

**SEMESTER WISE COURSE STRUCTURE
& EVALUATION SCHEME**

**MASTER OF TECHNOLOGY
CHEMICAL ENGINEERING**

(Effective from the session 2025-26 for new entrants)



**DEPARTMENT OF CHEMICAL ENGINEERING
HARCOURT BUTLER TECHNICAL UNIVERSITY KANPUR**

Chemical Engineering Department

OUR VISION

To emerge as a global leader in the areas of education and research in Chemical Engineering to handle the technological challenges in Chemical Engineering & Allied Field and catering the requirement of present and future stakeholders and society.

OUR MISSION

1. To provide state-of-art technical education to the undergraduate and post graduate students.
2. To create a conducive and supportive environment for the overall growth of our students.
3. To cultivate awareness of social responsibilities in students to serve the society.
4. To groom students with leadership skills helpful in Startups, professional ethics and accountability along with technical knowledge to face the changing needs of industry and environment.
5. To impart consultancy services to the Chemical and Allied industries of region, state and the country.

For PG

Programme Educational Outcomes (PEOs)

Post Graduates from our department will be able to

1. Independently conduct fundamental and applied research in industries and academia.
2. Work in a team for a multidisciplinary approach in problem solving for varied fields of chemical process industries.
3. Demonstrate good professional ethics and engineering judgment on the global, economical, environmental and social issues.

Programme Specific Outcomes (PSOs)

1. Identify, formulate and solve engineering problems in core chemical industry processes and R&D.
2. Undertake technical projects and consultancy in their chosen fields of specialization.
3. Contribute to the development of scientific and technical knowledge by effectively communicating the acquired knowledge and core competence among students, industry professionals, clients and society.

SEMESTER WISE COURSE STRUCTURE & EVALUATION SCHEME M. TECH. (CHEMICAL ENGINEERING) (FULL TIME PROGRAMME)

SEMESTER - I

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	NCH 501	Advanced Chemical Engineering Thermodynamics	4 [3-1-0]	30	20	-	50	50	100
2	PCC	NCH 503	Advanced Chemical Reaction Engineering	4 [3-1-0]	30	20	-	50	50	100
3	PCC	NCH 511	Modeling And Simulation of Chemical Processes	4 [3,1,0]	30	20	-	50	50	100
4	PCE	NCH 507/ 509/ 519	Elective - I	4 [3-1-0]	30	20	-	50	50	100
			Total Credits		16					

Elective - I [3-1-0]

NCH 507	Artificial Intelligence in Chemical Engineering
NCH 509	Advanced Mathematical Methods in Chemical Engineering
NCH 519	Instrumental Methods of Analysis

SEMESTER - II

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	NCH 502	Advanced Transport Phenomena	4 [3-1-0]	30	20	-	50	50	100
2	PCC	NCH 504	Advanced Separation Processes	4 [3,1,0]	30	20	-	50	50	100
3	PCC	NCH 522	Optimization of Chemical Processes	4 [3,1,0]	30	20	-	50	50	100
4	PCE	NCH 508/ 510/ 512	Elective - II	4 [3,1,0]	30	20	-	50	50	100
			Total Credits		16					

Elective - II [3-1-0]

NCH 508	Statistical Design of Experiments
NCH 510	Nanomaterials in Science & Engineering
NCH 512	Water Pollution Monitoring and Control

SEMESTER - III

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PEC	NCH601/603/611	Elective-III	4 [3-1-0]	30	20	-	50	50	100
2	OEC	OCH 601	Waste to Energy	3 [3-0-0]	30	20	-	50	50	100
4	PCC	NCH607	Seminar	1 [0-0-4]		50	-	50	50	100
5	PCC	NCH609	Dissertation	8 [0-0-16]		50	-	50	50	100
			Total Credits	16						

Elective – III [3-1-0]

NCH 601 Plant Safety Hazard and Risk Assessment

NCH 603 Design of Piping System for Chemical Plants

NCH 611 Polymer Science and Engineering

SEMESTER - IV

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	NCH 602	Dissertation	16 [0-0-32]	-	50	-	50	50	100
			Total Credits	16						

NCH 605 Dissertation will have Internal Evaluation while NCH 602 Dissertation will have External Evaluation.

SYLLABUS
M. TECH CHEMICAL ENGINEERING

NCH 501 ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: To learn advanced topics of classical thermodynamics with emphasis on basic concepts, laws, and thermodynamic relationships and to familiarize students with knowledge of advanced thermodynamics especially in chemical engineering related fields.

Course Outcomes:

Students completing the course will be able to

CO1	Perform Legendre transformation of Energy equation and derive Maxwell relations.	Understand, Apply,
CO2	Calculate phase equilibrium conditions (BUBL P, BUBL T, DEW T and DEW P) for non-ideal mixtures using the gamma-phi approach and Evaluate equilibrium constant and Gibbs free energy change of a chemical reaction by applying criterion of equilibrium.	Apply, Evaluate
CO3	Calculate the effect of curvature on thermodynamic properties such as vapour pressure and solubility.	Analyze, Evaluate
CO4	Calculate changes in U, H, and S for ideal gases, and also for non-ideal gases through the use of residual properties and colligative properties such as Boiling point elevation, freezing point depression.	Understand, Apply, Evaluate
CO5	Demonstrate introductory understanding to various concepts of statistical thermodynamics	Understand, Apply,

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	-	-	-	-	-	-	-	1
CO2	3	3	3	2	-	-	-	-	-	-	-	1
CO3	3	3	3	3	-	-	1	-	-	-	-	1
CO4	3	3	2	2	-	-	-	-	-	-	-	-
CO5	3	3	2	3	-	-	-	-	-	-	-	1
Avg	3	3	2.4	2.2	0	0	1	0	0	0	0	1

Module 1 (12 Lectures)

Introduction to Thermodynamics and statistical mechanics, Internal energy, First law of thermodynamics, Intensive and extensive properties Concept of entropy, Second law of thermodynamics: Extremum principles of Energy and Entropy., Legendre transforms of energy and reformulation of second law in terms of the Legendre transforms, Maxwell relations, Maximum work theorem.

Module 2 (10 Lectures)

Conditions of phase equilibrium and its applications, Gibbs Duhem relations, Gibbs phase rule, Conjugate variables, Criteria for stability and its implications. Chemical reactions: condition of equilibrium for a reaction mixture, Equilibrium constants, Heat of reaction Thermodynamics of fluid-fluid interfaces: Dividing surface, surface excess quantities, condition of equilibrium at interfaces, Kelvin equation, Gibbs adsorption isotherm, Thermodynamics of fluid-solid interfaces: condition of equilibrium with respect to dissolution and growth of solids.

Module 3 (8 Lectures)

Classical mechanics: Lagrangian formulation, Constants of motion, Hamilton's principle, and phase space, concept of statistical ensemble, Statistical independence of macroscopic bodies, Liouville equation, Measurements and ensemble averages. Micro-canonical, and Grand-canonical ensembles. Gibbs entropy formula and Boltzmann entropy formula, Partition functions, Fluctuations and stability.

