Department of Chemical Engineering

Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

Institute Vision

To become a Globally Recognized Academic Institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the National needs.

Institute Mission

- To educate students at Undergraduate, Post Graduate Doctoral and Post-Doctoral levels to perform challenging engineering and managerial jobs in industry.
- To provide excellent research and development facilities to take up Ph.D. programmes and research projects.
- To develop effective teaching and learning skills and state of art research potential of the faculty.
- To build national capabilities in technology, education and research in emerging areas.
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society.

Department Vision

To be a centre of excellence for the provision of effective teaching/learning, skill development and research in the areas of chemical engineering and allied areas through the application of chemical engineering principles.

Department Mission

1) To educate and prepare graduate engineers with critical thinking skills in the areas of chemical engineering & polymer science and engineering, who will be the leaders in industry, academia and administrative services both at national and international levels.

2) To inculcate a fundamental knowledge base in undergraduate students which enable them to carry out post-graduate study, do innovative interdisciplinary doctoral research and to be engaged in long-life learning.

3) To train students in addressing the challenges in chemical, petrochemical, polymer and allied industries by developing sustainable and eco-friendly technologies.

Program Educational Objectives (PEOs) – M.TECH (Chemical Engineering)

PEO 1: To address complex industrial and technological problems through an advanced knowledge in chemical engineering to impart ability to discriminate, evaluate, analyze critically and design pertaining to state of art and innovative research.

PEO 2:To solve complex chemical Engineering problems with commensurate research methodologies as well as modern tools to evaluate a broad spectrum of feasible optimal solutions keeping in view socio- cultural and environmental factors.

PEO 3: To possess wisdom regarding group dynamics to efficaciously utilize opportunities for positive contribution to collaborative multidisciplinary engineering research and rational analysis to manage projects economically.

PEO 4: To communicate with engineering community and society at large adhering to relevant safety regulations as well as quality standards.

PEO 5: To inculcate the ability for life-long learning to acquire professional and intellectual integrity, ethics of scholarship and to reflect on individual action for corrective measures to prepare for leading edge position in industry, academia and research institutes.

Program Outcomes (PO)

A post graduate student must be able

PO1: to independently carry out research /investigation and development work to solve practical problems.

PO2: to write and present a substantial technical report/document.

PO3: to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO4: To prepare students for professional work in development, design, modelling, simulation, optimization and operation of chemical products and processes.

PO5: With due emphasis on interdisciplinary and industrial collaboration, students are prepared for employment in such industries as chemical, petroleum, electrochemical, biochemical, semiconductor, aerospace, plastics, paints and adhesives, rubber etc.

PO6: Prepare students with high scholastic attainment to pursue doctoral research in chemical engineering, Polymer Engineering and other inter-related professional, scientific, and engineering fields.

COURSE INFORMATION SHEET

Course code: CL501
Course title: Advanced Transport Phenomena – I
Pre-requisite(s): B.E./B.Tech. in Chemical Engineering.
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M. Tech.
Semester/Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To impart knowledge on momentum, heat and mass transfer in Chemical engineering systems and their analogous behaviour.

Course Outcomes:

After the completion of the course students will be able to:

CO1	Identify and describe mechanisms of transport phenomena, present in given isothermal and non-isothermal, laminar and turbulent flow systems.
CO2	Distinguish interrelations between the molecular, microscopic and macroscopic descriptions of transport phenomena.
CO3	Explain similarities and differences between the descriptions of the combined fluxes and the equations of change for mass, momentum and heat transport.
CO4	Apply the method of dimensional analysis to reformulate and then find the form of solutions of the equations of change, to determine the dependence of the interfacial fluxes on system parameters.
CO5	Elaborate conceptual and mathematical models, from conservation principles, to complicated systems involving simultaneous mass, momentum, and/or heat transfer processes as well as reactions or other sources/sinks of transport for multi-component mixtures.

SYLLABUS

Module I:

Vectors & Tensors: Geometric representation of vectors; Einstein summation convention; Basic review of vector algebra; Representation using Kronecker delta and alternating unit tensor; Review of vector calculus. Tensors: dyadic products with another tensor, vector etc; tensor operations required for stress analysis. (8L)

Module II:

Transport by molecular motion: Newton's law and viscosity, Fourier's law of Heat conduction., Fick's law of Diffusion. (8L)

Module III:

Kinematics: Motion, streamlines, pathlines and streaklines, Governing equations of fluid mechanics. Introduction: Equation of continuity, equation of motion, Euler equation, Bernoulli equation, Momentum boundary layer theory (Laminar boundary theory & turbulent boundary layer theory), dimensionless number and its significance. (8L)

Module IV:

Navier-stokes equation, creeping flow around a solid sphere, expression for total drag, Turbulent flow: Transition to turbulence, Prandtl' mixing length, Turbulence models. Boundary layer on immersed bodies, two dimensional boundary layer equation, laminar boundary layer on flat plate (Blasius exact solution), Von-Karmann's integral momentum equation, boundary layer separation flow and pressure drag, Flow of compressible fluids, thermodynamic considerations, continuity and momentum equation for one dimensional compressible flow, one dimensional normal shock, flow through fluidized beds. Navier-Stokes equation and various approaches of simulation (stream velocity, primitive variable).

