M. TECH. SYLLABUS

Department of Chemical Engineering

Faculty of Technology

Dharmsinh Desai University, Nadiad – 387 001, Gujarat, India.

(2021-2022)

https://www.ddu.ac.in

TEACHING SCHEME FOR THE COURSE DEPLOMA

CHEMICAL ENGINEERING

L – Lecture **T – Tutorial** **P – Practical**
Th. – Theory **Ext - External** **S – Sessional**
TW – Term Work **Teaching Scheme – hr/week**

SEMESTER-I

Subject Code	Subject Name	Teaching Scheme			Exam Scheme (Marks)				Credit
		L	T	P	Th.	S	TW	Total	
MC141	Advanced Transport Phenomena	3	1	0	60	40	50	150	5
MC142	Advanced Chemical Reaction Engineering	3	1	0	60	40	50	150	5
MC143	Particulate Technology	3	1	0	60	40	0	100	4
MC144	Process Modeling and Identification	3	1	0	60	40	50	150	5
MC146	Seminar	0	0	4	0	0	50	50	1
MC147	Introduction to Environmental Engineering	3	1	0	60	40	50	150	5
	Total	**15**	**5**	**4**	**300**	**200**	**250**	**750**	**25**

SEMESTER-II

Subject Code	Subject Name	Teaching Scheme			Exam Scheme (Marks)				Credit
		L	T	P	Th.	S	TW	Total	
MC231	Optimization Techniques	3	1	0	60	40	50	150	5
MC232	Advanced Chemical Engineering Thermodynamics	3	1	0	60	40	0	100	4
MC233	Computational and Numerical Methods	3	1	0	60	40	50	150	5
MC236	Seminar	0	0	4	0	0	50	50	1
MC237	Process Synthesis	3	1	0	60	40	50	150	5
MC238	New Separation Techniques	3	1	0	60	40	50	150	5
	Total	**15**	**5**	**0**	**300**	**200**	**250**	**750**	**25**

SEMESTER-III

Subject Code	Subject Name	Teaching Scheme			Exam Scheme (Marks)					Credit
		L	T	P	Th.	S	P	TW	Total	
MCxxx	Research Methodology and Professional Communication	3	1	0	60	40	0	50	150	5
MC311	Project Dissertation (Part-I)	0	0	0	0	0	225	125	350	8
MC312	Seminar	0	0	4	0	0	0	50	50	2
	Total	**3**	**1**	**4**	**60**	**40**	**225**	**225**	**550**	**15**

SEMESTER-IV

Subject Code	Subject Name	Teaching Scheme			Exam Scheme (Marks)					Credit
		L	T	P	Th.	S	P	TW	Total	
MC232	Project Dissertation (Part-I)	0	0	0	0	0	300	150	450	13
MC236	Seminar	0	0	4	0	0	0	50	50	2
	Total	**0**	**0**	**4**	**0**	**0**	**300**	**200**	**500**	**15**

SEMESTER-I

Subject Code	Subject Name	Teaching Scheme			Exam Scheme (Marks)				Credit
		L	T	P	Th.	S	TW	Total	
MC141	Advanced Transport Phenomena	3	1	0	60	40	50	150	5
MC142	Advanced Chemical Reaction Engineering	3	1	0	60	40	50	150	5
MC143	Particulate Technology	3	1	0	60	40	0	100	4
MC144	Process Modeling and Identification	3	1	0	60	40	50	150	5
MC146	Seminar	0	0	4	0	0	50	50	1
MC147	Introduction to Environmental Engineering	3	1	0	60	40	50	150	5
	Total	**15**	**5**	**4**	**300**	**200**	**250**	**750**	**25**

M. TECH. – SEMESTER-I
ADVANCED TRANSPORT PHENOMENA (MC141)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	**T**	**P**	**Total**	**Ext**	**S**	**P**	**TW**	**Total**
3	**1**	**0**	**4**	**60**	**40**	**0**	**50**	**150**

A. COURSE OVERVIEW

Motivation: Transport phenomena is the subject which deals with the different transport processes such as momentum, energy and mass, ubiquitous in industry as well as in nature.

Objectives:

- To acquire knowledge on momentum, heat and mass transfer in Chemical engineeringsystems and their analogous behavior.
- Momentum, heat and mass transfer are taught together due to the underlying similarities ofthe mathematics tools and molecular mechanisms describing such processes.
- The students will be made aware of the core scientific connections and will be encouraged to solve problems based on relevant analogies

Learning Outcomes: On successful completion of course, students will be able to -

- Identify transport properties and analyze the mechanism of momentum, energy and mass transport.
- Apply conservation laws to formulate differential form of equations of change for mass, momentum and heat transfer problems.
- Solve linear partial differential equations along with appropriate boundary conditions to get the velocity, temperature and concentration profiles of different engineering problems.
- Recognize non-Newtonian fluids and apply appropriate models to solve them

B. DETAILED SYLLABUS

	TOPICS
1.	**Transport by Molecular motion -** Momentum, energy and mass transport by molecular level
2.	**Transport in turbulent flow and eddy transport properties –** Turbulent momentum, energy and mass transport
3.	**Transport across the phase boundaries -** Friction factor, Heat transfer co-efficient and mass transfer co-efficient with use of empirical correlation
4.	**Transport in large system -** Macroscopic balance in pieces of equipment or parts thereof for isothermal, non-isothermal and mixtures
5.	**Transport by other mechanism -** Momentum transport in polymeric liquid, Energy transport by radiation and mass transport in multi component system.

