Chemical and Petrochemical Plants, Vols. 1, 2, 3,Gulf Publishing
6. Biegler, L.T., Grossmann I.E. and Westerberg, Systematic methods of chemical process design, Prentice Hall Inc., 1997.
7. Smith, R., Chemical process design, McGraw Hill Inc. 1995

Paper Name: **Refinery and Petrochemicals**	**L**	**T**	**P**	**Credit**
Paper Code: **MChE 214 (Program Specific Elective - IV)**	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:

Energy Resources & Utilization, Chemical Process Technology, Mass Transfer, Chemical Reaction Engineering at undergraduate level

Course Objectives:

1. To familiarize the students on the global situation of petroleum refining and petrochemicals.

2. To teach the students on various petroleum refining processes along with refinery safety and hazard issues.
3. To teach the students on commercial production of petrochemicals with safety aspects.
4. To teach the students on commercial production of petrochemicals with safety issues.

Course outcomes:

Students completing the course will be able to:

CO1	Understand therole of petroleum as energy source in India as well as World	Understand
CO2	Apply operating processes for petroleum oil refinery as well as safety aspects	Apply
CO3	Apply operating processes for production of petrochemicals as well as safety aspects.	Apply
CO4	Apply operating processes for production of polymers as well as safety aspects.	Apply

Course Contents:

Module I **(No. of classes: 13)**

Petroleum economy: national and global scenarios, Petroleum - crude and its specification and classification. Current and future trends of petroleum refining in India.

Processing of Crude Petroleum – Atmospheric distillation and Vacuum distillation, column control schemes, detailed process description; Conventional thermal cracking; Coking/Delayed Coking and Decoking. Catalytic conversion processes – fluid catalytic cracking with special reference to FCC reactions, thermodynamics of FCC Reactions, catalyst and reactor design configurations, process description. Hydroconversion: hydro-treating, hydrodesulphurization and hydro-cracking; Catalytic Reforming & Isomerization: process, reactions, catalyst, reactor design configuration; Isomerization.

Module II **(No. of classes: 13)**

Alkylation and Polymerization. Lube oil – processing and blending, solvent de-asphalting, solvent de-waxing. Product blending or Production of finished petroleum goods like, LPG, Kerosene, Petrol, Diesel, Lubricating Oil, Bitumen. Supporting processes for refinery.

Acid Gas processing and mercaptans removal: Absorption of acid gases – physical and chemical solvents, Membrane absorption; Sulfur recovery process – Claus Process, SCOT process, Mercaptan removal.

Additive production from refinery feed stock Cost estimation and economic evaluation. Refinery planning, Product scheduling and Optimization. Flare – design and operation.

Refinery Safety Procedures: Hazards in refinery, Accident prevention measures, Hazard Analysis, Safety considerations in plant layout.

Module III **(No. of classes: 13)**

Brief history and survey of Indian petrochemical industry; Feedstocks used in petrochemical industry.

Petrochemicals on the basis of carbon number and their applications. Commercial production, process and plant descriptions, design and safety aspects of (i) Non-hydrcarbon intermediate (synthesis gas) and its production.(ii) Chemicals based on synthesis gas: methanol, oxo aldehydes and alcohols, ethylene glycol, (iii) Hydrochlorination of acetylene to vinyl chloride, balanced vinyl chloride from ethylene, ethylbenzene, (iv) Aromatics from petrochemical feed stocks.

Module IV **(No. of classes: 13)**

Commercial production, process and plant descriptions, design and safety aspects on -

(a) Chemicals from propane, chemicals from propylene.

(b) Isobutene and its derivatives, butanol.

Fundamentals of polymer chemistry, Commercial productions of different monomers and respective polymers (such as elastomers, polyamides, polyesters, polyurethanes) – process and plant description, design and safety aspects.