Module 4 (5 Lectures)

Ideal gas: Analytical derivations of the partition functions of ideal gas in various ensembles and thermodynamic properties, Ideal solid: Analytical derivation of partition function, heat capacity, Non-ideal gases, Virial equation of state, Second virial coefficient, Liquids: Distribution functions, pair correlation function $g(r)$ and experimental measurement of $g(r)$ by diffraction, Mean-field theory and perturbation theory.

Module 5 (5 Lectures)

Dilute solutions and colligative properties: Derivation of Raoult's law, Henry's law, Van'tHoff's formula for osmotic pressure. Boiling point elevation, freezing point depression Introductory Quantum Statistical mechanics: Schrödinger Wave equation, Degeneracy, Partition functions. Ideal gas of polyatomic particles, Molecular partition functions, Einstein and Debye theory of perfect crystals.

Suggested Text Books

1. Herbert B. Callen, Thermodynamics and an Introduction to thermo statistics, John Wiley and Sons, 1985.
2. McQuarrie D. A. and Simon, J. D., Molecular Thermodynamics, Viva Books Pvt. Ltd., 2004

Suggested Reference Books

1. David Chandler, Introduction to modern statistical mechanics, Oxford University Press, 1987

NCH503 ADVANCED CHEMICAL REACTION ENGINEERING

Assessment:

Sessional: 50 marks End

Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: To learn the heterogeneous catalyzed reactions and the models involved in reactor design. To appreciate the importance of both external and internal transport effects in gas-solid and liquid-solid systems.

Course Outcomes:

Students completing the course will be able to

CO1	Develop basic concepts involved in using reaction rate equations and kinetic constants for homogenous and heterogeneous reactions.	Understand, Apply,
CO2	Perform model discrimination and parameter estimation for heterogeneous catalytic reactions and Predict the role of temperature, concentration, and interphase mass transfer in the rate equations.	Apply, Evaluate
CO3	Derive design equations and perform calculations for various multiphase reactors	Analyse, Evaluate
CO4	Determine optimal reactor configurations and operating policies for systems involving multiple reactions	Understand, Apply, Evaluate
CO5	Perform analysis of falling film catalytic wall reactors, trickle bed reactors and chromatographic reactors.	Understand, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	-	-	-	-	-	-	-	1
CO2	3	3	2	2	-	-	-	-	-	-	-	-
CO3	3	3	2	3	-	-	-	-	-	-	-	-
CO4	3	3	1	3	-	-	-	-	-	-	-	-
CO5	3	3	2	3	-	-	-	-	-	-	-	-
Avg	3	3	1.8	2.8	0	0	0	0	0	0	0	1

Module 1 (6 Lectures)

Kinetics of heterogeneous catalytic reactions, rate equations, model discrimination and parameter estimation.

Module 2 (7 Lectures)

Deactivating catalysts, mechanisms of catalyst deactivation, the rate and performance equations, design.

Module 3 (7 Lectures)

Mass Transfer and Reaction in a packed bed, Stoichiometric table, Pressure drop in a Reactor, Ergun's equation, Flow through a packed bed.

Module 4 (10 Lectures)

Types of multiphase reactors, mass transfer reactors, mass transfer equations, Interfacial surface area, mass transfer between phases, multiphase reactor equations, equilibrium between phases, membrane reactors, falling film reactors, bubble column reactors.

Module 5 (10 Lectures)

Falling film catalytic wall reactor, trickle bed reactors, multiphase reactors with catalysts, other multiphase reactors, reactor-separator integration, catalytic distillation, chromatographic reactors, iron ore refining, petroleum refinery.

Suggested Text Books

1. Levenspiel, O., Chemical Reaction Engineering, Wiley India, 1998.
2. Froment G. F. and Bischoff, K. B., Chemical Reactor Analysis and Design, John Wiley and Sons, 1979.

Suggested Reference Books

1. Fogler, H. S., Elements of Chemical Reaction Engineering, 2nd edition, Prentice-Hall, 2000.
2. Schmidt, Lanny D., The Engineering of Chemical Reactions, 2nd edition, Oxford University Press, 2010.

NCH 511 MODELING AND SIMULATION OF CHEMICAL PROCESSES

Assessment: Sessional:

50 marks End Semester:

50 marks

L	T	P	C
3	1	0	4

Course Objective:

To give an overview of various methods of process modeling, different computational techniques for simulation. The focus shall be on the specific applications so that the student can take up modeling and simulation challenges in his profession.

Course Outcome:

CO1	Select the type of model to be used based on the problem. That is make a selection simple vs. rigorous model, lumped parameter vs. distributed parameter, Steady state vs. dynamic, Transport phenomena based vs. Statistical models.	Understand, Apply
CO2	Development of process models based on conservation principles and process data	Apply, Evaluate
CO3	Develop steady state models for various heat transfer and mass transfer equipment.	Apply, Evaluate
CO4	Develop mathematical models of Batch reactors, Continuous-stirred tank reactors and Plug-flow reactors	Understand, Apply,
CO5	Demonstrate the knowledge of various simulation packages and available numerical software libraries.	Understand, Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	-	-	-	-	-	-	-	-
CO2	3	3	2	2	-	-	-	-	-	-	-	-
CO3	3	3	3	1	1	-	-	-	-	-	-	-
CO4	3	3	2	2	1	-	-	-	-	-	-	-
CO5	3	3	3	3	3	-	-	-	3	-	-	1
Avg	3	3	2.4	2.2	1	0	0	0	0.6	0	0	0.2

Module 1 (10 Lectures)

Fundamentals of mathematical modeling-Principles of formulations, Fundamental laws: Continuity equations, energy equation, equation of motion, transport equations, equation of state, equilibrium, chemical kinetics; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes; Classification of models-Simple vs. rigorous, lumped parameter vs. distributed parameter, Steady state vs. dynamic, Transport phenomena based vs. Statistical; Concept of degree of freedom for steady state and unsteady state systems.

Module 2 (8 Lectures)

Mathematical models of heat-transfer equipments: Double pipe heat exchanger, Shell & tube heat exchangers, Evaporators, Fired heaters, Partial condensers

Module 3 (6 Lectures)

Mathematical models of mass-transfer equipments: Batch and continuous distillation columns, Reactive distillation columns, packed absorption columns, Dehumidifiers

Module 4 (8 Lectures)

Mathematical models of reactors: Batch reactors, Continuous-stirred tank reactors, Plug-flow reactors, Industrial reactors-Ammonia converter, Sulphuric acid converter, Methanol reactor, FCC reactor, Claus reactor, etc.

Module 5 (8 Lectures)

Numerical methods: Linear and non-linear simultaneous algebraic equations, Ordinary-differential equations-Initial-value problems & boundary-value problems, Partial-differential equations Different approaches to flow sheet simulation- Sequential modular approach, Simultaneous modular approach, Equation oriented approach; Review of thermodynamic procedures and physical property data banks.