C. TEXT BOOK

1. Bird R B, Stewart W E and Light fort R N, “Transport Phenomena”, John Wiley and Sons (2002)

D. REFERENCE BOOK

1. Welty J R , Wilson R E and Wicks C E , “Fundamentals of Momentum , Heat and Mass Transfer”, 4th ed, John Wiley and Sons (2001).
2. John C Slattery, “Momentum, Energy and Mass transfer in continua”, McGraw Hill, Co. (1972)
3. Bennet C U and Myers J E, “Momentum, Heat and Mass Transfer” Tata McGraw Hill Publishing Co. (1975)
4. Robert S Brodkey and Harry C Hersing, “Transport Phenomena a Unified approach” McGraw Hill Book Co. (1988)

E. COURSE MATRIX

COs	CO1	CO2	CO3	CO4	CO5	CO6	AVG
Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems	2	3	3	3	3	2	**2.7**
Problem Analysis: Identify, formulate, review research literature, and analyses complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.	2	3	3	3	2	2	**2.5**
Design/Development of Solutions: Design solutionsfor complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	1	2	3	2	3	2	**2.2**
Conduct Investigations of Complex Problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions for complex problems	2	2	2	3	2	2	**2.2**
Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.	2	2	2	2	3	2	**2.2**
The Engineer and Society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	2	2	2	2	2	2	**2**
Environment and Sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	3	2	2	2	2	2	**2.2**
Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms ofthe engineering practice.	1	2	2	2	2	2	**1.8**
Individual and Team Work: Function effectively as an individual, and as a member or leader in diverseteams, and in multidisciplinary settings.	2	2	2	2	2	2	**2**

Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations,and give and receive clear instructions.	1	2	2	2	2	2	**1.8**
Project Management and Finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	1	2	2	2	2	2	**1.8**
Life-long Learning: Recognize the need for, andhave the preparation and ability to engage in independent and lifelong learning in the broadestcontext of technological change.	2	2	2	2	2	2	**2**

M. TECH. – SEMESTER-I
ADVANCED CHEMICAL REACTION ENGINEERING (MC142)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	**T**	**P**	**Total**	**Ext**	**S**	**P**	**TW**	**Total**
3	**1**	**0**	**4**	**60**	**40**	**0**	**50**	**150**

A. COURSE OVERVIEW

Non-isothermal reactor design under steady state and unsteady state conditions, non-ideal flow modelling in real reactors, catalytic and non-catalytic heterogeneous reactions and reactor design, application of MATLAB for solving reaction engineering problems.

Objectives:

To introduce students to advanced topics of chemical reaction engineering, such as non-isothermal reactor design, multi-phase reactions and reactor design, catalytic reactions and reactor design and application of software for solving the associated problems of advanced topics of chemical reaction engineering

B. DETAILED SYLLABUS

	TOPICS	COs
1.	**Non-isothermal reactor design** Energy balance for CSTR/PFR/Batch reactor under adiabatic and non-adiabatic conditions, multiple steady states in CSTR/PFR, use of MATLAB for design/analysis of non-isothermal reactors.	**CO1 to CO6**
2.	**Non-ideal flow and mathematical modeling** Zero parameter, one parameter and two parameter modeling of non-ideal flow in reactors	**CO1 to CO6**
3.	**Fluid-fluid heterogeneous reactor design** Gas-liquid and liquid-liquid heterogeneous reactions, mathematicalmodels, reactor design for fluid-fluid heterogeneous reactions	**CO1 to CO6**
4.	**Fluid-solid heterogeneous reactor design** Gas-solid and liquid-solid heterogeneous reactions, mathematicalmodels, reactor design for fluid-solid heterogeneous reactions	**CO1 to CO6**
5.	**Catalytic reactors** Solid catalyzed reactions and reactor design, mathematical models andreactor design	**CO1 to CO6**

C. SEMINAR AND TERM WORK

A seminar topic of relevance to advanced reaction engineering is assigned to the student that may involve simulation and students are supposed to present the seminar work and submit theseminar project at the end the semester

D. TEXT BOOK

1. Levenspiel, O., Chemical Reaction Engineering, 3rd edition, Wiley Eastern Pvt. Ltd
2. Fogler, H. S., Elements of Chemical Reaction Engineering, Prentice-Hall.

E. REFERENCE BOOK

1. Smith, J. M., Chemical Engineering Kinetics, 3rd Edition, Mc-Graw Hill Publication

F. COURSE OUTCOME

COs	Skills	Statement
CO1	**Understanding**	**Remember** and **understand** the non-isothermal reactor design, non-ideal flow modeling, heterogeneous catalytic and non-catalytic reactions and reactor design
CO2	**Analyzing**	Carry out the **analysis** of non-isothermal reactors and heterogeneous reactors
CO3	**Applying**	**Apply** software such as MATLAB, for design and analysis of non-isothermal reactors and heterogeneous reactors.
CO4	**Evaluating**	**Do critical** evaluation of the non-isothermal reactors and heterogeneousreactors performances using simulations.
CO5	**Creating**	**Design** reactors for non-isothermal conditions and for heterogeneousreactions
CO6	**Remembering evaluating**	**Generate** a MATLAB program for industrial application to carry out steady state and dynamics analysis of non-isothermal reactors and heterogeneous reactors

G. COURSE OUTCOME

	CO1	CO2	CO3	CO4	CO5	CO6	Avg
PO1	2	2	2	3	2	3	2.3
PO2	1	1	3	3	3	3	2.3
PO3	1	2	3	3	3	3	2.5
PO4	1	1	2	3	2	3	2
PO5	0	0	2	3	3	3	1.8
PO6	2	2	3	3	3	3	2.7
PO7	2	3	3	3	3	3	2.8
PO8	1	1	2	2	2	3	1.8
PO9	2	2	3	2	3	3	2.5
PO10	1	2	3	2	2	3	2.2
PO11	2	3	3	2	2	3	2.5
PO12	3	3	3	2	3	3	2.8
PSO 1	3	3	3	3	2	2	2.67
PSO 2	2	2	2	2	2	2	2
PSO 3	3	3	3	3	2	2	2.67
PSO4	3	3	3	3	2	2	2.67