(8L)

Module V:

Modes of heat transfer; concepts of (a) thermal conductivity – constant and temperature dependent, (b) thermal diffusivity and (c) heat transfer coefficient. Fourier's law of heat conduction. Shell energy balance and boundary conditions – Heat conduction with electrical, nuclear, viscous and chemical heat source, Heat conduction through composite walls, Heat conduction in fins. Free convection-flow between two vertical walls. (8L)

Books recommended:

TEXT BOOK

1. R.B. Bird, W.E. Stewart, and E.N. Lightfoot, Transport Phenomena, Second edition, John Wiley and Sons, 2002. **(T1)**
2. R.W. Fox, A.T. Mc Donald, P.J. Pritchard, Introduction to Fluid Mechanics, Willey, 6th edition. **(T2)**
3. Chemical Engineering by Coulson and Richardson, Volume I. **(T3)**

REFERENCE BOOK

1. The Flow of Complex Mixtures in Pipes by Govier and Aziz. **(R1)**
2. Non-Newtonian Flow and Heat Transfer by A. H. P. Skelland. **(R2)**
3. J.G. Knudsen and D.L. Katz, Fluid Dynamics and Heat Transfer, McGraw Hill, New York, 1958.**(R3)**

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations.

Gaps in the syllabus (to meet Industry/Profession requirements):
Numerical methods for solving industrial problems.
POs met through Gaps in the Syllabus: **PO5**

Topics beyond syllabus/Advanced topics/Design:
Numerical solution of fluid/heat/mass related industrial problems.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Tutorials/Assignments
CD3	Self- learning such as use of NPTEL materials and internets

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	3
CO2	3	1	-	3	-	3
CO3	3	1	-	3	2	3
CO4	3	1	3	3	-	3
CO5	3	2	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL502
Course title: Advanced Mathematical Techniques in Chemical Engineering
Pre-requisite(s): BE (Chemical Engineering) or equivalent
Co- requisite(s): NIL
Credits: 3 L:3 T:0 P:0
Class schedule per week: 3
Class: M. Tech.
Semester / Level: I/05
Branch: Chemical Engineering

Course Objectives:
This course enables the students:

1.	Introduction of vector space; Metric, Norm, Inner Product space.
2.	Develop appropriate methods solve a linear system of equations.
3.	Develop appropriate numerical methods to solve a ordinary differential equation (IVP).
4.	Develop appropriate numerical methods to solve a special ordinary differential equation.
5.	Develop appropriate numerical methods to solve a partial differential equation.

Course Outcomes:
After the completion of this course, students will be:

CO1	Familiar with vector space; Metric, Norm, Inner Product space.
CO2	Solve linear system of equations.
CO3	Evaluate a derivative at a value using an appropriate numerical method calculate a definite integral using an appropriate numerical method.
CO4	Solve a differential equation using an appropriate numerical method.
CO5	Solve a partial differential equation using an appropriate numerical method.

SYLLABUS

Module I:
Introduction of vector space, Metric, Norm, Inner Product space, completeness of space. Vectors: Linear combination of vectors, dependent/independent vectors; Orthogonal and orthonormal vectors; Gram-Schmidt orthogonalization; Examples. Contraction Mapping: Definition; Applications in Chemical Engineering with examples. Matrix, determinants and properties. (8L)

Module II:
Eigenvalue Problem: Various theorems, Solution of a set of algebraic equations, Solution of a set of ordinary differential equations, Solution of a set of non-homogeneous first order ordinary differential equations (IVPs). Applications of eigenvalue problems: Stability analysis, Bifurcation theory. (8L)

Module III:
Partial Differential equations: Classification of equations, Boundary conditions, Principle of Linear superposition. Special ODEs and Adjoint operators: Properties of adjoint operator, Theorem for eigenvalues and eigenfunctions. (8L)

Module IV:
Solution of linear, homogeneous PDEs by separation of variables: Cartesian coordinate system & different classes of PDEs, Cylindrical coordinate system, Spherical Coordinate system. (8L)