Suggested Text Books:

1. Luyben, W. L., Process Modeling, Simulation, and Control for Chemical Engineering, 6th ed. McGraw-Hill Education, 2016.
2. Denn, M.M. Process Modelling, Wiley, New York, 1990.
3. Hussain Asghar, "Chemical Process Simulation", Wiley Eastern Ltd., New Delhi, 1986.
4. Holland C.D. and Liapis, A.I. Computer Methods for Solving Dynamic Separation Problems, McGraw Hill, 1983.

Suggested Reference Books:

1. Holland, C.D. Fundamentals of Modelling Separation Processes, Prentice Hall, 1975.
2. Walas, S.M. Modelling with Differential Equations in Chemical Engineering, Butterworth, 1991.

ARTIFICIAL INTELLIGENCE IN CHEMICAL ENGINEERING

NCH 507

Assessment:

Sessional: 50 marks End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives:

- To introduce the principles and applications of artificial intelligence (AI) in chemical engineering.
- To understand various AI techniques and their implementation in solving chemical engineering problems.
- To explore case studies and real-world applications of AI in the chemical industry.
- To develop the ability to apply AI tools for optimization, control, and data analysis in chemical engineering processes.
- To assess the impact of AI on the future of chemical engineering.

Course Outcomes:

Students completing the course will be able to

CO1	Understand the fundamental concepts of AI and machine learning.	Remember, Understand
CO2	Apply Supervised machine learning techniques for chemical engineering applications	Apply, Evaluate
CO3	Apply Unsupervised machine learning techniques for chemical engineering applications	Apply, Evaluate
CO4	Develop AI models and algorithms for process modelling, optimization, and control.	Apply, Create
CO5	Assess the ethical implications and future trends of AI in chemical engineering.	Analyze, Apply

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	3	-	-	-	-	-	1	2
CO2	3	3	3	2	3	-	-	-	-	-	1	2
CO3	3	2	2	3	2	-	-	-	-	-	1	2
CO4	3	3	2	2	2	-	-	-	-	-	-	2
CO5	3	3	2	3	3	-	-	-	-	-	-	2
Avg	3	2.8	2.2	2.4	2.4	0	0	0	0	0	1	2

Unit 1: Introduction to AI, Machine Learning, and Data Analysis

Overview of AI and its evolution, development of AI, Key concepts and definitions, Machine Learning Basics, supervised, unsupervised, and reinforcement learning, Applications of AI in Chemical Engineering, Methods of data collection in chemical engineering, Data storage and management techniques, Data Preprocessing Techniques, Data cleaning and normalization, Feature extraction and selection

Unit 2: Supervised Machine Learning

Regression Analysis - Linear and non-linear regression techniques, Applications in process modelling and optimization, Classification Algorithms, Decision trees, random forests, support vector machines, and neural networks, Applications in quality control and predictive maintenance, Performance Evaluation, Metrics for evaluating supervised learning models, Implementation of supervised learning in chemical engineering scenarios

Unit 3: Unsupervised Machine Learning

Clustering Techniques, K-means, hierarchical clustering, and DBSCAN, Applications in process

monitoring and anomaly detection, Dimensionality Reduction, Principal component analysis (PCA) and t-SNE, Applications in data visualization and noise reduction, Association Rule Learning, Apriori and Eclat algorithms, in chemical process optimization, Implementation of unsupervised learning in chemical engineering scenarios

Unit 4: Process Modeling and Optimization

AI in Process Modeling, Development of AI-based models for chemical processes, Case studies on AI applications in process modeling, Optimization Techniques-Genetic algorithms, particle swarm optimization, and simulated annealing, Applications in process optimization and control, Use of AI in process simulation and predictive analytics

Unit 5: Advanced Topics and Future Trends

Introduction to deep learning and neural networks, Applications of deep learning in chemical engineering, AI in Materials Science and Discovery, Role of AI in discovering new materials and catalysts, Case studies on AI-driven materials research, Ethics and Challenges in AI, Challenges and limitations of AI in chemical engineering, Future Trends and Innovations, Emerging trends in AI and their potential impact on the chemical industry, Preparing for the future: skills and knowledge required for AI in chemical engineering

Text Book:

1. Lindholm, Andreas, et al. *Machine learning: a first course for engineers and scientists*. Cambridge University Press, 2022.
2. Chowdhary, K. R. *Fundamentals of artificial intelligence*. New Delhi: Springer India, 2020.

Reference Books

3. Hopgood, Adrian A. *Intelligent systems for engineers and scientists: a practical guide to artificial intelligence*. CRC press, 2021.
4. Hunt, Earl B. *Artificial intelligence*. Academic Press, 2014.

TCH 509 ADVANCED MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: To give students an insight in various Chemical Engineering processes using advanced analytical methods and provide adequate background of Mathematics to deal with Chemical Engineering Problems, to understand research papers on relevant topics involving advanced Mathematics.

Course Outcomes:

Students completing the course will be able to

CO1	Solve problems of algebraic equations	Understand, Apply,
CO2	Solve problems of differential equations and simultaneous equations	Apply, Evaluate
CO3	Solve problems of partial differential equations	Analyse, Evaluate
CO4	Apply Frobinious method to solve Bessel equation	Apply, Evaluate, Create
CO5	Apply Frobinious method to solve hypergeometric equation	Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	3	-	-	-	-	-	1	1
CO2	3	3	3	2	3	-	-	-	-	-	1	1
CO3	3	2	2	3	2	-	-	-	-	-	1	1
CO4	3	3	2	2	2	-	-	-	-	-	-	-
CO5	3	3	2	3	2	-	-	-	-	-	-	-
Avg	3	2.8	2.2	2.4	2.4	0	0	0	0	0	1	1

Module 1 (12 Lectures)

Ordinary Differential Equations, Separable equations, Equations made separable by change of variables, Homogeneous Equations, Equations with first order and first degree with linear coefficients, Exact equations, Linear equation of first order, Bernoulli's equation, Other integrating factors, Integration of Exact equations, Equations of first order and higher degree, Clairaut's equation, Singular solutions, Equations with missing terms, General properties of

Linear equations, Linear equations with constant coefficients, Determination of the complementary function, exponential functions, Determination of the particular integral, the Euler equation, Simultaneous Linear Differential equations.

Module 2 (6 Lectures)

Power series method, theory of the power series method, Legendre's equation, Legendre's Polynomials, Frobenius Method.

Module 3 (6 Lectures)

Bessel's equation, Bessel Functions $J_v(x)$, Bessel Functions $J_v(x)$ for any $v \geq 0$. Gamma Function, Solution $J_{-v}(x)$ of the Bessel Equation, Backbones of Bessel's Theory, $J_v(x)$ with $v = \pm 1/2, \pm 3/2, \pm 5/2$.

Module 4 (8 Lectures)

Definition of matrix, some special definitions and operations involving matrices, Determinants, Theorems on determinants, Inverse of a matrix, Orthogonal and unitary matrix. Orthogonal vectors, System of linear equations, Systems on n equations with n unknowns, Cramer's Rule, Eigen values and Eigen vectors.