M. TECH. – SEMESTER-I
PARTICULATE TECHNOLOGY (MC143)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	T	P	Total	Ext	S	P	TW	Total
3	1	0	4	60	40	0	0	100

A. COURSE OVERVIEW

This online course is intended as an introduction to particle technology. The topics included have been selected to give coverage of the broad areas of particle technology: particle size analysis packed and fluidized beds, storage and transport (hopper design, pneumatic conveying, standpipes, slurry flow), separation (filtration and gas cyclones), safety (fire and explosion hazards, health hazards). For each of the topics studied, the fundamental science involved is introduced and this is linked, where possible, to industrial practice.

B. DETAILED SYLLABUS

	TOPICS	COs
1.	**Physical properties & characteristic of material**: bulk density, packed density, particulate density, angle of repose, angle of friction, angle of slide, adhesion etc. Particle size measurement techniques. Particulate matter sampling and analysis in ambient air as well as in stationary emission sources. Various air pollution control measures likeESP, bag filters, cyclone separators etc.	CO1 CO2
2.	**Flow through bins:** Flow regimes, mass flow, tunnel flow design of storage vessel, Mohr circle, pressure in bins hoppers and silos, pressure in masses of particles	CO1 CO2
3.	**Fluidization:** flow regimes in fluidized bed, Geldart particle characterization, concept of minimum fluidization velocity, determination of Minimum Fluidization Velocity. Industrial applicationof fluidized bed, Gross behavior of fluidized beds, pressure drop, terminal velocity in fluidized beds, choice of distributor type, Voidage in fluidized beds, transport disengaging height.	CO2 CO3
4.	**Particle oscillation in fluidized bed:** Development of model to account for the phenomenon, analysis of forces acting on a vertical arrayof particle.	CO3 CO4
5.	**Particle segregation in gas fluidized bed:** Mechanism of particle mixing and segregation for binary mixture, effect of particle size density, shape and gas velocity. Bubble dynamics, Onset fluidization and Jet penetration theory. Entrainment phenomena in Fluidization	CO3 CO4
6.	**Pneumatic conveying**: Introduction, Positive and Negative systems, Combined and dual combined systems, pressure drop and rating in pneumatic conveying. Type of feeders and valves.	CO5

C. COURSE OUTCOME

CO	Skills	Statement
CO1	Comprehension	Understand the types particle properties and characteristic for handling of various solids.

CO2	**Comprehension**	Understand standard methods for particulate matter sampling and analysis as well as various air pollution control measures for particulate matter.
CO3	**Application**	Fluidization techniques and determination of various operating parameters of fluidization operation.
CO4	**Analysis**	Development of fluidization models to account for various phenomenon.
CO5	**Application**	Pneumatic conveying for utilization in various industries for effective handling and conveying of solids.

D. COURSE OUTCOME

	CO1	CO2	CO3	CO4	CO5	Avg
PO1	2	3	3	3	3	2.8
PO2	3	3	3	3	3	3
PO3	2	3	3	3	3	2.8
PO4	3	2	3	3	3	2.8
PO5	3	2	3	3	3	2.8
PO6	2	3	3	3	3	2.8
PO7	3	3	3	3	3	3
PO8	2	3	3	3	3	2.8
PO9	2	3	3	3	3	2.8
PO10	2	3	3	3	3	2.8
PO11	3	2	3	3	3	2.8
PO12	3	2	3	3	3	2.8
PSO 1	2	3	3	3	3	2.8
PSO 2	2	3	3	3	3	2.8
PSO 3	2	3	3	3	3	2.8
PSO4	3	3	3	3	3	3

M. TECH. – SEMESTER-I
PROCESS MODELING AND IDENTIFICATION (MC144)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	T	P	Total	Ext	S	P	TW	Total
3	1	0	4	60	40	0	50	150

A. DETAILED SYLLABUS

TOPICS

1. **Introduction to modeling**: Classification of modeling schemes. Introduction to first principle models, gray box models, black box models.
2. **Statistical Preliminaries:** random process, random variables, time invariance, correlation, correlation coefficient etc.
3. **Input signal design:** Concept of persistency of excitation, concept of plant friendly ness, design and implementation of input signals like RGS, PRBS, Maximum length signals, Multi-level signals, Relay feedback signals, Introduction to Signal design for closed loop systems
4. **Linear models:** Introduction to the concept of local linearization. Detailed discussion on time series and state space model development. Introduction to linear regression, analysis of least squares estimates, best linear unbiased estimate, Recursive identification methods, Partial least squares, total least squares, introduction to prediction error methods and Instrumental variable methods. Introduction to commercial softwares on system identification.
5. **Nonlinear models:** Introduction to ANN based nonlinear model identification. Modeling of complex nonlinear systems using fuzzy decomposition and multi model approach. Modeling of nonlinear systems using Volterra series models. Concept of block oriented nonlinear model identification. Development of nonlinear models using Ortho normal basis functions
6. **Model order:** Introduction to concept of structure selection and model order, conventional model order reduction techniques. Introduction to nonlinear model order reduction techniques
7. **Stochastic modeling:** Development of stochastic time series models, Introduction to concept of Kalman filtering, Introduction to nonlinear ARX and nonlinear ARMAX type models. Introduction to extended Kalman filters.