Module V:
Solution of non-homogeneous PDEs by Green's theorem, Solution of PDEs by Similarity solution method, Solution of PDEs by Integral method, Solution of PDEs by Laplace transformation, Solution of PDEs by Fourier transformation. (8L)

Books recommended:

TEXT BOOK

1. Mathematical Methods in Chemical Engineering by S. Pushpavanam, Prentice Hall of India. **(T1)**
2. Applied Mathematics and Modeling for Chemical Engineers by R. G. Rice & D. D. Do, Wiley. **(T2)**

REFERENCE BOOK

1. Mathematical Method in Chemical Engineering by A. Varma & M. Morbidelli, Oxford University Press. **(R1)**

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations

<u>Gaps in the syllabus (to meet Industry/Profession requirements):</u>
Numerical solution of real life problems.
POs met through Gaps in the Syllabus: **PO4**

<u>Topics beyond syllabus/Advanced topics/Design:</u>
Global optimization algorithms such as Genetic algorithm.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO3 & PO4**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Mini projects/Projects
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	1	1	-
CO2	3	1	1	-	2	2
CO3	3	1	1	2	2	2
CO4	3	1	1	2	2	2
CO5	3	1	1	2	1	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD4, CD5

COURSE INFORMATION SHEET

Course code: CL503
Course title: Advanced Reaction Engineering
Pre-requisite(s): BE in Chemical Engineering or equivalent.
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester/Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To learn the energy balance, temperature and concentration profiles in various reactors.
2.	To design chemical Reactors.

Course Outcomes:

After the completion of the course students will be able to:

CO1	Determine kinetics from experimental data.
CO2	Perform the energy balance and obtain concentration profiles in multiphase reactors.
CO3	Determine the chemical reaction equilibria for various reactions.
CO4	Evaluate heterogeneous reactor performance considering mass transfer limitations.
CO5	Determine kinetics of a bio-reactor.

SYLLABUS

Module I:

Basics - mass and energy balance equations for reactors, Kinetics - rate law, theories of rate constants, determination of kinetics from experimental data, multiple reaction kinetics. Kinetics of different reaction: biochemical reactions (Michaelis–Menten kinetics, Monod model kinetics), polymerization reactions kinetics. (8L)

Module II:

Design of biochemical reactor, polymerization reactor. Other reactor types - Semi-batch, Packed Bed, Fluidized Bed, Membrane, Slurry, Trickle Bed. Gas-Liquid reactions/reactors – Fundamentals.

(8L)

Module III:

Non-ideal reactor models- Flow, Reaction and Dispersion, Numerical solutions to flows with dispersion and reaction, Modelling real reactors with combinations of ideal reactors. (8L)

Module IV:

Gas-Solid reactions/reactors - Catalytic and Non-Catalytic Reaction fundamentals Concepts of catalysis- Kinetics, Deactivation, Effectiveness factor, Diffusion effects, External resistance to mass transfer, Shrinking core model. (8L)

Module V:

Chemical Reaction Equilibria: Criterion of chemical reaction equilibrium, Application of Equilibrium Criteria to Chemical Reactions, the standard Gibbs Energy Change and the Equilibrium Constant, Effect of Temperature on the Equilibrium Constant, Evaluation and Relation of Equilibrium Constants, Equilibrium Conversions for single Reactions, Phase Rule and Duhem’s Theorem for Reacting Systems. (8L)

Books recommended:

TEXT BOOK

1. Elements of chemical reaction engineering, H.S. Fogler. **(T1)**
2. Chemical Reactor Analysis and Design, G. F. Froment and K. B. Bischoff **(T2)**
3. Chemical Engineering Kinetics, J. M. Smith. **(T3)**

REFERENCE BOOK

1. Heterogeneous Catalysis in Industrial Practice, Satterfield, C. N., **(R1).**

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Case studies in industrial process reactor design and operation.
POs met through Gaps in the Syllabus: **PO5**

Topics beyond syllabus/Advanced topics/Design:
Computational chemistry
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5 & PO6**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments
CD3	Self- learning such as use of NPTEL materials and internets

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	3
CO2	3	1	3	3	-	3
CO3	3	-	3	3	2	3
CO4	3	-	3	2	-	3
CO5	3	-	2	2	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

Programme Elective-I

COURSE INFORMATION SHEET

Course code: CL511
Course title: Complex Fluid Technology
Pre-requisite(s): CL210, CL203
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester/Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To have concepts required to analyse the behaviour of such fluids which are Non-Newtonian and are encountered in various engineering applications.
2.	To describes the most commonly used classes of material systems and their rheological behaviour.

