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) – ME (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)

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

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

PO3: Students should be able 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 acquire 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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignments/Seminars
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.	To develop appropriate methods to solve a linear system of equations.
2.	To develop appropriate numerical methods to solve a ordinary differential equation (IVP)/ special ordinary differential equation/ partial differential equation.

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

CO1	Explain 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

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

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

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments/Seminars
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.

<u>SYLLABUS</u>

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

<u>Gaps in the syllabus (to meet Industry/Profession requirements) :</u>
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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments/seminars
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:

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, PO4**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

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 acquire 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

<u>Gaps in the syllabus (to meet Industry/Profession requirements) :</u>
Case studies.
POs met through Gaps in the Syllabus: **PO5**

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

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignments/seminars
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

Open Elective-I

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: I/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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

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	-	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

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: 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: I/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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments/seminars.
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™ 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)

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

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

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

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
CD4	Seminar

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, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4

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 simulate free convection momentum and heat transport from bluff body using CFD software.
2.	To determine liquid physical properties using molecular simulation.

Course Outcomes:

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

CO1	Formulate the free convection problem for Newtonian fluids.
CO2	Create proper domain and grid for flow geometries using Computational Fluid Dynamics Software.
CO3	Solve momentum and heat transport governing equations for bluff bodies in Newtonian fluids using Computational Fluid Dynamics Software.
CO4	Determine optimized structure of molecules using Quantum chemistry.
CO5	Determine physical properties of liquid using molecular simulation.

SYLLABUS

1. Laminar steady natural convection momentum transport from a cylinder in Newtonian fluid using Computational Fluid Dynamics Software.
2. Laminar steady natural convection heat transport from a cylinder in Newtonian fluid using Computational Fluid Dynamics Software.
3. Laminar steady natural convection momentum transport inside a cavity in Newtonian fluid using Computational Fluid Dynamics Software.
4. Laminar steady natural convection heat transport inside a cavity in Newtonian fluid using Computational Fluid Dynamics Software.
5. Laminar steady natural convection momentum transport from a confined cylinder in Newtonian fluid using Computational Fluid Dynamics Software.
6. Laminar steady natural convection heat transport from a confined cylinder in Newtonian fluid using Computational Fluid Dynamics Software.
7. Geometry optimization of simple molecules using Quantum Chemistry.
8. Determination of single component liquid density using Monte Carlo Simulation.
9. Determination of vapor-liquid coexistence curve for *n*-Pentane using Monte Carlo Simulation.
10. Computation of physical properties of simple molecules using Molecular Dynamics Simulation.

Books recommended:

TEXT BOOK

1. Computer Simulation of Liquids, M. P. Allen, D. J. Tildesley, Clarendon Press, 1987. (**T1**)
2. Molecular Modelling: Principles and Applications, Andrew R. Leach, Leach AR, Prentice Hall, 2001. **(T2)**
3. Understanding Molecular Simulation: From Algorithms to Applications, Daan Frenkel, Berend Smit, Academic Press, 1996. **(T3)**
4. Quantum Chemistry, Donald A McQuarrie, Viva Student Edition, University Science Books, 2011. **(T4)**

REFERENCE BOOK

1. Essentials of Computational Chemistry: Theories and Models, Christopher J. Cramer, Wiley, 2005. **(R1)**
2. Molecular Simulation of Fluids, Richard J. Sadus, Elsevier, 2002. **(R2)**
3. The Art of Molecular Dynamics Simulation, D.C. Rapaport, Cambridge University Press. (**R3**)

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

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

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

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.
CD4	Seminar

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, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4

COURSE INFORMATION SHEET

Course code: CL506
Course title: Advanced Transport Phenomena – II
Pre-requisite(s): Advanced Transport Phenomena – I
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester/Level: II/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To acquire knowledge on systematic analysis of mass and heat transfer with emphasis on analogies and specific techniques.

Course Outcomes:

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

CO1	Perform energy and mass balances for a given system at macroscopic/microscopic scale.
CO2	Develop modelling thinking by relating a problem involving heat and mass transfer to the fundamental transport equations and specify initial and boundary conditions.
CO3	Solve the governing equations to obtain temperature and concentration profiles.
CO4	Analyze transport related problem and predict the physical behaviour of the process.
CO5	Identify and solve problems of simple cases of two-phase flow.