B. TEXT BOOK

1. System Identification by Torsten Soderstrom and Petre stoica, Prentice Hall International series insystems and control engineering
2. System Identification Theory for the user, Lennert Ljung, Prentice hall PTR, Upper saddle River,NJ, 07458.
3. Lessons in estimation theory for signal Processing communications and control, by JerryM. Mendal, Prentice hall signal processing series.
4. Perturbation signals for system identification, Editor Keith Godfrey, Prentice Hall International series
5. System identification special addition, Automatica, 1995 November.

C. COURSE OUTCOMES

COs	Skills	Statement
CO1	Remember Understand Application Analysis Evaluate Create	Application of fundamental concepts and development of white boxstate space models.
CO2		Development of discrete time state space models and theirapplications
CO3		Development of linear time series models and their applications
CO4		Development of nonlinear models including Artificial Intelligencebased models and their applications
CO5		Application of model order reduction techniques
CO6		Development of stochastic models and their applications

D. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	CO6	Avg
PO1	3	3	3	3	3	2	2.8
PO2	3	3	3	3	2	2	2.5
PO3	3	2	3	2	2	2	2.3
PO4	2	2	2	2	2	2	2
PO5	2	2	2	2	2	2	2
PO6	2	2	2	2	2	2	2
PO7	2	2	2	2	2	2	2
PO8	3	2	3	2	3	3	2.7
PO9	2	2	2	2	2	2	2
PO10	3	3	3	2	2	2	2.5
PO11	2	2	2	2	2	2	2
PO12	3	3	3	2	2	2	2.5
PSO 1	3	3	3	2	3	3	2.8
PSO 2	3	3	3	3	3	3	3
PSO 3	3	3	3	3	3	3	3
PSO4	3	3	3	3	3	2	2.8
PSO5	3	3	2	3	3	3	2.8

M. TECH. – SEMESTER-I
INTRODUCTION TO ENVIRONMENTAL ENGINEERING (MC144)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	**T**	**P**	**Total**	**Ext**	**S**	**P**	**TW**	**Total**
3	**1**	**0**	**4**	**60**	**40**	**0**	**50**	**150**

A. DETAILED SYLLABUS

	TOPICS	COs
1.	**Introduction to Environmental Engineering** Ecology and various cycles, Acid rain, ozone depletion, greenhouse gases, photochemical smog, various types of pollutants, Environmental laws, introduction to environmental chemistry	CO1
2.	**Air Pollution and Control** Air pollution sources and its classification, Effects of air pollutants, meteorological aspects of air pollution, Dry/wet adiabatic lapse rate and environmental lapse rate, atmospheric stability and plume behavior, Gaussian plume behavior model for area, line and point source. Air pollutant sampling and measurement, various types of air pollution control methods, equipment and its design, selection criteria of air pollution control equipment	CO1 CO2
3.	**Industrial Waste Water Treatment** Sources of industrial waste water and its characteristics, need of waste water treatment methods, use of various types of physical, chemical and biological methods for waste-water treatment under primary, secondary and tertiary methods, advanced oxidation processes, membrane technology for waste water treatment	CO3 CO4
4.	**Solid Waste Management** Types and classification of solid waste, collection and transportation of solid waste, Solid waste disposal methods and 5R concept	CO5
5.	**Cleaner Production** – objectives, methods, Planning and strategy, case studies, Circular economy, Green Chemistry concept	CO3 CO4
6.	Noise Pollution sources of noise pollution & their control methods	CO5

B. TEXT BOOKS

1.	Environmental Pollution Control Engineering by C. S. Rao, Wiley Eastern Ltd
2.	Waste Water Engineering – Treatment, Disposal & Reuse by Metcalf & Eddy Inc. Tata McGraw Hill Publications

C. REFERENCE BOOKS

1.	Introduction to Environmental Engineering by Mackenzie L. Davis & David A. Cornwell, McGraw Hill International Publications
2.	Environmental Engineering by Raw, Peavy & Tchobanoglous

3.	Chemistry for Environmental Engineering 3rd Ed. by Sawyer &McCarty McGraw Hill

D. COURSE OUTCOMES

COs	Skills	Statement
CO1	Remembering Understanding Applying Analysing Evaluating Creating	Understand the sources and effect of different types of pollution on the environment (Air, Water, Land etc.), Environmental Laws
CO2		Meteorological aspects of air pollution, Atmospheric stability and plume behavior, sampling and measurement of air pollutants, Air pollution control equipment and its design
CO3		Types of water pollutants and waste water characteristics, Collection and testing of waste water samples, Waste water treatment schemes
CO4		Evaluate the significance of advanced oxidation processes for waste water treatment, Cleaner and greener route of production, Circular economy
CO5		Understand about solid waste and its classification, Collection and Transportation of solid waste, Various disposal methods for hazardous solid waste, noise pollution and its control

E. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	Avg
PO1	2	3	3	3	2	2.6
PO2	2	3	3	2	1	2.2
PO3	1	2	2	3	2	2
PO4	2	2	2	2	3	2.2
PO5	3	2	2	2	3	2.4
PO6	2	2	2	2	2	2
PO7	3	2	2	2	2	2.2
PO8	3	2	2	2	3	2.4
PO9	2	2	2	2	2	2
PO10	3	2	2	3	2	2.4
PO11	3	3	2	2	2	2.4
PO12	2	2	2	2	2	2
PSO 1	2	2	2	3	2	2.2
PSO 2	2	3	2	3	2	2.4
PSO 3	2	3	3	3	2	2.6
PSO4	2	2	3	3	2	2.4