Suggested Text/Reference Books:

1. Prasad R., Petroleum Refining Technology, Khanna Publishers, New Delhi, 2000.
2. Gary J.H., Handwerk G.H., Kaiser M.J., Petroleum Refining Technology and Economics, 5th Ed. CRC Press, New York, 2007.
3. Hobson G.D., Pohl W., Modern Petroleum Technology, 6th Ed. Wiley, New York, 2000.
4. Nelson W.L., Petroleum Refinery Engineering, McGraw-Hill Publishing Company Ltd, 1985.
5. Rao B.K.B., A Text on Petrochemicals, Khanna Publishers, New Delhi, 2008.
6. Raychaudhuri U., Fundamentals of Petroleum and Petrochemical Engineering, CRC Press, 2018.
7. Meyers R.A., Handbook of Petroleum Refining Processes, 2nd Ed. McGraw-Hill, New York, 1996.
8. Moulijin J.A., Makkee M., Van Diepen A., Chemical Process Technology, Wiley, New York, 2001.
9. Mall I.D., Petrochemical Process Technology, Macmillan India Ltd, New Delhi, 2007.
10. Matar S., Hatch L.F., Chemistry of Petrochemical Processes, Gulf Publishing Company, Houston, Texas, 2000.

Paper Name: Advanced Chemical Engineering Laboratory	**L**	**T**	**P**	**Credit**
Paper Code: MChE 205 (Laboratory – II)	**0**	**0**	**4**	**2**
Total Contact Hour = 52				

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td rowspan="3">Continuous Assessment</td><td>Assessment of all Practical sessions</td><td>50</td><td rowspan="3">60</td></tr>
<tr><td>Active participation in routine practical classes</td><td>05</td></tr>
<tr><td>Overall conduct, attendance, manners, skills etc.</td><td>05</td></tr>
<tr><td rowspan="4">End Semester Examination</td><td>Examination shall be of 4 (four) hours duration and shall jointly be conducted by two Internal Examiners.</td><td></td><td rowspan="4">40</td></tr>
<tr><td>Practical Notebook</td><td>10</td></tr>
<tr><td>Experimental Study</td><td>20</td></tr>
<tr><td>Viva-Voce</td><td>10</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">100</td></tr>
</table>

Pre-requisite:

Fluid Flow, Heat and Mass Transfer, Reaction Engineering, Process Control

Course Objectives:

1. To provide through understanding of Reaction Engineering.
2. To design reactor and identity type of reactor by suiting chemical kinetics and using information from thermodynamics, heat and mass transfer economics.
3. Characteristics of a fluidized bed reactor
4. Understanding of Advanced Process Control.

Course outcomes:

Students completing the course will be able to:

CO1	Students will able to know the solid-liquid, liquid –liquid reactions.
CO2	Students will be able to know the compact heat exchanger
CO3	Students will be able to know the membrane separation technique(s)
CO4	Students will be able to know the computer interfaced process control strategy

Course Contents:

List of Laboratory Experiments:

[At least six Experiments shall be conducted]

1. Determination of Effective thermal conductivity (ETC) in granular material
2. Plate Type Heat Exchanger
3. Kinetics for solid catalyzed esterification reaction in a batch reactor
4. Ultrasonic cavitation based reactions
5. Corrosion characteristics of a metal in a given electrolyte
6. Membrane Separation for water purification
7. Adsorption isotherm and kinetics study with nano adsorbents
8. Cascade Control in a PC-PLC based control system
9. Ratio Control in a PC-PLC based control system

Suggested Text/Reference Books:

5. Heat& Mass transfer Text/Reference books
6. Reaction Engineering books
7. Advanced Process Control books
8. Laboratory Manual

Paper Name: Mini Project	**L**	**T**	**P**	**Credit**
Paper Code: MChE 206	**0**	**0**	**4**	**2**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Continuous Assessment	Sessional Work/Assessment by the Supervisor(s)	60	
End Semester Examination	A student has to present a Seminar at the Examination. The Examination shall be conducted by a Board of Examiners consisting at least one Internal Examiner and one External Examiner.		
	Report	10	40
	Presentation	15	
	Viva Voce.	15	
Total			**100**

- Each student will be allotted the topic of the Mini Project at the beginning of the **Semester–II**.
- Each student will have to carry out the Mini Project under the supervision of a faculty member /faculty members of the Department.
- A student has to submit a Report (three copies) certified and approved by the Supervisor(s) at least 10 days prior to the commencement of the End Semester Examination.

Pre-requisite:
Attended all the courses as required in Semester–I

Course Objectives:
To familiarize the students prior to taking up Dissertation.