Course Outcomes:

After the completion of the course students will be able to

CO1	Analyse fluid flow problems with the application of the momentum and energy equations.
CO2	Analyse mixing processes of polymer melts.
CO3	Explain principles of Brownian Motion.
CO4	Explain Theories of Polymer Statics and Dynamics.
CO5	Examine the behaviour of complex fluids by using of probes like Rheology, Microscopy, Light Scattering.

SYLLABUS

Module I:

Overview of complex fluids Definition of complex fluids Examples from the kitchen, industry, and research. Basic principles of Micro-hydrodynamics: Creeping flow equations, Langevin equation Resistance/Mobility relations, Lorentz Reciprocal Theorem, Foxen's Law, Greens Identity, Oseen Tensor. [8L]

Module II:

Simple systems Calculation of effective viscosities Pair interactions and hydrodynamic interactions Sedimentation. [8L]

Module III:

Basic principles of Brownian Motion: Langevin equation, Connection with diffusion equation, Fluctuation dissipation theorem, Stokes Einstein relation, Simulations of Brownian dynamics. [8L]

Module IV:

Polymers: Theories of Polymer Statics, Rouse Dynamics, Zimm Dynamics. Other Colloidal Forces: Van Der Waals Interactions, Electrostatic Interactions, Poisson-Boltzmann Equation. [8L]

Module V:

Probes of complex fluids: Rheology, Microscopy, Light Scattering. [8L]

Books recommended:

TEXT BOOK

1. Larson, R.G. The Structure and Rheology of Complex Fluids Oxford University Press, 1999. **(T1)**
2. Russel, Saville, and Schowalter Colloidal Dispersions Cambridge University Press, 1989. **(T2)**
3. Leal, G.L. Laminar Flow and Convective Transport Processes Butterworth-Heinemann, 1992. **(T3)**

REFERENCE BOOK

1. Deen, W.M. Analysis of Transport Phenomena Oxford University Press, 1998. **(R1)**
2. Doi & Edwards The Theory of Polymer Dynamics Oxford University Press, 1986. **(R2)**
3. Kim & Karrila Micro-hydrodynamics: Principles and Selected Applications Butterworth-Heinemann, 1991. **(R3)**

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Experimental techniques for investigating complex fluids.
Phase transitions in liquid crystals.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Structural organization.
Liquid crystal phases at high concentration.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments.
CD3	Self- learning such as use of NPTEL materials and internets.

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	2	1	3
CO2	3	-	3	1	1	3
CO3	3	-	2	-	-	1
CO4	3	-	2	-	-	1
CO5	3	1	3	2	2	3

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: **CL512**
Course title: **Biochemical Engineering**
Pre-requisite(s): **CL209, CL302, CL308**
Co- requisite(s):
Credits: L: 3 T: 0 P: 0
Class schedule per week: 3
Class: M. Tech.
Semester / Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	To understand the basics of biology and Principles of biochemical processes.
2.	To gain knowledge on enzyme kinetics, metabolic pathways and microbial growth.
3.	Introduction to the basics of bioreactor design.

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

CO1	Analyse and evaluate kinetics of biochemical processes.
CO2	Understand and develop models for biochemical processes.
CO3	Design bioreactors for specific applications.
CO4	Evaluate mechanisms of biochemical processes.
CO5	Evaluate microbial population models.

SYLLABUS

Module I:
Basics of Biology; Overview of Biotechnology; Diversity in Microbial Cells, Cell Constituents, Chemicals for Life. (8L)

Module II:
Kinetics of Enzyme Catalysis. Immobilized Enzymes: effects of intra and inter-phase mass transfer on enzyme kinetics (8L)

Module III:
Major Metabolic Pathways: Bioenergetics, Glucose Metabolism, Biosynthesis. (8L)

Module IV:
Microbial Growth: Continuum and Stochastic Models. Design, Analysis and Stability of Bioreactors. (8L)

Module V:
Kinetics of Receptor-Ligand Binding Receptor-mediated Endocytosis Multiple Interacting Microbial Population: Prey-Predator Models. Bio-product Recovery & Bio-separations; Manufacture of Biochemical Products. (8L)

Books recommended:

TEXT BOOK

1. Biochemical Engineering Fundamentals by J. E. Bailey & D. F. Ollis, McGraw Hill Book Company, 1986. **(T1)**
2. Biochemical Engineering by H. W. Blanch & D. S. Clark, Marcel Dekker, Inc., 1997. **(T2)**

REFERENCE BOOK

1. Bioprocess Engineering (Basic Concepts) by M. L. Shuler & F. Kargi, Prentice Hall of India, 2003. **(R1)**
2. Transport Phenomena in Biological Systems by G. A. Truskey, F. Yuan, D. F. Katz, Pearson Prentice Hall, 2004. **(R2)**

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

Design of bioreactors for specialized applications such as pharmaceutical products

POs met through Topics beyond syllabus/Advanced topics/Design: PO2, PO3 and PO4

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments.
CD3	Seminars.
CD4	Self- learning such as use of NPTEL materials and internets.