SEMESTER-II

Subject Code	Subject Name	Teaching Scheme			Exam Scheme (Marks)				Credit
		L	T	P	Th.	S	TW	Total	
MC231	Optimization Techniques	3	1	0	60	40	50	150	5
MC232	Advanced Chemical Engineering Thermodynamics	3	1	0	60	40	0	100	4
MC233	Computational and Numerical Methods	3	1	0	60	40	50	150	5
MC236	Seminar	0	0	4	0	0	50	50	1
MC237	Process Synthesis	3	1	0	60	40	50	150	5
MC238	New Separation Techniques	3	1	0	60	40	50	150	5
	Total	15	5	0	300	200	250	750	25

M. TECH. – SEMESTER-II
OPTIMIZATION TECHNOLOGY (MC231)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	**T**	**P**	**Total**	**Ext**	**S**	**P**	**TW**	**Total**
3	**1**	**0**	**4**	**60**	**40**	**0**	**50**	**150**

A. COURSE OVERVIEW

Motivation: Study, understand, utilize the appropriate mathematical models and tools to solve the process problems associated with any field or industry in the most optimistic manner.

B. DETAILED SYLLABUS

	TOPICS	COs
1.	**Introduction to Operational Research** • Introduction, • Engineering Application, • Methods of Operation Research, • Formulation, • Graphical method of Solution	**CO1** **CO3** **CO4**
2.	**Linear Programming** • Simplex method • Degeneracy • Big-M method • Revised Simplex method	**CO2** **CO3** **CO4**
3.	**Transportation Model** • North-West Corner rule, • Row and Column Minima method, • Least-cost method, • Vogel's approximation method, • Degeneracy in transportation problem, • stepping stone method, • modified distribution method, • unbalanced supply and demand, • profit maximization problem, • trans-shipment problems	**CO3** **CO4** **CO5**
4.	**Assignment Model** • Hungarian method for solution • Variation of the assignment problem - non-square matrix,restriction on assignments. • Maximization problem • Travelling salesman problem • Travelling salesman problem (shortest cyclic route models)	**CO2** **CO3** **CO4**

5.	**Scheduling Optimization and Related Models on Sequencing** • Batch Scheduling • Formulation of sequencing models and its applications. • Introduction to Gantt Chart and its Application to Different types of Transfer policies.	**CO5** **CO6**
6.	**Advanced topics in Linear Programming** • Duality in Linear Programming • Primal to Dual conversion • Duality Theorem and Dual Simplex method	**CO2** **CO3** **CO4**
7.	**Dynamic programming** • Bellman's principle of optimality, • Examples on the application of routing problem, inventoryproblem, marketing problem	**CO4** **CO5** **CO6**
8.	**Non-Linear Programming** • Elimination Methods — Unrestricted Search, Exhaustive Search, Dichotomous search, Fibonacci method, Golden Section Method, • Kuhn tucker condition	**CO1** **CO2** **CO3** **CO4**

C. TEXT BOOKS

1. Gupta P., Hira D.S., "Operation Research", S. Chand & Company Ltd
2. Rao S.S., "Engineering Optimization: Theory and Practice", Willey Publication
3. Vohra N D, Quantitative Techniques in Management, Tata McGraw Hill, New Delhi

D. REFERENCE BOOKS

1. Sharma S D & Sharma H, Operations Research: Theory, methods & applications
2. K. Nath R. Nath Arora J.S., "Introduction to Optimum Design", Elsevier Academic Press
3. Hiller & Libermann, Introduction to Operations Research, Tata McGraw Hill
4. Hamdy A. Taha, "Operation Research", Pearson Education
5. Operation Research – V. K. Kapoor, S. Chand Publication

E. COURSE OUTCOMES

CO	Skills	Statement
CO1	**Define**	**Define** the type of the problem in terms of Linear programming problem or Non-linear programming problem
CO2	**Describe**	**Describe** the formulation of the problem into mathematical approach/model
CO3	**Application**	**Apply** the types of numerical/mathematical methods to be used in industry to have optimal solution
CO4	**Solution**	**Solve** the type of the problem using the appropriate method
CO5	**Development**	**Develop** a skill to deal with type of problem to get best possibleresult
CO6	**Use**	**Use** the mathematical tool to solve the trickiest problem

F. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	CO6	Avg
PO1	3	3	3	3	2	2	2.7
PO2	3	3	3	3	2	2	2.7
PO3	3	3	2	2	2	2	2.3
PO4	2	2	2	2	1	2	1.8
PO5	2	2	2	2	3	3	2.3
PO6	2	2	2	2	1	1	1.7
PO7	2	2	1	1	1	1	1.3
PO8	2	2	1	1	1	1	1.3
PO9	2	2	1	1	1	1	1.3
PO10	2	2	1	1	1	1	1.3
PO11	2	2	1	1	1	1	1.3
PO12	2	1	1	1	1	1	1.2
PSO 1	3	3	3	2	3	3	2.8
PSO 2	3	3	3	2	3	3	2.8
PSO 3	3	3	3	2	2	2	2.5
PSO4	3	3	3	3	3	2	2.8
PSO5	3	3	2	2	2	3	2.5

M. TECH. – SEMESTER-II
ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS (MC232)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	T	P	Total	Ext	S	P	TW	Total
3	1	0	4	60	40	0	0	100

A. COURSE OVERVIEW

To understand any specific phenomena occurring in the chemical process industries, it is essential to know the cause of that phenomena. The study of behavior of chemical propertieswith independent parameters is essential to accurately predict the separation phenomena or chemical reactions. Classical thermodynamics gave reasons for such behavior and Statisticalthermodynamics provides better insight in to such phenomena from molecular level. Most of separations in chemical industries are equilibrium based which includes vapor-liquid, liquid- liquid, vapor-liquid-liquid, solid-liquid at equilibrium. This course encompasses the study of both macroscopic level and molecular level understanding of key thermodynamic properties to handle such equilibrium cases and explore possible ways of solving problems associated withnon-ideality in VLE, LLE, VLLE, SLE & reaction equilibria for multicomponent mixtures. These concepts will be applied in understanding several important industrial and academic applications. Apart from this, the behavior of gases at molecular level, its interaction with other gases will be studied at molecular level. The study of behavior of solids whether as a reactant or as a catalyst will be done at molecular level.