Course outcomes:
Students completing the course will be able to:

CO1	Review a set of published literature on a given topic
CO2	Summarise the essence of the available literature on the given topic
CO3	Find out the gap in the available work on the given topic and to identify the need of research
CO4	Present the observations and summary of the reviewed literature in report and seminar forms.

Course Contents:
Any topic related to the field of Chemical Engineering/allied subject(s) of Chemical Engineering.

Paper Name: Constitution of India	**L**	**T**	**P**	**Credit**
Paper Code: MChE 207 (Audit # 2)	**2**	**0**	**0**	**0**
Total Contact Hour = 28				

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td rowspan="3">Internal Assessment</td><td>Sessional Assessments through Class Test/ Assignments/ Flipped-classroom technique</td><td>20</td><td rowspan="3">30</td></tr>
<tr><td>Active participation in routine classes</td><td>5</td></tr>
<tr><td>Overall conduct, attendance, manners, skills etc.</td><td>5</td></tr>
<tr><td colspan="3">End Semester Examination
• The students only need to pass this paper, however no Grade will be awarded. To pass this paper, a student has to obtain either 50 marks or above out of 100. In the Mark/Grade-Sheet, only QUALIFIED(Q)/ FAIL (F) will be mentioned against this paper. In case of FAIL(F), the student has to be re-evaluated as in the Regulations for 2-year 4-semester M. Tech. Program.</td><td>70</td></tr>
<tr><td colspan="3">Total</td><td>100</td></tr>
</table>

Pre-requisite:
Nothing specific.

Course Objectives:

1. To make students understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
2. To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
3. To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

Course outcomes:

Students completing the course will be able to:

CO1	Describe historical background of the constitution making and the philosophy of Constitution of India.
CO2	Describe the constitutional rights emphasizing the value of the fundamental rights and duties for becoming good citizen of India.
CO3	Analyze the constitutional powers and functions as well as the decentralization of power among central, state, district and local self government.
CO4	Analyze the constitutional powers and functions as well as the decentralization of power among central, state, district and local self government.

Course Contents:

Module I **(No. of classes: 7)**

History of Making of the Indian Constitution: History, Drafting Committee, (Composition & Working).

Philosophy of the Indian Constitution: Preamble, Salient Features.

Module II **(No. of classes: 7)**

Constitutional Rights: Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

Organs of Governance: Parliament, Composition, Qualifications and Disqualifications.

Module III **(No. of classes: 7)**

Constitutional Powers and Functions: Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications.

Local Administration – District Level: District's Administration head: Role and Importance, Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation.

Module IV **(No. of classes: 7)**

Local Administration – Panchyat/Block/Village Level: Pachayati Raj: Introduction, PRI: Zila Pachayat. Elected officials and their roles, CEO Zila Pachayat: Position and role. Block level: Organizational Hierarchy (Different departments), Village level: Role of Elected and Appointed officials, Importance of grass root democracy.

Election Commission: Election Commission: Role and Functioning; Chief Election Commissioner and Election Commissioners; State Election Commission: Role and Functioning; Institute and Bodies for the welfare of SC/ST/OBC and women.

Suggested Texts/Reference Books:

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Busi S. N., Dr. B.R. Ambedkar Framing of Indian Constitution, 1st Ed. Ava Publications.2015.
3. Jain M. P., Indian Constitution Law, 8th Ed. Lexis Nexis. 2018.
4. Basu D.D., Introduction to the Constitution of India, 24th Ed. Lexis Nexis. 2020.

SEMESTER # III

For conducting **-End Semester Examination** (applicable to all Theory papers, including Electives):

- The Examination will be of 3 hours duration.
- There will be at least 2 (two) paper-setters (internal) for each theoretical paper for End Semester Examination and the answer scripts will be examined by at least two Examiners (Internal).
- Each question paper shall consist of 4 (four) compulsory sections giving equal weightage to each individual module of the syllabus. Questions shall be set taking all the course outcomes specified for the paper.
- There will be no external paper setter or External Examiner for theoretical papers.