SYLLABUS

Module I:

Equation of energy (general convection-diffusion equation) – rectangular coordinate system. Use of the Energy equation - Unsteady state conduction in finite and semi-infinite slabs. Concept of thermal boundary layer vis-a-vis hydrodynamic boundary layer – effect of Prandtl number on thermal boundary layer thickness. Dimensional analysis of equation of Energy. Radiation-Direct radiation between black bodies and non-blackbodies at different Temperature. (8L)

Module II:

Concentrations, Velocities and Mass and Molar fluxes. Concept of Mass diffusivity and Mass transfer coefficient. Fick's law of diffusion. Shell mass balance and boundary conditions – Diffusion through stagnant gas film, Diffusion in a falling film, Diffusion with heterogeneous chemical reaction, Simultaneous mass and heat transfer problem. (8L)

Module III:

Equations of Continuity for binary mixture, simplification of general equation for special cases. Dimensional analysis of the equations of Continuity – role of Schmidt number. (8L)

Module IV:

Generalized Transport Equation: General Advection-Diffusion equation - conservation equations (Motion, Energy and Species concentration) in terms of general variable (Φ) and diffusivity. Concept of coupled equations. (8L)

Module V:

Flow of multiphase mixtures: Two phase gas vapor liquid flow, horizontal and vertical flows of gas liquids, liquid, gas – solid mixtures, slip and hold up effects, phase separation and settling behavior, pressure, momentum and energy relations, practical methods for evaluating pressure drop. (8L)

Books recommended:

TEXT BOOK

1. Advanced Heat and Mass Transfer, A. Faghri, Y. Zhang, J. Howell. **(T1)**
2. Process Heat Transfer: Kern D.Q., McGraw Hill. **(T2)**
3. Unit Operations of Chemical Engineering: McCabe, W.L., Smith, J.C., Harriot, P.,McGraw Hill, 1993. **(T3)**
4. R.B. Bird, W.E. Stewart, and E.N. Lightfoot, Transport Phenomena, Second edition, John Wiley and Sons, 2002. **(T4)**

REFERENCE BOOK

1. Mass Transfer Operations: Treybal R.E., Mc Graw Hill, 1981. **(R1)**
2. Chemical Engineering, vol. 1, Coulson & Richardson, Butterworth Heinemann. **(R2)**
3. Kothandaraman, C.P. and S. Subramanyan, Heat and Mass Transfer Data Book. New Age International. **(R3)**

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

Gaps in the syllabus (to meet Industry/Profession requirements):
Turbulence Modeling.
POs met through Gaps in the Syllabus: **PO4**

Topics beyond syllabus/Advanced topics/Design:
Numerical methods for the solution of Multiphase flow.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments/Seminars.
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	2	3	3	3
CO2	3	1	2	3	3	3
CO3	3	1	2	3	3	3
CO4	3	1	2	3	3	3
CO5	3	1	2	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: **CL507**
Course title: **Advanced Process Modelling, Simulation & Optimization**
Pre-requisite(s): BE (Chemical Engineering)
Co- requisite(s):
Credits : 3 L: 3 T: 0 P: 0
Class schedule per week: 3
Class: M. Tech
Semester/Level: II/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives

This course enables the students:

1.	To learn optimization techniques for the solution of linear and nonlinear systems and apply them in real chemical engineering problems.
2.	To learn global optimization techniques.

Course Outcomes

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

CO1	Develop information flow diagram from real process, from information flow diagram to numerical form.
CO2	Design, manage and operate procedures for the simulation, control and instrumentation of chemical processes.
CO3	Apply Conservation of Mass, Momentum and Energy to Chemical Engineering Systems.
CO4	Develop Mathematical Model Equations and Solve the Equations using Numerical Techniques for Chemical Engineering Systems.
CO5	Solve Chemical Engineering Optimization Problems.