B. DETAILED SYLLABUS

	TOPICS	COs
1.	**Introduction to Phase Equilibria** General principles of Classical Thermodynamics, basic postulates,estimation of Thermodynamic Properties, fundamental equations- equations of state, Gibbs-Duhem equation, Gaseous Mixtures and Fugacity, Liquid Mixtures and Fugacity.	**CO1** **CO2**
2.	**Models for Activity Coefficients using Excess Gibbs Energy** Introduction to excess Gibbs energy, Activity models such as Redlich- kister equation, Wohl's equation, Van Laar equation, Margule's equation, Wilson equation, NRTL, UNIQUAC & UNIFAC, Thermodynamic consistency test for VLE data, Liquid-Liquid Equilibria; Vapor-Liquid-Liquid Equilibria; Solid-Liquid Equilibria; Solid-Gas Equilibria, Ethics concern with VLE data.	**CO1** **CO2**
3.	**Introduction to Chemical Reaction Equilibria** Equilibrium criterion for a chemical reaction, concept of Equilibrium conversion (x), equilibrium constant (k), evaluation of equilibrium constants at different temperatures, equilibrium conversion of single reactions and multi reaction equilibria, Phase rule for chemically reacting systems.	**CO1** **CO2**
4.	**Introduction to Statistical Thermodynamics** Probability theory, Different thermodynamic distributions- Boltzmann, Bose – Einstein & Fermi-Dirac, Laws of thermodynamics & theirapplications, Properties of elementary particles.	**CO3** **CO4** **CO5**

5.	**Partition Function, Ensembles** Behavior of Monatomic gases and solids, Behavior of Diatomic andpolyatomic gases, Models to predict properties of such gases and solids	**CO3 CO4 CO5**
6.	**Chemical Equilibrium** Equilibrium constant, Equilibrium Composition, Simultaneousreactions, Ionization	**CO4 CO5**

C. TEXT BOOKS

1. Smith, J. M.; Van Ness, H. C. Introduction to Chemical Engineering Thermodynamics; Fourth Edition, McGraw Hill Book Company: Singapore, 1987
2. Sonntag, R. E. & Van Wylen, Gordon J. Fundamentals of Statistical Thermodynamics; First Edition, John Wiley & Sons: United States of America, 1968

D. REFERENCE BOOKS

1. Narayan, K. V. A Textbook of Chemical Engineering Thermodynamics; Second Edition, PHI Learning Private Limited: Delhi, 2013
2. Rao, Y.V.C. Chemical Engineering Thermodynamics; First Edition, Universities Press India Private Limited: Hyderabad, 1997
3. S. Sandler, "Chemical, Biochemical and Engineering Thermodynamics",4th edition, Wiley, India

E. COURSE OUTCOMES

COs	Skills	Statement
CO1	**Remembering Understanding Applying Analyzing Evaluating Critiquing**	Understand and Apply the relationship between the fundamental thermodynamic properties.
CO2		Selection of thermodynamic models to estimate the properties for mixtures involving equilibria of different phases such as VLE, LLE, VLLE, SLE, SVE as well as reactions.
CO3		Introducing concept of quantum mechanics and analyze the effect of various energy levels for estimating behavior of components.
CO4		Applying Statistical Thermodynamics at molecular level for addressing change in properties of key thermodynamic quantities.
CO5		Critiquing behavior of solids and gases during separation or reactions at molecular level.

F. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	Avg
PO1	2	3	3	3	3	2.8
PO2	3	3	3	3	3	3
PO3	2	3	3	3	3	2.8
PO4	3	2	3	3	3	2.8
PO5	3	2	3	3	3	2.8
PO6	2	3	3	3	3	2.8
PO7	3	3	3	3	3	3

PO8	2	3	3	3	3	2.8
PO9	2	3	3	3	3	2.8
PO10	2	3	3	3	3	2.8
PO11	3	2	3	3	3	2.8
PO12	3	2	3	3	3	2.8
PSO 1	2	3	3	3	3	2.8
PSO 2	2	3	3	3	3	2.8
PSO 3	2	3	3	3	3	2.8
PSO4	3	3	3	3	3	3

M. TECH. – SEMESTER-II
COMPUTATIONAL AND NUMERICAL METHODS (MC233)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	**T**	**P**	**Total**	**Ext**	**S**	**P**	**TW**	**Total**
3	**1**	**0**	**4**	**60**	**40**	**0**	**50**	**150**

A. COURSE OVERVIEW

Numerical solutions of various mathematical models such as lumped parameter models and distributed parameter models describing steady state and dynamic behaviors of Chemical Process Systems and parameter estimation using numerical methods in Chemical Engineering.