Paper Name: Design of Experiments and Parameter Estimation	**L**	**T**	**P**	**Credit**
Paper Code: MChE 301 (Program Specific Elective – V)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments throughClass Test/ Assignments	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisite:

Mathematics and statistics at under graduate level

Course Objectives:

1. Use statistics in experimentation.
2. Understand the important role of experimentation in new product design, manufacturing process development, and process improvement.
3. Analyze the results from such investigations to obtain conclusions; become familiar methodologies that can be used in conjunction with experimental designs for robustness and optimization.

Course outcomes:

Students completing the course will be able to:

CO1	Plan experiments for a critical comparison of outputs.
CO2	Include statistical approach to propose hypothesis from experimental data.
CO3	Implement factorial and randomized sampling from experiments.
CO4	Estimate parameters by multi-dimensional optimization.

Course Contents:

Module I **(No. of classes: 13)**

Design of experiments: Basic concepts, Bias and confounding, controlling bias, causation, Examples. **Random Variables**: Introduction to discrete and continuous random variables, quantify spread and central tendencies of discrete and continuous random variables.

Module II **(No. of classes: 13)**

Exploratory Data Analysis: Variable types, Displaying the distribution, mean variance and typical spread, quartiles and unusual spread, multivariate data: finding relations. **Probability**: Definition of a random variable, expectation, percentiles, common distributions such as the binomial, Poisson and normal distributions.

Module III **(No. of classes: 13)**

Point Estimation: Estimators as random variables, sample mean and the central limit theorem, normal approximations, assessing normality. **Interval Estimation**: Confidence intervals for the mean when the variance is known, confidence interval for the mean when the variance is unknown, confidence intervals for a single proportion, sample size, Student distribution. **Hypothesis Testing**: Hypothesis testing for a mean or proportion, testing the equality of two means assuming equal variances, testing the equality of two means with unequal variances, comparison of two proportions.

Module IV **(No. of classes: 13)**

Linear Regression analysis: The linear regression model, Parameter estimation, accuracy of the coefficient estimates, checking the model, multiple linear regression, confidence and prediction intervals, potential issues, high leverage points, outliers. Matrix approach to linear regression, Variance-Covariance matrix, ANOVA in regression analysis, quantifying regression fits of experimental data, Extra sum of squares approach, confidence intervals on regression coefficients,
lack of fit analysis. **Response Surface Methodology**: Method of steepest ascent, first and second order models, identification of optimal process conditions.

Suggested Text/Reference Books:

1. Hanneman R.A., Kposowa A.J., Riddle M.D., Basic Statistics for Social Research. John Wiley & Sons. 2012.
2. Brown R.B., Saunders M., Dealing with Statistics: What You Need to Know. McGraw-Hill Education. 2007.
3. Cowles, M., Statistics in Psychology: An Historical Perspective, 2^{nd} Ed. Psychology Press. 2000.

Paper Name: **Computer Aided Design**	L	T	P	Credit
Paper Code: MChE 311 (Program Specific Elective-V)	3	1	0	4
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:

Thermodynamics, Reaction Engineering, Mass Transfer, Heat Transfer, Mathematics

Course Objectives:

1. To understand importance and applications of CAD in the field of chemical engineering
2. To understand the basic structure and components of CAD software
3. To understand the underlying thermodynamic and physical principles
4. To give insight into the approaches used in the simulation of flow sheets
5. To understand flow charts, computer languages and numerical methods used for writing algorithms

Course outcomes:

Students completing the course will be able to

CO1	Explain the application of CAD in Chemical Engineering	Understand
CO2	Identify the various mathematical method used in CAD	Understand
CO3	Application of different thermodynamics properties to prepare computer Aided Flow Sheet Synthesis	Apply
CO4	Design of different process equipment (Evaporators; Distillation columns; Reactors, Adsorption columns) using CAD	Apply

Course Contents:

Module I **(No. of classes: 13)**

Introduction to CAD, Scope and applications in chemical Engineering, Mathematical methods used in flow sheeting and simulation, Introduction to solution methods for linear and non-linear algebraic equations, solving one equation one unknown, solution methods for linear and nonlinear equations, general approach for solving sets of differential equations, solving sets of sparse non-linear equations.