Module 5 (8 Lectures)

Partial Differential equations, some definitions involving partial differential equations, linear partial differential equations, some important partial differential equations, Method of solving boundary-value problems, General solutions, Separation of variables, Laplace transform methods.

Suggested Text Books

1. Mickley, Reid and Sherwood, "Applied Mathematics in Chemical Engineering", Tata McGraw Hill, New Delhi (1981).
2. E. Kreyszig, "Advanced Engineering Mathematics", 8th edition, John Wiley and Sons (1999).

Suggested Reference Books

1. M. R. Spiegel, "Advanced Mathematics for Engineers and Scientists", Schaum Outline Series, McGraw Hill, (1971).

NCH 519**INSTRUMENTAL METHODS OF ANALYSIS****Assessment:**

Sessional: 50 marks End

Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objective:

This course introduces theoretical principles behind modern analytical instrumentation

techniques and practical considerations, scope and limitations of each of them.

Course Outcomes:

Students completing the course will be able to

CO1	Select a suitable method for analysis of a given sample	Understand, Apply
CO2	Analyze the data obtained from any technique to infer meaningful results.	Apply, Evaluate
CO3	Identify the scope and limitations of various techniques.	Analyze, Evaluate
CO4	Identify sources of error in each technique and minimize the errors incurred in analysis.	Understand, Apply, Evaluate
CO5	Design the instrument for basic parameters testing.	Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	-	-	-	-	-	-	-	-
CO2	3	2	1	1	-	-	-	-	-	-	-	-
CO3	3	2	3	2	3	-	-	-	-	-	-	-
CO4	3	3	2	2	3	-	-	-	-	-	-	-
CO5	3	3	3	3	2	-	-	-	-	-	-	-
Avg	3	2.6	2.2	1.8	2.75	0	0	0	0	0	0	0

Module 1 (9 Lectures)

Introduction to spectroscopic techniques, UV - Vis Spectrophotometry, Nephelometry, Turbidimetry, Reflectance Spectrometry, Fluorescence, Phosphorescence Spectrometry.

Module 2 (8 Lectures)

Flame Emission and Atomic Absorption Spectrometry, Electro thermal AAS, Hydride generation AAS and Flameless mercury analysis. Inductively Coupled Plasma Atomic Emission Analysis.

Module 3 (9 Lectures)

Infrared spectrometry, Introduction to X-Ray techniques, XRF. Introduction to NMR spectroscopy and mass spectrometry.

Module 4 (7 Lectures)

Electro analytical techniques: Potentiometry, Voltametry, Polarography Chromatographic analysis: GC, LC

Module 5 (7 Lectures)

Chromatographic analysis, HPLC, Hyphenated techniques. Errors, statistical methods of data handling

Suggested Text Books:

1. H. Willard, L.L Meritt, J.A Dean and F.A. Settle: Instrumental Methods of Analysis, 6th Edition, CBS.
2. A.I. Vogel: Quantitative Inorganic Analysis, 5th Edition, ELBS.

Suggested Reference Books:

1. G.W. Ewing: Analytical Instrumentation Hand book, Marcell Dekker, New York, 1990.

NCH 502 ADVANCED TRANSPORT PHENOMENA

Assessment:

Sessional: 50 marks End

Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objective: The course will accustom the students with import topics in advanced transport phenomena (momentum, heat and mass transport). The focus will be to develop physical understanding of principles discussed and with emphasis on chemical engineering applications. In addition to the text, the student will be exposed to classic and current literature in the field.

Course Outcome:

Students completing the course will be able to

CO1	Set up and solve differential momentum, heat, and mass balances for 1-D steady state problems and quasi-steady-state problems occurring in laminar and turbulent flows in terms of vector and tensor fluxes.	Understand, Apply
CO2	Formulate conservation statements in heat, mass, and momentum at multiscale from microscopic to macroscopic in both steady and unsteady modes.	Apply, Evaluate
CO3	Analyze advanced transport problems in heat, mass, and momentum, both macroscopic and microscopic, formulate simultaneous energy and mass balances in chemical processes.	Analyse, Evaluate
CO4	Understanding of differential equation application in transport of heat, fluid and mass.	Understand, Evaluate
CO5	Conceptual understanding of heat, fluid and mass transfer.	Understand, Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	-	-	-	-	-	-	-	-
CO2	3	2	1	1	-	-	-	-	-	-	-	-
CO3	3	3	3	2	3	-	-	-	-	-	-	-
CO4	3	3	3	2	3	-	-	-	-	-	-	-
CO5	3	3	3	3	2	-	-	-	-	-	-	-
Avg	3	2.8	2.4	1.8	2.75	0	0	0	0	0	0	0

Module 1 (6 Lectures)

Philosophy and fundamentals of three transport phenomena: Importance of transport phenomena; analogous nature of transfer process; basic concepts, conservation laws.

Molecular transport of momentum, Heat and mass, laws of molecular transport, Newton's law of viscosity, Fourier law of heat conduction, and Fick's law of diffusion. Transport coefficients – viscosity, thermal conductivity, and mass diffusivity. Estimation of transport coefficients and temperature / pressure dependence.

Module 2 (8 Lectures)

one dimensional transport in laminar flow (shell balance): Newtonian and non-Newtonian fluids, General method of shell balance approach to transfer problems; Choosing the shape of the shell; most common boundary conditions; momentum flux and velocity distribution for flow of Newtonian fluids in pipes, for flow of Newtonian fluids in planes, slits and annulus, Time derivatives, The equation of continuity, the equation of motion, the equations of change in curvilinear, co-ordinates, use of the equations of change to set up steady flow problems.

Module 3 (9 Lectures)

Unsteady state momentum transport, Flow near a wall suddenly set in motion, Momentum transport phenomena in turbulent flow. Definitions of friction factors, friction factor for flow in tubes, for flow around spheres, for packed bed column.

Module 4 (9 Lectures)

shell energy balance, boundary conditions, Heat conduction with an electrical heat source, Heat conduction in a cooling fin, heat conduction with exothermic reactions. Temperature distributions with more than one independent variables: Unsteady state heat conduction in solids, Boundary layer theory.

Module 5 (8 Lectures)

Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity, Maxwell's law of diffusion. Shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with heterogeneous chemical reaction, Diffusion with homogeneous chemical reaction, Diffusion in to a falling liquid film.