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	3
CO2	3	1	3	3	1	3
CO3	3	-	3	3	3	3
CO4	3	-	2	-	3	2
CO5	3	-	2	-	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4

COURSE INFORMATON SHEET

Course Code: CL513
Course title: Process Safety and Management
Pre-requisite(s): BE Chemical Engineering or equivalent.
Co- requisite(s):
Credits: 03 L: 03 T: 00 P: 00
Class schedule per week: 03
Class: M. Tech
Semester/Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course enables the students:

1.	To provide comprehensive knowledge of safety and hazards aspects in industries and the management of hazards.
2.	To develop a safe protocol by safety audit and risk assessment and minimize potential damages to process equipment's, people and the environment.

Course Outcomes:

After the completion of this course, students will be able:

CO1.	To understand the importance of plant safety and safety regulations, personal protective equipment's, principles and procedures of safety audit.
CO2.	To implement various safety aspect of fire and explosion in a chemical plant
CO3.	To identify and mitigate different types of toxic chemical hazards
CO4.	To assess and mitigate different hazards due to storage and transportation of chemicals plant operations.
CO5	To design safety protocols for chemical industry using various hazard evaluation tools.

SYLLABUS

Module I:

Introduction: Industrial processes and hazards potential, mechanical electrical, thermal and process hazards. Safety and hazards regulations, Industrial hygiene. Factories Act, 1948 and Environment (Protection) Act, 1986 and rules thereof. (8L)

Module II:

Fire & Explosion and their prevention: Shock wave propagation, vapor cloud and boiling liquid expanding vapors explosion (VCE and BLEVE), mechanical and chemical explosion, multiphase reactions, transport effects and global rates. Preventive and protective management from fires and explosion-inserting, static electricity passivation, ventilation, and sprinkling, proofing, relief systems – relief valves, flares, scrubbers. (8L)

Module III:

Leaks and Leakages: Spill and leakage of liquids, vapours, gases and their mixture from storage tanks and equipment; Estimation of leakage/spill rate through hole, pipes and vessel burst; Isothermal and adiabatic flows of gases, spillage and leakage of flashing liquids, pool evaporation and boiling; Release of toxics and dispersion. Naturally buoyant and dense gas dispersion models; Effects of momentum and buoyancy; Mitigation measures for leaks and releases. (8L)

Module IV:

Hazard Identification and Evaluation:

Hazards identification-toxicity, fire, static electricity, noise and dust concentration; Material safety data sheet, hazards indices- Dow and Mond indices, hazard operability (HAZOP) and hazard analysis (HAZAN). (8L)

Module V:

Safety Management:

Safety policy, Safety standards, Techniques to measure safety performance, Safety targets and objectives, Audits of safety standards and practices. (8L)

Books recommended:

TEXT BOOK

1. Chemical Process Safety: Fundamentals with Applications: Daniel A. Crowl and J.F.Louvar. **(T1)**
2. F.P. Lees, Loss Prevention in Process Industries, Vol. 1 and 2, Butterworth, 1983. **(T2)**

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :

Case studies.

POs met through Gaps in the Syllabus: **PO5**

Topics beyond syllabus/Advanced topics/Design:
Management of change, Emergency Planning and Response.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignments
CD3	Self- learning such as use of NPTEL materials and internets

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	2	3	1
CO2	2	-	3	2	3	1
CO3	1	-	3	2	3	2
CO4	1	-	3	2	3	2
CO5	1	1	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL516
Course title: Heterogeneous Catalysis and Catalytic Processes
Pre-requisite(s): BE Chemical Engg. Or equivalent
Co- requisite(s):
Credits: L: 3 T:0 P:0
Class schedule per week: 03
Class: M. Tech
Semester/Level: II/5
Branch: Chemical Engineering
Name of Teacher:

Course Objectives

This course enables the students:

1	This course examines the detailed structures, preparation methods and reactivities of solid catalysts.
2	Several important catalyst properties and their determination techniques such as surface area and pore size measurements, temperature Programmed desorption (TPD), and various spectroscopic techniques.
3	The relationship between the structures and reactivities of important catalysts used in various applications.

Course Outcomes
After the completion of this course, students will be able to:

CO1	Explain various catalyst preparation methods for an end application.
CO2	Evaluate various properties of catalysts.
CO3	Correlate the structure of catalyst with its reactivity.
CO4	Evaluate catalyst deactivation kinetics.
CO5	Model the various catalytic reactors.