SYLLABUS

Module I:

Mathematical Model: Introduction and Necessity Definition of modelling and simulation - validation with experiments, benchmarking; Need of models – predictive capability, trend analysis; Micro, meso and macroscale models - concept of multiple scales using crystallizer as an example, deterministic and stochastic descriptions Experimentation, empiricism, data correlation and mathematical modeling using examples. (8L)

Module II:

Examples from Crystallization of solid, Coagulation, Coalescence and breakage of drops, Grinding, Microbial population dynamics, Reaction in a porous particle etc. Monte Carlo methods – Basics of random no. and probability distributions Poisson process, Birth-death process, Solution of Laplace's diffusion eqn. Time and event driven simulation methods, Interval of quiescence Lattice simulation – examples from particle deposition, catalyst sintering etc. (8L)

Module III:

Optimization basics and convexity, Multidimensional constrained optimization Gradient Secant and Newton methods. Karsh-Kuhn-Tucker optimality conditions. Linear programming Simplex method, Nonlinear programming Sequential quadratic programming (SQP). (8L)

Module IV:

Generalized reduced gradient method (GRG) and penalty function methods, mixed integer linear programming (MLP) mixed integer nonlinear programming (MNLP) evolutionary optimization techniques. (8L)

Module V:

Genetic Algorithm, Simulated Annealing, Particle swarm optimization, differential evolution, self-organizing migrating algorithm, and scatter search. (8L)

Books recommended:

TEXT BOOK

1. T.F. Edgar and D. M. Himmelblau, Optimization of Chemical Processes 2nd Edition, McGraw Hill International Editions, Chemical Engineering Series, 2001. **(T1)**
2. Floudas, C.A., Nonlinear and Mixed Integer Optimization: Fundamentals and Applications, Oxford University Press, New York 1995. **(T2)**
3. G.V, Reklatis, A. Ravindran and K.M.Ragsdell, Engineering Optimization – Methods and Applications. **(T3)**

REFERENCE BOOK

1. S. S. Rao, Engineering Optimization, Theory and Practice 4th Ed, John Wiley and sons 2009. **(R1)**
2. L.T.Biegler, I,E, Grossmann, and A. W. Westergerg, systematic Methods of Chemical Process Design, Prentice Hall International Series, 1997. **(R2)**

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

Gaps in the syllabus (to meet Industry/Profession requirements):
Industrial optimization problems.
POs met through Gaps in the Syllabus: **PO5**

Topics beyond syllabus/Advanced topics/Design:
Recent nature inspired global optimization problems.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Tutorial/Assignment
CD3	Seminars
CD4	Mini Projects
CD5	Laboratory experiments/teaching aids

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	2	3
CO2	3	2	3	3	2	3
CO3	3	1	2	2	2	3
CO4	3	1	3	3	2	3
CO5	3	1	3	3	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, CD4, CD5
CO2	CD1, CD2, CD3, CD4, CD5
CO3	CD1, CD2, CD3, CD5
CO4	CD1, CD2, CD3, CD4, CD5
CO5	CD1, CD2, CD3, CD4,CD5

COURSE INFORMATION SHEET

Course code: CL508
Course title: Advanced Thermodynamics
Pre-requisite(s):BE (Chemical Engineering)
Co- requisite(s):
Credits: 3 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 will enable the students to:

1.	Learn basics of statistical thermodynamics.
2.	Learn advanced concepts in thermodynamics with emphasis on thermodynamic relations, equilibrium and stability of multiphase multi-component systems.

Course Outcomes:

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

CO1	Understand the terminology associated with chemical engineering thermodynamics.
CO2	Estimate thermodynamic properties of substances in gas or liquid state of ideal and real mixture.
CO3	Explain the basics of statistical thermodynamics.
CO4	Explain the basics of quantum mechanics and molecular simulation.
CO5	Solve problems involving equilibria of different phases as well as reaction equilibria.

SYLLABUS

Module I:

Review of Basic Postulates, Maxwell's relations, Legendre Transformation, Pure Component properties. Theory of corresponding states, real fluids Equilibrium, Phase Rule, Single component phase diagrams. (8L)

Module II:

Introduction to Multicomponent Multiphase equilibrium, introduction to Classical Mechanics, quantum Mechanics, Canonical Ensemble, Microcanonical Ensemble, Grand Canonical Ensemble, Boltzmann, Fermi-Dirac and Bose Einstein Statistics, Fluctuations, Monoatomic and Diatomic Gases. (8L)

Module III:

Introduction to Classical Statistical Mechanics, phase space, liouville equation, Crystals, Inter molecular forces and potential energy functions, imperfect Monoatomic Gases, Molecular theory of corresponding states. (8L)