Suggested Text Books:

1. R.B. Bird, W.E. Stewart and Lighfoot, E.W., Transport Phenomena, 2nd Edition. John Wiley, 2002
2. Wilty J.R., Wilson, R.W. and Wicks, C.W., Fundamentals of Momentum Heat and Mass Transfer, 4th Edition, John Wiley, New York, 2001

Suggested Reference Books:

1. Christie J. Geankopolis, Transport Processes and Separation Process Principles 4th Edition. Printice-Hall, 2003
2. Brodkey, R.S. and Hershey H.C., Transport Phenomena – A Unified Approach, McGraw Hill, 1988

NCH 504 ADVANCED SEPARATION PROCESSES

Assessment:

Sessional: 50 marks End

Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: To learn the principle and technical concept of advanced separation processes. Create awareness among students with new and unconventional separation processes, Acquire sufficient knowledge in energy intensive processes for separation of components, Students will be equipped with the applications in Down-streaming processes

Course Outcome:

Students completing the course will be able to

CO1	Analyze multicomponent distillation using shortcut methods.	Understand, Apply
CO2	Calculate the enhancement factor for absorption with chemical reactions and estimate the effect of reversibility of chemical reaction on the mass transfer rate.	Apply, Evaluate
CO3	Select a suitable membrane for a given separation process and determine the effect of process variables on gas separation by membranes.	Analyze, Evaluate
CO4	Analyze the effect of process variables on Reverse osmosis membrane processes and Ultrafiltration membrane processes.	Analyze, Apply, Evaluate
CO5	Explain Supercritical fluid extraction, Supercritical fluid chromatography, and Supercritical fluid reactions.	Understand, Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	2	-	-	-	-	-	-	-	-
CO2	3	3	1	1	-	-	-	-	-	-	-	-
CO3	3	2	1	2	-	-	-	-	-	-	-	-
CO4	3	2	2	2	2	-	-	-	-	-	-	-
CO5	3	1	3	3	2	-	-	-	-	-	-	-
Avg	3	1.8	1.6	2	0.8	0	0	0	0	0	0	0

Module 1 (5 Lectures)

Fundamentals of separation process, Review of Distillation, Multi component distillation –Bubble point and dew point calculations and Short cut methods, Azeotropic distillation; Extractive distillation; Molecular distillation; Reactive distillation

Module 2 (8 Lectures)

Absorption with chemical reaction; Enhancement factor; Simultaneous diffusion and chemical reaction near an interface – Film theory, Penetration theory, Surface renewal theory Surfactant based separation processes: Liquid membranes: fundamentals and modeling. , Micellar enhanced separation processes, Cloud point extraction.

Module 3 (8 Lectures)

Supercritical fluid extraction – Supercritical fluids, Phase equilibria, Industrial applications; Important supercritical processes – Decaffination of coffee, Extraction of oil from seeds, Residuum oil supercritical extraction (ROSE), Supercritical fluid chromatography, Supercritical fluid reactions etc. Centrifugal Separation processes chromatographic separation processes

Module 4 (10 Lectures)

Classification of membrane processes; Liquid permeation membrane processes or dialysis – Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis; Gas permeation membrane processes – Types of membranes and permeabilities for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes); Types of flow in gas permeation; Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes; Effect of processing variables on gas separation by membranes

Module 5 (9 Lectures)

Reverse osmosis membrane processes – Osmotic pressure of solution, flux equation, Types of equipment and Complete mixing model; Effect of operating variables; Concentration polarization; Permeability constants

Ultrafiltration membrane processes – Types of equipment, flux equation, effects of processing variables

Suggested Text Books:

1. Geankoplis, C. J., Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
2. Sherwood, T. K., Pigford R. L., and Wilke, C.R., Mass Transfer, McGraw-Hill, New York, 1975.

Suggested Reference Books:

1. Treybal, R. E., Mass-Transfer Operations, McGraw-Hill, New York, 1980.
2. Latest articles from journals

NCH 522 OPTIMIZATION OF CHEMICAL PROCESSES

Assessment:

Sessionals: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objective: To understand the concepts and origin of the different optimization methods. To get a broad picture of the various applications of optimization methods used in Chemical Engineering. Optimizes different methods in industry for design and production, both economically and efficiently.

Course Outcome:

Students completing the course will be able to

CO1	Demonstrate comprehensive understanding of various optimization techniques.	Understand
CO2	Formulate various process optimization problems.	Apply, Evaluate
CO3	Explain the need for optimization where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives.	Analyse, Evaluate
CO4	Implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques.	Understand, Apply,
CO5	Identify, formulate and solve a practical engineering problem of their interest by applying or modifying an optimization technique.	Understand, Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	1	2	1	-	-	-	-	-	-	-
CO2	3	3	1	2	1	-	-	-	-	-	-	-
CO3	3	2	3	2	1	-	-	-	-	-	-	-
CO4	3	1	2	1	3	-	-	-	-	-	-	-
CO5	3	3	2	3	2	-	-	-	-	-	-	1
Avg	3	2.2	1.8	2	1.6	0	0	0	0	0	0	1

Module (7 Lectures)

Introduction to process optimization; formulation of various process optimization problems and their classification, Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.

Module 2 (10 Lectures)

Optimization of one-dimensional functions, unconstrained multivariable optimization- direct search methods. Bracketing methods: Exhaustive search method, Bounding phase method

Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic estimation method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method. Root-finding using optimization techniques.

Module 3 (7 Lectures)

Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers, Direct search for constraint minimization: Variable elimination method, complex search method.

Module 4 (6 Lectures)

Linear Programming: Graphical solution, Primal Simplex method, Artificial starting solution, Dual Simplex method, Primal-Dual relationship, Duality, Sensitivity analysis. Revised Simplex method.

Module 5 (10 Lectures)

Transportation Problem, Optimization of staged and discrete processes. Dynamic programming, Specialized & Nontraditional optimization techniques: Simulated annealing; Genetic algorithms; Differential evolution. Application of optimization in the design of separation process, chemical reactor and large-scale process plant.

Suggested Text books:

1. Edgar T. F., and Himmelblau, D. M., Optimization of Chemical Processes, Mc GrawHill, International editions, chemical engineering series, 1989.
2. G.S. Beveridge and R.S. Schechter, Optimization theory and practice, Mc GrawHill, New York, 1970.
3. Hamdy A. Taha, Operation Research, Pearson, 2008

Suggested Reference Books:

1. Reklitis, G.V., Ravindran, A., and Ragdell, K.M., Engineering Optimization-Methods and Applications, John Wiley, New York, 1983.
2. Latest articles from journal

NCH 508 STATISTICAL DESIGN OF EXPERIMENTS

Assessment:

Sessionals: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: The aim of the course is to give competences in the field of applied statistical methods for work concerning planning and analysis of experiments, regression analysis, optimization of processes and multivariate analysis.

Course Outcome:

Students completing the course will be able to

CO1	Understand the importance of randomization and replication of experimental data set.	Understand, Apply
CO2	Estimate statistical variance and perform analysis of variance, regression analysis, correlation analysis on a given experimental data	Apply, Evaluate
CO3	Design full factorial and fractional factorial experiments and analyse the data	Analyse, Evaluate, Apply
CO4	Develop nested designs, block designs and response surface designs	Understand, Evaluate
CO5	Recognize what design was followed and perform the appropriate analysis given the description of how a set of data was collected.	Analyse, Apply, Evaluate

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	1	1	-	-	-	-	-	-	-
CO2	3	3	2	2	1	-	-	-	-	-	-	-
CO3	3	2	3	3	2	-	-	-	-	-	-	-
CO4	3	3	3	2	1	-	-	-	-	-	-	-
CO5	3	3	2	3	2	-	-	-	-	-	-	-
Avg	3	2.6	2.4	2.2	1.4	0	0	0	0	0	0	0

Module 1 (7 Lectures)

Introduction to statistics for engineers: Simplest discrete and continuous distributions, Statistical inference, Statistical estimation, tests and estimates on statistical variance, Analysis of variance, Regression analysis (Simple linear, multiple, polynomial, nonlinear), Correlation analysis (Correlation in linear regression, correlation in multiple linear regression)

Module 2 (8 Lectures)

Design and analysis of experiments: Introduction to design of experiments, Preliminary examination of subject of research, Screening experiments

Basic experiment-mathematical modeling: Full factorial experiments and fractional factorial experiments, Second-order rotatable design (Box-Wilson design).