SYLLABUS

Module I:
Basic concepts in heterogeneous catalysis, catalyst preparation and characterization, poisoning and regeneration. (8L)

Module II:
Industrially important catalysts and processes such as oxidation, processing of petroleum and hydrocarbons, synthesis gas and related processes. (8L)

Module III:
Commercial reactors: adiabatic and multi-tubular packed beds, fluidized bed, trickle-bed, slurry reactors. (8L)

Module IV:
Heat and mass transfer and its role in heterogeneous catalysis. Calculations of effective diffusivity and thermal conductivity of porous catalysts. (8L)

Module V:
Reactor modelling; Chemistry and engineering aspects of catalytic processes along with problems arising in industry. Catalyst deactivation kinetics and modeling. (8L)

Books recommended:

TEXT BOOKS:

1. Catalytic Chemistry: Bruce Gates **(T1)**
2. Optimal distribution of catalyst in a pellet: Morbidelli and Verma **(T2)**
3. Catalysis of Organic reactions: editor M.E.Ford, Marcel Dekker Inc. **(T3)**

REFERENCE BOOK

1. Heterogeneous Reactions Vol 1 and Vol II : M. M. Sharma and Doraiswamy **(R1)**
2. Principles and practice of heterogeneous Catalysis: Thomas, J.M., Thomas W.J. **(R2)**

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Industrial reactor data analysis and its application towards better reactor design.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Design and analysis of Non-isothermal industrial reactor.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments.
CD3	Self- learning such as use of NPTEL materials and internets.

<u>MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES</u>

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	-	1	3
CO2	3	-	3	2	2	3
CO3	3	-	3	1	-	3
CO4	3	-	2	-	3	2
CO5	3	-	2	-	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

<u>MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD</u>

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL515
Course title: Process Intensification
Pre-requisite(s):BE (Chemical Engg.) or equivalent
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester/Level: III/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1	To provide an understanding of the concept of Process Intensification.
2	To provide knowledge and understanding of application of intensification techniques to a range of processes e.g. heat and mass transfer, separation processes.
3	To provide an understanding of basic operating principles of a variety of intensified process equipment such as spinning disc reactor, rotary packed beds, oscillatory flow reactors, compact heat exchangers and micro-reactors etc.

Course Outcomes:

After the completion of the course students will be able to:

CO1	Explain the concept of Process Intensification and the methodologies for PI.
CO2	Explain the benefits of PI in the process industries.
CO3	Explain the operating principles of a number of intensified technologies.
CO4	Analyse the range of potential applications of intensified equipment.
CO5	Design compact heat exchanger.

SYLLABUS

Module I:

Introduction: Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process Intensifying Equipment, Process intensification toolbox, Techniques for PI application. [8L]

Module II:

Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Implementation of Micro reaction Technology, From basic Properties to Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and Their Potential Solutions, Microfabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes. [8L]

Module III:

Scales of mixing, Flow patterns in reactors, Mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer Ultrasound Atomization, Nebulizers, High intensity inline MIXERS reactors Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers, Design Principles of static Mixers Applications of static mixers, Higee reactors. [8L]

Module IV:

Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Applications, Reactive absorption, Reactive distillation, Applications of RD Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification. Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes, Design of compact heat exchanger - example. [8L]

Module V:

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor design, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sono-crystallization, Reactive separations, Supercritical fluids. [8L]

Books recommended:

Text books:

1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003. **(T1)**
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008. **(T2)**
3. Kamelia Boodhoo (Editor), Adam Harvey (Editor), Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, Wiley, 2013. **(T3)**

Reference books:

1. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.) Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016. **(R1)**
2. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013. **(R2)**

Course Evaluation:
Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Case studies of industrial problems.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Process simulation of Reactive distillation.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments
CD3	Self- learning such as use of NPTEL materials and internets

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	3
CO2	2	-	3	2	-	3
CO3	2	1	3	2	1	3
CO4	2	-	3	2	-	3
CO5	2	-	2	2	-	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL504
Course title: Design and Simulation Lab
Pre-requisite(s): BE (Chemical Engineering) or equivalent
Co- requisite(s):
Credits: 2 L:0 T:0 P:4
Class schedule per week: 04
Class: M. Tech.
Semester/Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To simulate steady state chemical engineering processes using ASPEN PLUS.
2.	To simulate steady state chemical engineering processes using SIMULINK.

Course Outcomes:

After the completion of the course students will be able to:

CO1	Analyse heat and mass transfer operation using Aspen plus simulator.
CO2	Simulate chemical process plant and effect of process variables on the plant operation using ASPEN PLUS.
CO3	Develop governing equations of unsteady state chemical engineering processes, based on mass and energy balance.
CO4	Control the process variables using SIMULINK.
CO5	Analyse phase equilibria data using various regression methods.