Module II **(No. of classes: 13)**

Physical properties of compounds, Thermodynamic properties of gases and binary mixtures, Viscosity, Vapour pressure, Latent heat, Bubble point and drew point calculation, phase equilibria, Vapour-liquid equilibria, Liquid phase activity coefficients, K-values, Liquid phase activity coefficients, K-values, Liquid-Liquid equilibria, Gas solutions.

Module III **(No. of classes: 13)**

Computer aided Design of Equipment: Design of Shell and Tube Heat exchangers; Design of Evaporators; Design of Distillation columns; Design of Reactors, Design of adsorption columns. Distillation columns (specific attention to multi components systems. Heat exchangers)

Module IV **(No. of classes: 13)**

Computerized physical property systems – physical property calculations, degrees of freedom in process design, degrees of freedom for a unit, degrees of freedom in a flow sheet, steady state flowsheeting and process design, approach to flow sheeting systems, Numerical recipes in Linear and nonlinear equations, Ordinary and partial differential equations, Absorption and distillation columns,Introduction to special software for steady and dynamic simulation of Chemical engineering systems. Introduction to various commercial design software and optimizers used in field of chemical engineering.

Suggested Text/Reference Books:

1. Douglas James M., "Conceptual design of Chemical Processes", McGraw -Hill Book Company, New York, 1988

2. Remirez, W.F. - " Computational methods for Process Simulations ", Butterworths, New York, 1989
3. Sinnott R.K. "Chemical Engineering", Volume 6, Pergamon Press, New York, 1989
4. Westerberg A.W., et al, "Process Flow Sheeting", Cambridge University Press
5. Biegler Lorenz T, et al, "Systematic method of Chemical Process Design", Prentice Hall
6. Crowe C.M., et al, "Chemical Plant Simulation-An Introduction to Computer Aided Steady State Analysis", Prentice Hall
7. Anil Kumar, "Chemical Process Synthesis and Engineering Design",TMH,1981

Paper Name: **Composite Materials**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 302 (Open Elective)	**3**	**1**	**0**	**4**
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite:
Fundamental knowledge of Strength of Materials, Solid Mechanics.

Course Objectives:
1. Gain a comprehensive introduction to composite materials, their types, and the enhancement of properties in comparison to standard materials, including an overview of their applications in various industries.
2. Learn about different reinforcement and matrix materials, their properties, interface and bonding mechanisms, and the mechanical behavior of composites under various conditions.
3. Acquire knowledge of various manufacturing techniques for composites, including advanced methods and characterization/testing processes, to understand the production of metal, polymer, and ceramic matrix composites.
4. Study the structural, electrical, electromagnetic, dielectric, optical, and magnetic applications of composite materials, focusing on their role in modern technological advancements and specialized applications.

Course outcomes:
Students completing the course will be able to

CO1	Fundamental understanding of composite materials includes knowledge of their primary components and various types.	Understand
CO2	Understanding of composite materials for structural, electrical, electromagnetic, dielectric, optical, and magnetic applications	Understand
CO3	Explores the fundamentals of reinforcements and matrix materials utilized in composite structures.	Apply
CO4	Acquire the concept ofprocessing methods for matrix composites manufacturing, including their benefits and drawbacks	Apply

Course Contents:

Module I **(No. of classes: 13)**

Introduction and overview of composite materials, Enhancement of properties, Types of Composite Materials, Carbon Fibre composites, Properties of composites in comparison with standard materials, Applications of metal, ceramic and polymer matrix composites.

Module II **(No. of classes: 13)**

Reinforcement Materials, Matrix Materials, Types of reinforcements, Interface and Bonding in Composites, Properties and applications of whiskers, particle reinforcements, Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures. Iso-strain and Iso-stress conditions.

Module III **(No. of classes: 13)**

Manufacturing Techniques for Composites, Advanced Manufacturing Processes, Characterization and Testing of Composites, Manufacturing methods : Hand and spray lay - up, injection moulding, resin injection, filament winding, pultrusion, centrifugal casting and prepregs. Manufacturing of Metal Matrix Composites(MMC), Manufacturing of Polymer Matrix Composites(PMC), Ceramic matrix composites(CMC).