Module 3 (9 Lectures)

Orthogonal second order design (Box Benken design), D-optimality, Bk-designs and Hartleys second order design.

Statistical analysis: Determination of experimental error, Significance of the regression coefficients, Lack of fit of regression models

Module 4 (7 Lectures)

Experimental optimization of research subject: Problem of optimization, Gradient optimization method, canonical analysis of response surface.

Module 5 (9 Lectures)

Mixture design `composition-property': Screening design `composition-property', Simplex lattice design, Scheffe simplex lattice design, Simplex centroid design, Extreme vertices design, D-optimal design, Draper-Lawrence design, Factorial experiments with mixture, Full factorial combined with mixture design.

Suggested Text Books:

1. Z. R. Lazic, Design of experiments in chemical engineering: A practical guide, Wiley, 2005.

NCH 510 NANOMATERIALS IN SCIENCE & ENGINEERING

Assessment:

Sessionals: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: • This course aims to provide a broad overview of fundamental principles and laws governing the properties at nanometer scale. Students will learn various top down and bottom up approaches for nanostructure synthesis and experimental techniques to characterize them. This course will also introduce various applications of nanotechnology in chemical engineering.

Course Outcomes:

Students completing the course will be able to

CO1	Describe the basic science behind the novel and superior properties of materials at the nanometer scale	Remember, Understand,
CO2	Demonstrate a comprehensive understanding of the state-of-the-art nanofabrication methods	Understand, Apply
CO3	Compare and select suitable techniques for characterization of a given nanomaterial	Understand, Apply
CO4	Explain how nanotechnology can be put to use in varied areas of science and engineering	Apply, Analyze
CO5	Evaluate the impact of nanotechnology on society and environment. Evaluate current constraints such as regulatory, ethical, political, social and economic; when putting nanotechnology to use.	Understand, Apply, Evaluate, Analyze

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	3	1	-	-	-	-	-	1
CO2	3	3	1	1	2	-	-	-	-	-	-	1
CO3	3	3	3	2	3	-	-	-	-	-	-	1
CO4	3	2	1	2	3	-	-	-	-	-	-	-
CO5	3	2	3	3	2	-	-	-	-	-	-	3
Avg	3	2.2	1.8	1.8	2.6	1	0	0	0	0	0	1.5

Module 1 (6 hours): Introduction to Nanotechnology

Emergence and challenges, Nanomaterials and its classification, Properties of individual nanoparticles, Methods of synthesis, Reactivity of nanoparticles, List of stable carbon allotropes extended, Synthesis of carbon Bucky balls, Fullerenes, Metallo-fullerenes, solid C60, Nanotubes, Nanowires, Carbon nanostructures.

Module 2 (6 hours): Synthesis of Nanomaterials

Methods of synthesis of Nanomaterials: Bottom-up (building from molecular level) and Top-down (breakdown of bulk/microcrystalline materials) approaches. Manufacturing of nanoscale materials: Chemical vapor deposition of carbon nano tubes, Plasma deposition of ultra thin

functional films on Nanomaterials, Solution based Synthesis of Nanoparticles, Vapour Phase Synthesis & Synthesis with framework, Nanolithography, Dip Pen Lithography. Artificially Layered Materials: Quantum Well, Quantum Dots.

Module 3 (6 hours): Characterization of Nanomaterials

Optical Microscopy, Electron Microscopy, Secondary electron scattering, Back scattering, Scanning Probe Microscopes, Focused Ion Beam Technique, X-ray imaging, Transmission Electron Microscope (TEM), Scanning Probe Microscope (SPM)- Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM).

Module 4 (6 hours): Classification of Nano-materials

Amorphous, Crystalline, microcrystalline, quasi-crystalline and nano-crystalline materials, Intermolecular forces, Aqueous, Biological, Van der-waal, Electro static, Double layer forces.

Module 5 (6 hours): Applications of Nano-materials

Nano biotechnology: Drug Delivery, Nanoclay, Nanocomposites, Surface coatings, Selfcleaning Materials, Hydrophobic Nanoparticles, Biological nanomaterials, Nano electronics, Nano machines & Nano devices, Nano hydrogel, Photocatalytic reactors, Nano clay Synthesis, Polymer nanocomposite, Waste Water Treatment, Societal, Health and Environmental Impacts, Introduction to industries which produces commercial nanomaterials.

Suggested Text Books

1. G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, Introduction to NanoScience, CRC Press of Taylor and Francis Group, 2008
2. Pools C.P. and Owens F.J., Introduction to Nanotechnology, Wiley-Interscience, 2003
3. G.Cao, Nanostructures and Nanomaterials, Synthesis, Properties and Applications, Imperial College Press, 2004.

Suggested Reference Books

1. Bhusan B., Springer Handbook of Nanotechnology, 4th Ed., 2017

TCH 514 WATER POLLUTION MONITORING AND CONTROL

Assessment:

Sessionals: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course objectives:

- To create awareness about importance of water and effects of Waste water.
- To familiarize the students with the concepts of Physical and biological wastewater treatment

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

CO1	Understand the nature of Wastewater and fundamentals of physical treatment process such as Aeration ,Coagulation and Flocculation, Setting and Sedimentation, Filtration Adsorption & Ion Exchange	Remember, Understand, Apply
CO2	Gaining knowledge about Membrane and Advance treatment processes	Understand, Apply,
CO3	Learn the methods for Biological Treatment of waste waster.	Understand, Analyse,
CO4	Analyze the Aerobic and anaerobic Biological Treatment of waste waster	Understand, Evaluate
CO5	Learn the methods of Sludge Management	Understand, analyse

Course Articulation Matrix:

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

UNIT 1:

Introduction to Water Pollution and Control, Pre-treatment & Physical treatment: Flow equalization & Aeration Pre-treatment & Physical treatment: Coagulation and Flocculation Setting and Sedimentation & Settling Chamber Design Filtration & Filtration System Design Wastewater treatment by Adsorption & Ion Exchange

UNIT 2:

Wastewater treatment by Membrane Based Technologies, Advanced Oxidation Processes: Introduction, Fenton and catalytic treatment Photo-induced processes, Sono- and Electro-chemical Treatment.

UNIT III

Biological treatment fundamentals: Microbiology and ecology, Fundamentals of Biochemical Operations; Conversion processes of organic and inorganic matter. Wastewater characterization; Modeling of biological treatment processes: Stoichiometric, reaction and bacterial growth kinetics; reactor hydraulics. Mass and heat balance, Aeration and sedimentation.