Objectives:

To apply numerical methods for solving various problems in chemical engineering systems and to develop computer programs using languages like C/C++ and commercial software like MATLAB in order to educate the students for solving research-oriented problems. Fundamentals of numerical methods/algorithms to solve systems of different mathematical equations (e.g. linear/nonlinear algebraic equations, ordinary / partial differential equations) will be introduced. Practical are designed for solving actual chemical engineering problems through computer programming and coding

B. DETAILED SYLLABUS

	TOPICS	COs
1.	**Basics of Vectors, Scalars and matrix algebra** Addition/subtraction, multiplication/division of vectors, matrix multiplication, inverse of matrix, determinant and rank of matrix, eigen values, sparse matrices, Use of MATLAB for matrix algebra, approximation and concept of error and error analysis	**CO1** **CO3**
2.	**Numerical methods for linear algebraic equations** Gauss elimination method, Gauss-Jordan method, Jacobi method, Successive – over relaxation method, tri-diagonal matrix, MATLAB programming	**CO1** **CO2** **CO3**
3.	**Numerical methods for nonlinear algebraic equations** Successive substitution method, Newton-Raphson method, Secant method, False position method, single variable and multivariable case studies, MATLAB functions for nonlinear algebraic equations	**CO1** **to** **CO5**
4.	**Eigen Value Problems** Eigen value analysis of linear and nonlinear systems and solution of homogeneous equations using eigen values	**CO1** **CO2** **CO3**
5.	**Regression, interpolation, curve fitting, numerical integration** Simple interpolation, Lagrange's interpolation, Newton's interpolation, Simpson's rule, trapezoid method, linear regression, polynomial regression, exponential and power regression, MATLAB routines and commands	**CO1** **CO2** **CO3**
6.	**Numerical methods for IVP and BVP ordinary differential equations** Explicit and implicit ODEs, Euler's explicit and implicit methods, explicit Adams-Bashforth methods, implicit Adams- Mouton methods, Predictor – corrector methods, Runge-Kutta methods, MATLAB solvers for ODEs, Finite difference, Orthogonal collocation and Orthogonal collocation on finite- element methods for ODE-BVP, Shooting Methods for solving BVP	**CO1** **to** **CO6**

7.	**Numerical methods for Partial differential equations** Steady state and dynamic PDES, method of lines, Crank-Nicholson method, finite-difference, Orthogonal collocation and orthogonal collocation on finite element methods	**CO1 to CO6**

C. PRACTICAL AND TERM WORK

Simulation experiments are designed to use MATLAB software for solving linear/nonlinear algebraic equations for steady state problems in Chemical Engineering and for solving dynamic problems in Chemical Engineering. Simulation experiments for parameter estimation problems in chemical engineering systems are also designed.

D. TEXT BOOKS

1. Gupta, S. K. Numerical Methods for Engineers, 3rd ed.; New Age International Publishers: New Delhi, 2015
2. Chapra, S. C. Applied Numerical Methods with MATLAB for Engineers and Scientist, 3rd ed.; McGraw-Hill: New York, 2012

E. REFERENCE BOOKS

1. Beers, K J. Numerical Methods for Chemical Engineering Applications in MATLAB, Cambridge University Press: UK, 2006
2. Constantinides, A.; Mostoufi, N. Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall International Series: New Jercy, 1999.

F. COURSE OUTCOMES

COs	Skills	Statement
CO1	**Understanding**	**Remember** and **understand** the various numerical methods to solvevarious linear and nonlinear steady state and dynamic problems in chemical engineering systems described by ODE, PDE, AE and NAE
CO2	**Analyzing**	Carry out the **error analysis** in the numerical solutions of chemical engineering problems
CO3	**Applying**	**Apply** linear algebraic equation solution techniques and nonlinear algebraic equation techniques for solving steady states of chemical engineering systems. Use **MATLAB** to **implement** numerical methods in simulations.
CO4	**Evaluating**	**Do** critical evaluation of the performance of various numerical methodsusing simulations for solving chemical engineering problems.
CO5	**Creating**	Develop MATLAB codes for various numerical methods
CO6	**Remembering Evaluating**	**Generate** a MATLAB program for industrial application to carry out steadystate and dynamics analysis.

G. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	CO6	Avg
PO1	2	2	2	3	2	3	**2.3**
PO2	1	1	3	3	3	3	**2.3**
PO3	1	2	3	3	3	3	**2.5**

PO4	1	1	2	3	2	3	**2**
PO5	0	0	2	3	3	3	**1.8**
PO6	2	2	3	3	3	3	**2.7**
PO7	2	3	3	3	3	3	**2.8**
PO8	1	1	2	2	2	3	**1.8**
PO9	2	2	3	2	3	3	**2.5**
PO10	1	2	3	2	2	3	**2.2**
PO11	2	3	3	2	2	3	**2.5**
PO12	3	3	3	2	3	3	**2.8**
PSO 1	2	3	3	3	2	3	**2.67**
PSO 2	3	3	3	2	3	2	**2.67**
PSO 3	2	3	2	2	2	2	**2.17**
PSO4	3	3	3	3	3	3	**3**

M. TECH. – SEMESTER-II
PROCESS SYNTHESIS (MC237)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	**T**	**P**	**Total**	**Ext**	**S**	**P**	**TW**	**Total**
3	**1**	**0**	**4**	**60**	**40**	**0**	**50**	**150**

A. DETAILED SYLLABUS

	TOPICS	COs
1.	**Introduction:** Introduction to design and process synthesis. Preliminary process design. Basic steps in process flow sheet synthesis. Decompositionstrategies for process synthesis. A Case study: Synthesis of Ethyl Alcohol process.	**CO1**
2.	**Scheduling:** Introduction to design and scheduling of batch processes. Concepts of single and multi-product batch plants, transfer policies, parallel units and intermediate storage. Synthesis of flow shop plants.	**CO2**
3.	**Simulation in process design:** Process simulation modes, Methods of solving nonlinear equations, Recycle partitioning and tearing.	**CO3**
4.	**Heat and power integration:** The basic concepts of Heat Ex-changerNetwork Synthesis (HENS) and Mass Exchange Networks (MEN). Synthesis of ideal multi-component distillation systems. Heat integrated distillation systems.	**CO4**
5.	**Synthesis of reactors and reactor networks:** Mathematical approach andHeuristic approach.	**CO5**
6.	**Process flexibility:** Introduction to the concept of flexibility, Mathematical formulas for flexibility analysis and some solution methods.	**CO5**
7.	**Optimization for Process Synthesis:** Introduction to optimization techniques. MINLP problems. MINLP models to solve HENS, distillationsequences, reactor network synthesis.	**CO6**

B. TEXT BOOKS

1. Biegler, Grossmann, and Western berg., Systematic methods of chemical process design
2. Rudd Dole, F, Powers Gray J, Siirola, Jeffrey J, Process, Process synthesis, Engle wood cliffs, Printice hall, 1973.