Module IV **(No. of classes: 13)**

Structural Composites: Cement matrix composites, Steel Reinforced Concrete, Pre-stressed concrete, Thermal Control, Vibration reduction. Composite materials for Electrical, Electromagnetic and Dielectric applications, Microelectronics and Resistance heating, Electrical insulation, capacitors, piezoelectric, ferroelectric functions, electromagnetic windows, solid electrolytes, microwave switching. Composite materials for optical and magnetic applications

Suggested Text/Reference Books:

1. Principles of Materials Science and Engineering, William F. Smith, Third Edition, 2002,McGraw-Hill
2. Composite Materials: Engineering and Science, Matthews F.L., and Rawlings R. D., 1999, Woodhead Publishing Limited, Cambridge England.
3. The nature and Properties of Engg. Materials, Jastrzebaski, John Wiley & Sons, New York
4. Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.
5. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.
6. Composite Materials Handbook, Mel M. Schwartz (R), 2nd Edition, 1992, McGraw-Hill, New York.
7. Mechanics of Composite Materials, Autar K. Kaw, 1997, CRC Press, New York.
8. Fundamentals of Fiber Reinforced Composite Materials, A. R. Bunsell, J. Renard, 2005,IOP Publishing Ltd.

Paper Name: Waste to Energy	L	T	P	Credit
Paper Code: MChE 312 (Open Elective)	3	1	0	4
Total Contact Hour = 52				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite:
Energy resources and their utilization, Reaction Engineering, Environmental Science

Course Objectives:
1. To enable students to understand of the concept of Waste to Energy.
2. To familiarize students to link legal, technical and management principles for production of energy form waste.
3. To learn about the best available technologies for waste to energy.
4. To facilitate the students in developing skills in the decision making process.

Course outcomes:
Students completing the course will be able to

CO1	Demonstrate biomass gasification.
CO2	Analyze biomass conversion and biomass combustion.
CO3	Apply the knowledge of energy generation from wastes.
CO4	Apply biogas plant operation and MSW to energy under Indian conditions

Course Contents:

Module I **(No. of classes: 13)**
Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste, Municipal Solid Waste (MSW);Design, operation and applications of conversion devices – Incinerators, gasifier, digesters. Biomass Pyrolysis: Pyrolysis – Types, slow fast; Manufacture of charcoal – Methods, Yields and application; Manufacture of pyrolytic oils and gases, yields and applications.

Module II **(No. of classes: 13)**
Biochemical Conversion – Energy production from organic waste through anaerobic digestion and fermentation-types, methods, product yields and application.

Thermo-chemical Conversion – Combustion, Incineration and heat recovery, Pyrolysis, Gasification and other newer technologies-types, methods, product yields and application.

Module III **(No. of classes: 13)**
Biomass resources and their classification, Biomass conversion processes - Thermo chemical conversion & Direct combustion; biomass gasification, pyrolysis and liquefaction, biochemical conversion, anaerobic digestion; Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation, Operation of all the above biomass combustors. Biomass energy programme in India.

Module IV **(No. of classes: 13)**

Biogas: Properties of biogas (Calorific value and composition), Biogas plant technology and status, Bio-energy system, Detailed design, constructional and operational features, Types of biogas Plants, Applications. Option for MSW to energy under Indian conditions – Different approaches to produce energy from MSW, Design and operating features, Applicability; Initiatives of Government of India.

Suggested Text/Reference Books:

1. Desai A.V., Non Conventional Energy, Wiley Eastern Ltd. 1990.
2. Khandelwal K.C., Mahdi S. S., Biogas Technology - A Practical Hand Book, Vol. I & II, Tata McGraw Hill Publishing Co. Ltd. 1983.
3. Challal D. S., Food, Feed and Fuel from Biomass, IBH Publishing Co. Pvt. Ltd. 1991.
4. Wereko-Brobby C.Y., Hagan E. B., Biomass Conversion and Technology, John Wiley & Sons. 1996.
5. Municipal Solid Waste Management Manual, CPHEEO, 2016
6. Report of the task Force on Waste to Energy, Niti Ayog (Formerly Planning Commission) 2014.
7. Gazette Notification on Waste Management Rules 2016.