UNIT IV

Classification of biological treatment Processes. Biological nitrification, denitrification, and phosphorus removal , Aerobic Biological Treatment Processes: Aerated lagoon, activated sludge systems, trickling filter, rotating disc reactors; sequential batch reactor..

Anaerobic Biological Treatment Processes: UASB, and hybrid UASB reactors, bio towers. Advanced Biological Wastewater Treatment: Fluidized bed bioreactors; Membrane bioreactors (MBRs); Moving bed bio film reactor (MBBR), biological nitrogen removal

UNIT V

Sludge Management: Sludge characteristics, production, stabilization; thickening and dewatering; pathogen removal; sludge transformation and disposal methods, Sustainability in wastewater treatment plant designing; greater water availability; lower energy and chemical consumption; resource recovery. Case studies on few process industries

TEXT BOOKS:

1. Weber, W.J., “Physico-chemical Processes”, Wiley Interscience, 1983.
2. Eckenfelder W.W., “Industrial Water Pollution Control”, 2nd Ed., McGraw Hill, 1999.
3. Tchobanoglous G., Burton F.L., Stensel H.D., “Metcalf and Eddy Inc.- Waste Water Engineering Treatment and Reuse”, Tata McGraw-Hill, 2017

Reference Books:

4. Henze M., van-Loosdrecht M.C.M., Ekama G.A. and Brdjanovic D., “Biological Wastewater Treatment: Principles, Modelling and Design”, IWA publishing, 2008.
5. Márcia Dezotti, Geraldo Lippel, João Paulo Bassin, Advanced Biological Processes for Wastewater Treatment: Emerging, Consolidated Technologies and Introduction to Molecular Techniques, Springer Nature, 2018.
6. Davide Dionisi. Biological wastewater treatment processes: mass and heat balances. CRC Press, 2017.
7. Marcos von Sperling, Basic Principles of Wastewater Treatment. IWA Publishing, 2007.

PLANT SAFETY HAZARD AND RISK ASSESSMENT
NCH 601

Assessment:

Sessional: 50 marks End

Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives: Study of plant safety is an essential requirement providing an overview of the safety regulations and practices, plant hazards and their control, risk assessment and management along with accident analysis. The skills of safety/energy management, audit and risk analysis prepares the plant technical and operating team to emerge to a safe protocol and minimize potential damages to personnel, process equipment and the environment.

Course Outcomes:

Students completing the course will be able to

CO1	Identification of key concepts of safety, hazards, risk assessment and distinguishing typical sources of risk and hazard in a process plant	Understand, Apply
CO2	Develop an understanding/assessing of severity and the consequences of incidents and toxicological aspects	Understand, Analyze, Evaluate
CO3	Undertake a Hazard and Operability Study (HAZOP) for the identification of hazard, chances of occurring and consequences	Understand, Apply, Analyze, Evaluate
CO4	Getting aware about the various government/investigating agency for the analysis of safety related to process, environmental and human reliability and relevant aspects	Understand, Apply
CO5	Understanding the root cause and technical aspects of incidents and generating process design for reliable operations	Understand, Apply, Analyze, Create

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	1	1	2	2	-	-	2	-	3
CO2	3	2	1	1	1	2	2	-	-	2	-	2
CO3	3	3	2	1	1	1	2	1	-	2	2	3
CO4	3	3	2	1	2	1	2	1	-	2	1	3
CO5	3	3	2	1	2	3	2	1	-	2	2	3
Avg.	3.00	2.60	1.80	1.00	1.40	1.80	2.00	0.60	-	2.00	1.00	2.80

Module 1 (8 hours)

Introduction, key concepts: Safety, Hazard and Risk, nature of the accident process, inherent safety. OSHA, fatal accident, fatality rate. The accident Process: Initiation, Propagation, and Termination. Review of major chemical industry accidents. Toxicological studies, Dose versus response curves, Relative toxicity, Threshold Limit Values. Storage and handling of flammable and toxic chemicals.

Module 2 (8 hours)

Industrial Hygiene: Regulations, Identification, Evaluation and Control. Safety aspects related to

toxicity, noise, pressure, temperature, vibrations, radiation etc. MSDS, source models, fire triangle, flammability characteristics of liquids and vapors, flammability limit estimation, LOC and inerting, ignition energy, auto-ignition, auto-oxidation. VCE, BLEVE, vacuum and pressure purging, static electricity. Explosion proof equipment and instruments.

Module 3 (8 hours)

Identification of reactive chemical hazards, relief concept and types, relief systems, relief sizing. Hazard identification and risk assessment. Hazard and operability study (HAZOP); procedure and application. Probability theory and interaction between process units. Fault tree and event tree analysis. Hazard models and risk data.

Module 4 (8 hours)

Technology and process selection. Process safety strategies, safety reviews and accident investigations, process uncertainties, reliability engineering and economics of loss prevention. Design for process safety. Safety laws and regulations: Agencies involved.

Module 5 (8 hours)

Protections against fire, explosion and toxic hazards. Tackling disasters, plan for emergency. Risk management routines, Emergency shutdown systems, well integrated processes, process design for reliable operations. Introduction to safety audits. Occupational health and safety impacts of different industry sectors.

Suggested Text Books

1. Crowl D. A. and Louvar J. F., Chemical Process Safety: Fundamentals with applications, 3rd edition, Pearson 2014.
2. Lees', Loss prevention in the process Industries, 4th edition, Butterworth-Heinemann, 2012.

Suggested Reference Book

3. Wells G. L., Safety in Process Plant Design, John Wiley and Sons, 1980

DESIGN OF PIPING SYSTEM FOR CHEMICAL PLANTS

NCH 603

Assessment:

Sessionals: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objective:

The primary goal of this course is to provide an overview of state-of-the-art pipeline design, and the theoretical principles that underpin them. The aim is to provide students with the skills necessary to describe and formulate design problems and their use for solving several types of practically relevant pipeline design problems arising in pipeline industries.

Course Outcomes:

CO1	Understand the fundamentals for calculating the properties of compressible and non-compressible fluids	Remember, Understand
CO2	Apply the various equations and concepts for calculating pressure drop in compressible and non-compressible fluids	Apply, Evaluate
CO3	Understanding the process of laying, constructing, and operating of pipelines	Apply, Evaluate
CO4	Apply the knowledge of pumps and compressors used for oil and gas pipeline operations.	Apply, Evaluate, Analyze
CO5	Develop an understanding in problems incurred in operating the cross-country pipelines and methods to mitigate them	Understand, Analyze, Create

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	1	-	-	1	-	-	1	-	1
CO2	2	2	3	2	1	-	1	-	-	-	1	1
CO3	3	2	3	2	1	1	1	-	-	-	1	1
CO4	2	3	3	2	1	1	-	-	-	-	1	1
CO5	2	2	3	2	2	-	1	-	1	-	1	1
Avg	2.5	2.14	2.5	1.8	1.25	1.0	1.0	-	1.0	1.0	1.0	1

SYLLABUS

UNIT 1 (8 Lectures)