C. COURSE OUTCOMES

COs	Skills	Statement
CO1	**Remember Understand Application Analysis Evaluate Create**	Concept of design, synthesis along with basic steps for process flow sheet synthesis.
CO2		Scheduling of multi product and multipurpose batch plants and design of flow shop plant.
CO3		Process plant simulation including partitioning and tearing algorithms.
CO4		Concepts of HENS and MENS.
CO5		Synthesis of reactors and reactor networks using various methods. Introduction to process flexibility.
CO6		Optimization techniques and their use in process synthesis.

D. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	CO6	Avg
PO1	3	3	3	3	3	2	2.8
PO2	3	3	3	3	2	2	2.5
PO3	3	2	3	2	2	2	2.3
PO4	2	2	2	2	2	2	2
PO5	2	2	2	2	2	2	2
PO6	2	2	2	2	2	2	2
PO7	2	2	2	2	2	2	2
PO8	3	2	3	2	3	3	2.7
PO9	2	2	2	2	2	2	2
PO10	3	3	3	2	2	2	2.5
PO11	2	2	2	2	2	2	2
PO12	3	3	3	2	2	2	2.5
PSO 1	3	3	3	2	3	3	2.8
PSO 2	3	3	3	3	3	3	3
PSO 3	3	3	3	3	3	3	3
PSO4	3	3	3	3	3	2	2.8
PSO5	3	3	2	3	3	3	2.8

M. TECH. – SEMESTER-II
NEW SEPARATION TECHNIQUES (MC238)

Teaching Scheme (Hours/Week)				Examination Scheme				
L	T	P	Total	Ext	S	P	TW	Total
3	1	0	4	60	40	0	50	150

A. COURSE OVERVIEW

The course deals with the understanding of conventional separation techniques and new separation techniques used in chemical process industries. The subject focusing on the basics of multi component distillation and all types of membrane-based separation operations. The emphasis is given on the synthesis of membrane, characterization of membrane and selection of suitable type of membrane separation processes with industrial examples and other types of separation operations.

B. DETAILED SYLLABUS

	TOPICS	COs
1.	**Introduction to Separation technology** Fundamentals of Separation Processes and its classification, advantage and limitation of various conventional separation processes and need of new separation methods, basic terms associated with the membrane technology	**CO1**
2.	**Multicomponent Distillation** Concept of MCD, Bubble point dew point calculation, key component concept, short cut methods, number of stage calculation, Fensky and Underwood equation	**CO2**
3.	**Membrane types, materials, synthesis and characterization**: Definition of Membrane, Advantages and limitations of membrane technology compared to other separation processes, Membrane materials and properties, Synthesis methods of membrane, types of membrane andmembrane modules, Flux equation, transport mechanism, factors affecting on membrane operation	**CO3**
4.	**Membrane processes** Types of pressure driven membrane processes like microfiltration, ultra-filtration, reverse osmosis, nano filtration using membrane and their industrial applications,	**CO4**
5.	**Other types of Separation processes –** Gas separation, pervaporation, Ion exchange membrane and electrodialysis, introduction to liquid membrane, membrane distillation, membrane reactor, super critical fluid extraction	**CO5**

C. TEXT BOOKS

1. Membrane separation processes – Kaushik Nath, second edition, PHI learning private limited
2. Fundamentals of Multicomponent Distillation – Charles D Holland, McGraw Hill Chemical Engineering series

D. REFERENCE BOOKS

1. Basic Principles of Membrane Technology, Mulder M, Kluwer Academic Publishers, London, 1996.
2. Membrane Technology and Research, Baker R. W., Inc. (MTR), Newark, California, USA,

2004.
3. Separation Process Principles – J.D. Seader , E.J. Henley , Second edition, Wiley

E. COURSE OUTCOMES

COs	Skills	Statement
CO1	**Remembering Understanding Applying Analyzing Evaluating Creating**	Understand about various types of conventional and new separation methods used in industry with their advantages and limitations
CO2		Concept of multi component distillation
CO3		Types of Membrane, synthesis method, characterization of membrane, membrane modules, factors affecting on membrane operations
CO4		Various types of pressured driven membrane operations
CO5		Basics of other types of separation operation including gas separation, electro dialysis, ion exchange membrane, supercriticalfluid extraction, LEM

F. COURSE MATRIX

	CO1	CO2	CO3	CO4	CO5	Avg
PO1	2	3	3	3	2	2.6
PO2	2	3	3	2	1	2.2
PO3	1	2	2	3	2	2
PO4	2	2	2	2	2	2
PO5	2	2	2	2	2	2
PO6	2	2	2	2	3	2.2
PO7	3	2	2	2	2	2.2
PO8	3	2	2	2	3	2.4
PO9	2	2	2	2	2	2
PO10	1	2	2	2	2	1.8
PO11	1	2	2	2	2	2.8
PO12	2	2	2	2	2	2
PSO 1	2	2	2	3	2	2.2
PSO 2	2	3	2	3	2	2.4
PSO 3	2	3	3	3	2	2.6
PSO4	2	2	3	3	2	2.4