Module IV:

Introduction to Molecular Simulations, Mixtures, partial molar properties, Gibbs-Duhem's equations, fugacity and activity coefficients, Ideal and Non-ideal solutions. (8L)

Module V:

Molecular theories of activity coefficients, lattice models, multiphase Multicomponent phase Equilibrium. VLE/SLE/LLE/VLLE. Chemical Equilibrium and Combined phase and reaction equilibria. (8L)

Books recommended:

TEXT BOOK

1. McQuarrie D.A, Statistical Mechanics, Viva Books Private Limited, 2003. **(T1)**
2. Hill Terrel, An Introduction to Statistical Thermodynamics, Dover, 1960. **(T2)**
3. Allen MP, Tildesley DJ, Computer simulation of liquids, Oxford, 1989. **(T3)**
4. Callen, HB. Thermodynamics and an Introduction to Thermodstatics, 2nd Edition, John Wiley and Sons, 1985. **(T4)**

REFERENCE BOOK

1. Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics of fluid phase Equilibria (3rd edition), Prentice Hall Inc., New Jersey,1996. **(R1)**
2. J.M. Smith. H.C. Van Ness and M.M. Abott. "Introduction to Chemical Engineering Thermodynamics: McGraw Hill International edition (5th ed.). 1996. **(R2)**

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

Gaps in the syllabus (to meet Industry/Profession requirements):
Quantum-chemical thermodynamic models such as COSMO-RS.
POs met through Gaps in the Syllabus: **PO3, PO4, PO5, PO6**

Topics beyond syllabus/Advanced topics/Design:
Use of process simulation software such as Aspen to learn thermodynamic models.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO3, PO4, PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments/Seminars
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	2	3	3	3
CO2	3	1	2	3	3	3
CO3	3	1	3	3	3	3
CO4	3	1	3	3	3	3
CO5	3	1	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

Programme Elective-II

COURSE INFORMATION SHEET

Course code: CL514
Course title: Computational Fluid Dynamics
Pre-requisite(s):BE Chemical Engineering
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1	To be able to apply the CFD methods to solve Navier-Stokes equations for simple fluid flow problems.
2	To solve momentum and heat transport Problems using computational fluid dynamics.

Course Outcomes:

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

CO1	Solve the transport equations using suitable boundary conditions.
CO2	Formulate and Solve fluid flow problems using finite difference methods.
CO3	Solve Navier-Stokes equation for incompressible flows using SIMPLE algorithm.
CO4	Formulate and Solve fluid flow problems using finite volume methods.
CO5	Simplify chemical engineering problems.

SYLLABUS

Module I:

Philosophy of computational fluid dynamics (CFD), review of equations governing fluid flow and heat transfer, simplified flow models such as incompressible, inviscid, potential and creeping flow Classification of partial differential equations, initial and boundary conditions, review of applied numerical methods. (8L)

Module II:

Finite difference method: introduction, discretization method, consistency, error and stability analysis, fundamentals of fluid flow modeling. Finite difference applications in heat conduction and convection: steady and transient heat conduction in rectangular and cylindrical geometries, convective heat transfer. (8L)

Module III:

Solution of viscous incompressible flows by stream function-vorticity formulation; Solution of Navier-Stokes equation for incompressible flows using SIMPLE algorithm. (8L)

Module IV:

Finite Volume Method: Discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, application to the engineering problems. (8L)

Module V:

Introduction to multiphase and turbulence modeling, Solution of chemical engineering problems.

(8L)

Books recommended:

TEXT BOOK

1. K. Muralidhar and T. Sundararajan, Computational fluid flow and heat transfer, 2nd edition, Narosa Publishing House, 2003. **(T1)**
2. S.V. Patankar, Numerical Heat Transfer & Fluid Flow, Hemisphere Publishing Co-operation, McGraw-Hill, 1980. **(T2)**

REFERENCE BOOK

1. P.S. Ghoshdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw Hill, 1998. **(R1)**
2. J.D. Anderson, Computational Fluid Dynamics, McGraw Hill, 1995. **(R2)**

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

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

Finite Element method.