Modes of Transporting Oil & Gas, Importance of Pipelines, Pipeline Systems, Design Life of Pipelines, Size and Cost of Pipelines, History of Pipelines in India, Major Codes and Standards in

Pipeline, NPS Chart, Gases: Volume/Specific Gravity/Viscosity/Average Molecular Weight Compressibility Factor/Average Pressure Calculation/Heating Value Liquids: Mass/Volume/Specific Weight/API Gravity(Dependency on Temperature)/Specific Gravity of Blended Liquids/Viscosities of Liquid Mixtures(Variation with Temperature)/Bulk Modulus/Vapor Pressure, Design of piping and pipeline systems

UNIT 2: (10 Lectures)

Pressure Drop Calculations: A Incompressible fluids: Converting Pressure to Head Velocity of Liquid in Pipelines, Pressure Drop Equations (Hagen Williams Equation, Shell MIT Equation, Miller Equation) Looping and Branching in Pipeline (Gas and Liquid) B. Compressible fluids: Gas: Flow Equations, Generalized Flow Equation, Weymouth Equation, Panhandle A equation, Panhandle B Equation. Transmission Factor, Effect of Pipeline Elevation (Single Slope, Multiple Slope) Velocity of Gas in Pipeline, Erosional Velocity, Reynolds Number (gas pipeline), Friction Factor Calculations, optimum diameter calculations.

UNIT 3: (8 Lectures)

Pipeline Construction, Pipeline Laying, Pipe Specifications, Route Surveying, Trenching, Welding, Wrapping Pig launchers and receivers

UNIT 4: (8 Lectures)

Pumps and Compressors, Types of Pumps and Compressors, Pumps and Compressors Characteristics, Single and Multistage pumps and compressors, compressor location. Number of pumping stations

UNIT 5: (6 Lectures)

Pipeline issues and Mitigation Measures, Wax, Scaling, Condensate, Corrosion, Thermal Variations in Pipelines, Automation, and SCADA

Suggested Text Books

1. Menon, E. S. (2005). Gas pipeline hydraulics, CRC Press, Taylor and Francis Group, Boca Raton, FL.
2. Menon, E. S. (2005). Liquid pipeline hydraulics, CRC Press, Taylor and Francis Group, Boca Raton, FL.

Suggested Reference Books

1. E.W. McAllister (2002). Pipeline Rules of Thumb Handbook, Gulf Professional Publishing

POLYMER SCIENCE AND ENGINEERING
NCH 611

Assessment:

Sessionals: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objective: To provide fundamental and applied knowledge of polymer science and engineering

Course Outcome:

Students completing the course will be able to

CO1	Classify and differentiate the polymers on the basis of their thermal transitions and molecular weight	Remember, Apply, Analyze
CO2	Analyze the properties of natural, synthetic rubbers and sealants	Understand, Apply, Analyze
CO3	Select a suitable reinforcement material for blending with plastics in order to improve the mechanical properties	Understand, Apply
CO4	Analyze the various polymers processing techniques to select a suitable processing and manufacturing technique for a given polymer	Understand, Analyze, Create
CO5	Select suitable polymer for a given application	Understand, Analyze, Create

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	1	1	1	-	-	-	-	-	-	1
CO2	3	3	2	2	1	-	-	-	-	-	-	1
CO3	3	3	2	2	2	-	1	-	-	-	-	1
CO4	3	3	2	2	2	-	-	-	-	-	-	1
CO5	3	3	3	2	3	3	3	-	-	-	-	3
Avg	3	3	2	1.8	1.8	0.6	0.8	0	0	0	0	1.4

Module 1 (8 Lectures)

Classification of polymers, Addition polymers, Condensation polymers, Copolymers, Cross-linked polymers, Molecular symmetry and the tendency to form crystals, Distribution of relative molecular mass, Structure of the crystal, crystal shape, Crystallization and melting, the glass transition temperature, Molecular weight characterization

Module 2 (8 Lectures)

Structure of an ideal rubber, Elasticity of a network, Stress-strain relationship, Engineering rubbers, rubber

toughening, Viscoelasticity, Creep, Polymer selection : stiffness, synthetic elastomers and sealants

Module 3 (8 Lectures)

Yielding, Elastic-plastic fracture mechanics, Brittle fracture of polymer, Reinforced plastics, Forming of reinforced plastics, Mechanics of fiber reinforcement, fiber treatment, Reinforced polymers, polymer nanocomposites

Module 4 (8 Lectures)

The flow properties of polymer melts, Mixing and compounding, Extrusion, Injection Compression, Transfer and Blow molding, Coating, Casting, polymer blends

Module 5 (8 Lectures)

Materials selection, designing for manufacture, designing for engineering properties enhancement, Biopolymers and biodegradation of polymers

Suggested Text Books

1. McCrum N. G., Buckley C. P. and Bucknall C. B., Principles of Polymer Engineering, 2nd Edition, Oxford University Press, (1997).
2. Billmeyer Fred W., Textbook of Polymer Science, Wiley Student Edition, Wiley India Pvt. Ltd.
3. Williams D. J., Polymer Science and Engineering, Prentice Hall, 1971
4. Kumar A., Gupta R. K., Fundamentals of Polymer Engineering, 3rd Edition, CRC Press, 2018

Waste to Energy NCH 605

Sessional: 50 marks

End Semester: 50 marks

Course objectives:

- To create awareness about methods for converting waste to Energy
- To familiarize the students with the concepts and chemistry of Pyrolysis, Gasification Transestification.

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

CO1	Understand the nature of Waste and energy conversion methods	Remember, Understand,
CO2	Gaining knowledge about Pyrolysis and gasification	Understand, Apply,
CO3	Learn the methods to create the energy from waste	Understand, Analyse,
CO4	Analyze the performance Fuel cell and management of organic Waste	Understand, Evaluate
CO5	Gain knowledge about Fermentation and transestification	Understand, Create

Course Articulation Matrix:

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

Unit I

Lecture 8

Introduction, Characterization of wastes. Energy production from wastes through incineration, energy production through gasification of wastes.

Unit II

Lecture 8

Energy production through pyrolysis and gasification of wastes, syngas utilization. Densification of solids and efficiency improvement

Unit III**Lecture 8**

Energy and chemicals production from waste plastics, rubber tyres, gas cleanup.

Unit IV**Lecture 8**

Energy production from organic wastes through anaerobic digestion and fermentation, Introduction to microbial fuel cells.

Unit V**Lecture 8**

Energy production from wastes through fermentation and transesterification. Cultivation of algal biomass from wastewater and energy production from algae.

TEXT BOOKS:

- 1) Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store.
- 2) Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons.
- 3) Harker, J.H. and Backhurst, J.R., "Fuel and Energy", Academic Press Inc.
- 4) EL-Halwagi, M.M., "Biogas Technology- Transfer and Diffusion", Elsevier Applied Science.
- 5) Hall, D.O. and Overreed, R.P., "Biomass - Renewable Energy", John Wiley and Sons.
- 6) Mondal, P. and Dalai, A.K. eds., 2017. Sustainable Utilization of Natural Resources. CRC Press.