Paper Name: **Dissertation Phase – I**	**L**	**T**	**P**	**Credit**
Paper Code: MChE 303 (Dissertation)	**0**	**0**	**18**	**12**
Total Contact Hour = throughout the Semester				

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td>Continuous Assessment</td><td>Assessment on the overall performance of the candidate in identifying the problem by the Supervisor(s)</td><td colspan="2">150</td></tr>
<tr><td rowspan="4">End Semester Examination</td><td>A student has to present a Seminar at the Examination. The Examination shall be conducted by a Board of Examiners consisting at least two Internal Examiners including the Supervisors(s) and one External Examiner.</td><td colspan="2"></td></tr>
<tr><td>Dissertation Report</td><td>50</td><td rowspan="3">150</td></tr>
<tr><td>Presentation</td><td>50</td></tr>
<tr><td>Viva Voce Examination</td><td>50</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">300</td></tr>
</table>

- A research problem shall be assigned to a candidate at the beginning of Semester – III.
- The student shall work in this phase in identifying the problem based on literature survey, formulation of the problem and proposal of solutions. All these shall be appropriately included along with recording the continuous progress in the Foundation/Dissertation Phase – I Report.
- At the end of the Semester III, a student has to submit 3 (three) type-written copies of the Foundation/Dissertation Phase – I Report through the Supervisor(s) [at least 10 (ten) days prior to the commencement of the End Semester Examination] and defend the same through a Seminar presentation at the End Semester Examination in front of Board of Examiners duly constituted by the Post Graduate Board of Studies.

Pre-requisite:
Clearing all the required Credits in Semester–I & Semester–II.

Course Objectives:
1. Ability to synthesize knowledge and skills previously gained and applied to an in-depth study and execution of new technical problem.
2. Capable to select from different methodologies, methods and forms of analysis to produce a suitable research design, and justify their design.
3. Ability to present the findings of their technical solution in a written report.
4. Presenting the work in International/ National conference or reputed journals.

Course outcomes:
Students completing the course will be able to:

CO1	Identify research gap in the existing literature in an area
CO2	Formulate a research problem and set its aim and objectives
CO3	Chalk out a plan of research with methodology to follow
CO4	Start preliminary experiments and design experiments

SEMESTER # IV

Paper Name: **Dissertation Phase – II**	L	T	P	Credit
Paper Code: MChE 401 (Dissertation)	**0**	**0**	**30**	**20**
Total Contact Hour = throughout the Semester				

Evaluation:

Type of Evaluation		**Marks**	
Continuous Assessment	Assessment on the overall performance of the candidate by the Supervisor(s).	250	
End Semester Examination	A student has to present a Seminar at the Examination. The Examination shall be conducted by a Board of Examiners consisting at least two Internal Examiners including the Supervisors(s) and one External Examiner.		
	Dissertation Report	100	250
	Presentation	100	
	Viva Voce Examination	50	
Total		**500**	

During Dissertation Phase – II, student is expected to complete the proposed work as per the schedule. Accomplished results/ contributions/innovations shall be encouraged for publication in reputed journals/ presentation at conferences.

The complete report of Dissertation Phase – II should contain the works presented under both Dissertation Phase – I and Dissertation Phase – II.

At the end of the Semester IV, a student has to submit 3 (three) type-written copies of the complete report including Dissertation Phase – I through the Supervisor(s) [at least 10 (ten) days prior to the commencement of the End Semester Examination] and defend the same through a Seminar presentation at the End Semester Examination in front of Board of Examiners duly constituted by the Post Graduate Board of Studies.

Pre-requisite:
Satisfactory completion of Dissertation Phase–I in Semester–III of the program.

Course Objectives:

1. Ability to synthesize knowledge and skills previously gained and applied to an in-depth study and execution of new technical problem.
2. Capable to select from different methodologies, methods and forms of analysis to produce a suitable research design, and justify their design.
3. Ability to present the findings of their technical solution in a written report.
4. Presenting the work in International/ National conference or reputed journals.

Course outcomes:
Students completing the course will be able to:

CO1	Fix the methodology and experiments as designed before
CO2	Work to achieve the aim and objectives and organize the results
CO3	Present the research findings with discussion in the form of report and seminar.
CO4	Prepare manuscript for publication in peer-reviewed journals

End of the Program