SYLLABUS

Problem 1:

Study of Vapour Liquid Equilibrium using ASPEN PLUS

Property analysis and Simulation Method. Regression of binary VLE data. NIST thermo data engine analysis. Flash Calculation.

Problem 2:

Study of Liquid-Liquid Equilibrium using ASPEN PLUS

Analysis of liquid-liquid equilibrium data, Regression of liquid-liquid equilibrium. Study of Liquid–Liquid Extraction systems.

Problem 3:

Reactor Analysis using ASPEN PLUS.

Reactor study using RStoic, RYield, REquil, RGibbs, RCSTR, RPlug and RBatch reactor module and effect of Process variable using ‘Sensitivity Analysis’ tool. Study of Chemical Equilibrium using ASPEN PLUS.

Problem 4:

Study of Distillation Column using ASPEN PLUS

Shortcut Distillation Calculations using DSTWU module and Sensitivity analysis. Rigorous Distillation Calculation using RadFrac module and Sensitivity analysis.

Problem 5:

Chemical Plant Simulation using ASPEN PLUS

Simulation of a distillation train. Simulation of a vinyl chloride monomer production unit. Simulation of CO_2 capture plant using Physical/chemical solvent.

Problem 6:

Study of composition dynamics in a continuous stirred tank reactor CSTR

Objectives: i) To formulate time domain mass balance equation of a CSTR with 1^{st} order irreversible and isothermal reaction and construct MATLAB SIMULINK block diagram of the system of one equation ii) Transient analysis of the CSTR using SIMULINK.

Problem 7:

Control of composition in a continuous stirred tank reactor CSTR

Objectives: i) To construct MATLAB SIMULINK block diagram of a CSTR from mass balance equation ii) To control composition of CSTR manipulating inlet flow rate.

Problem 8:

Study of level and temperature dynamics in a stirred tank heater

Objectives: i) To formulate time domain mass balance and energy balance equation of a stirred tank heating system and construct MATLAB SIMULINK block diagram of the system of two equation ii) To obtain dynamics of level and temperature using SIMULINK, iii) Transient analysis of stirred tank heater.

Problem 9:

Study of temperature dynamics in a non-isothermal continuous stirred tank reactor (CSTR)

Objectives: i) To construct MATLAB SIMULINK block diagram of a non-isothermal CSTR from energy balance equation ii) To control temperature of CSTR manipulating inlet flow rate.

Problem 10:

Temperature control in a stirred tank heater

Objectives: i) To construct MATLAB SIMULINK block diagram of a stirred tank heater from mass and energy balance equation ii) To control temperature of stirred tank heater manipulating inlet flow rate.

Books recommended:

TEXT BOOK

1. Using Aspen Plus® in Thermodynamics Instruction A Step-by-Step Guide by Stanley I. Sandler. Wiley & Sons, Inc., Hoboken, New Jersey. **(T1)**

2. Process Simulation and Control Using Aspen Plus by Amiya K. Jana. PHI Leaning Private Limited, New Delhi**(T2)**

REFERENCE BOOK

1. Distillation Design And Control Using ASPEN^{TM} Simulation by William L. Luyben. Wiley & Sons, Inc., Hoboken, New Jersey. **(R1)**
2. Process Modeling, Simulation and Control for Chemical Engineers, William L. Luyben, McGraw Hill. **(R2)**
3. Introduction To MATLAB For Engineering Students by David Houcque. **(R3)**
4. A Beginner's Guide to MATLAB by Christos Xenophontos. **(R4)**

Course Evaluation:
Theory (Quiz), final examinations (Lab performance and Viva-voce)

Gaps in the syllabus (to meet Industry/Profession requirements):
Economic analysis of industrial processes.
POs met through Gaps in the Syllabus: **PO3 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Dynamic simulation of industrial plants using Aspen Plus.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Simulation practice
CD3	Self- learning such as use of NPTEL materials and internets

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	3
CO2	3	1	-	3	-	3
CO3	3	1	-	3	2	3
CO4	3	1	3	3	-	3
CO5	3	-	2	2	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL505
Course title: Computational Laboratory
Pre-requisite(s): BE (Chemical Engineering) or equivalent
Co- requisite(s):
Credits: 2 L:0 T:0 P:4
Class schedule per week: 04
Class: M. Tech.
Semester/Level: I/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To write and solve material balance & energy balance equations for a system with multiple unit operations with and without chemical reaction.
2.	To solve vapor-liquid equilibrium relationship for ideal and non-ideal liquid mixture.
3.	To simulate steady state chemical engineering processes using ASPEN PLUS.
4.	To analyse Transient behaviour using distributed parameter model.

Course Outcomes:

After the completion of the course students will be able to:

CO1	Formulate number of independent material balance and energy balance equations of the system for degree of freedom analysis.
CO2	Solve the set of linear/nonlinear equations using MATLAB user defined functions such as, matrix solver, fsolve, etc.
CO3	Solve the energy balance equations using MATLAB user defined functions like ode45, ode15s, etc.,
CO4	Solve vapor-liquid equilibrium relationship for ideal and non-ideal liquid mixture using computational algorithm and MATLAB/C codes.
CO5	Analyse Transient behaviour in a non-adiabatic CSTR/PFR using lumped parameter model.

SYLLABUS

Problem 1:

Computation of the steady state operating conditions of a system with multiple unit operations without chemical reaction.

Objectives: i) To formulate number of independent material balance equations of the system for degree of freedom analysis. ii) Solution of the set of linear/nonlinear equations using MATLAB user defined functions such as, matrix solver, fsolve, etc.

Problem 2:

Computation of the steady state operating conditions of a system with multiple unit operations involving chemical reaction.

Objectives: i) To formulate number of independent material balance equations of the system for degree of freedom analysis. ii) Solution of the set of linear/nonlinear equations using MATLAB user defined functions such as, matrix solver, fsolve, etc.

Problem 3:

Study of temperature and level dynamics of a stirred tank heater.

Objectives: i) To formulate energy balance equations for all the unit operations in terms of state variables, ii) Solve the energy balance equations simultaneously using MATLAB user defined functions like ode45, ode15s, etc., iii) Explain the dynamics of state variables (temperature of each tank) with the help of transient analysis.

Problem 4:

Computation of bubble point temperature of ideal liquid mixture.

Objectives: i) To formulate vapor-liquid equilibrium relationship for ideal liquid mixture using computational algorithm and MATLAB/C codes.

Problem 5:

Computation of bubble point temperature of non-ideal liquid mixture

Objectives: i) To formulate vapor-liquid equilibrium relationship for non-ideal liquid mixture using computational algorithm and MATLAB/C codes.

Problem 6:

Transient analysis in a non-adiabatic CSTR using lumped parameter model.

Objectives: i) To formulate unsteady material balance and energy balance equations of the non-adiabatic CSTR ii) linearize the model equations to make it a state-space model, iii) solution of the set of ordinary differential equations using MATLAB user defined functions such as, ode45, ode23, ode15s or C/C++ codes with Runge-Kutta method. iv) perform transient analysis.

Problem 7:

Transient analysis in a PFR using distributed parameter model.

Objectives: i) To formulate unsteady material balance equations of the PFR ii) Discretize the equation with finite difference scheme iii) solution of the discretized equation with finite difference numerical method iv) perform transient analysis

Problem 8:

Flash calculation using ASPEN PLUS.

Objectives: i) Prepare ASPEN PLUS flowsheet of a flash chamber ii) perform flash calculation.

Problem 9:

Making ASPEN PLUS steady state simulation of a chemical process plant.

Objectives: i) Prepare ASPEN PLUS flowsheet of a process for making benzene ii) perform steady state simulation.

Problem 10:

Making ASPEN PLUS steady state simulation of a chemical process plant.

Objectives: i) Prepare ASPEN PLUS flowsheet of a process for making ethanol ii) perform steady state simulation.

Books recommended:

TEXT BOOK

1. Process Modeling, Simulation and Control for Chemical Engineers, William L. Luyben, McGraw Hill. **(T1)**
2. Process Simulation and Control Using Aspen Plus by Amiya K. Jana. PHI Leaning Private Limited, New Delhi. **(T2)**
3. Using Aspen Plus® in Thermodynamics Instruction A Step-by-Step Guide by Stanley I. Sandler. Wiley & Sons, Inc., Hoboken, New Jersey. **(T3)**

REFERENCE BOOK

1. Distillation Design and Control Using ASPENTM Simulation by William L. Luyben. Wiley & Sons, Inc., Hoboken, New Jersey. **(R1)**
2. Introduction to MATLAB For Engineering Students by David Houcque. **(R2)**
3. A Beginner’s Guide to MATLAB by Christos Xenophontos. **(R3)**

Course Evaluation:
Theory (Quiz), final examinations (Lab performance and Viva-voce)

Gaps in the syllabus (to meet Industry/Profession requirements):
Economic analysis of industrial processes.
POs met through Gaps in the Syllabus: **PO3 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Dynamic simulation of industrial plants using Aspen Plus.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Simulation practice.
CD3	Self- learning such as use of NPTEL materials and internets.

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	2	2
CO2	3	-	3	3	2	3
CO3	3	-	3	3	2	3
CO4	3	-	3	3	2	3
CO5	3	-	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3