POs met through Gaps in the Syllabus: **PO5, PO6**

Topics beyond syllabus/Advanced topics/Design:
Solution of Navier-Stokes equation for incompressible flows using SIMPLER and PISO algorithm.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5, PO6**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	2	3
CO2	3	1	3	1	1	3
CO3	3	1	3	1	1	3
CO4	3	1	3	2	3	3
CO5	3	1	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: CL515
Course title: Process Intensification
Pre-requisite(s): CL308, CL210
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester/Level: II/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:

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

Reference books:

3. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.) Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016. **(R1)**
4. 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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors.
CD2	Assignments/seminars.
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: CL516
Course title: Heterogeneous Catalysis and Catalytic Processes
Pre-requisite(s): CL302,CH101, PH113, CL301
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:

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

REFERENCE BOOK

3. Heterogeneous Reactions Vol 1 and Vol II : M. M. Sharma and Doraiswamy **(R1)**
4. 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 OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

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	-	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

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

Open Elective-II

COURSE INFORMATION SHEET

Course code: CL614
Course title: Process Integration
Pre-requisite(s): CL308, CL210
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester /Level: II/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1	To learn the concept of Process Intensification.
2	To apply the techniques of intensification to a range of chemical processes and process Equipment's.

Course Outcomes:

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

CO1	Assess the importance and limitations of process intensification.
CO2	Explain the principles of intensified technologies/Equipments such as compact heat exchanger, Higee reactors, Reactive absorption, Reactive distillation.
CO3	Plan for research in new energy systems, materials and process intensification.
CO4	Explain basics of pinch technology and its application.
CO5	Explain and design of heat exchanger networks.

SYLLABUS

Module I:

Introduction to Process Intensification and Process Integration (PI). Areas of Application and Techniques available For PI, Onion Diagram, Process Integration in Chemical Industries, Formulation of a Design Problem, Chemical Process Design and Integration, Hierarchy of Chemical Process Design and Integration, Continuous and Batch Processes, New Design and Retrofit, Approaches to Chemical Process Design and Integration, Process Control. (8L)

Module II:

Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology. Key steps of Pinch Technology: Concept of ΔT_{min}, Data Extraction, Targeting, Designing, Optimization-Super targeting. Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve. (8L)

Module III:

Targeting of Heat Exchanger Network, Designing of Heat Exchanger Networks, Hot Composite Curve, Cold Composite Curve, Problem Table Algorithm, Grand Composite Curve, Area Targeting by Uniform Bath formula and Unit Targeting by Euler's formula, Heuristics for Pinch Design, Maximum Energy Recovery Design, Evolution of Network. (8L)

Module IV:

Choice of Idealized reactor model and reactor performance. Reactor configurations: Temperature Control, Gas-Liquid and Liquid Reactors, Choice of Reactors. Heat Integration characteristics of reactors, Appropriate placements of reactors. Use of GCC for Heat Integration of reactor. (8L)

Module V:

Distillation sequencing, Heat Integration characteristics of Distillation column, appropriate placement of distillation column, various configurations for heat integration of distillation column.

(8L)

Books recommended:

TEXT BOOK

1. Chemical Process Design and Integration Robin Smith, John Wiley and Sons. Ltd., New Delhi, 2005. **(T1)**
2. Product & Process Design Principles Warren D. Seider, J. D. Seader and Daniel R. Lewin, Wiley Publication. **(T2)**

REFERENCE BOOK

1. Heat Exchanger Network Synthesis U. V. Shenoy, Gulf Publication. **(R1)**

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

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

Case Studies related to industrial problems.

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

Topics beyond syllabus/Advanced topics/Design:
Use of commercial software for solving industrial problems.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4, PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	1	1	3
CO2	3	1	3	1	1	3
CO3	3	1	3	2	1	3
CO4	3	1	3	2	2	3
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, CD3
CO2	CD1, CD2 CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code:	**CL631**
Course title:	Composite Manufacturing Technology
Pre-requisite(s):	**CH101, PH111, MA103**
Co- requisite(s):	**Nil**
Credits:	L: 03 T: 00 P: 00
Class schedule per week:	**03**
Class:	**M. Tech**
Semester / Level:	**III/06**
Branch:	**Chemical Engineering**
Name of Teacher:	

Course Objectives:

This course enables the students:

1.	To impart the fundamentals of polymer composites and its applications.
2.	To know about manufacture, properties and application of polymer and fibre.
3.	Explain the basic properties, characteristics and constituents of composite materials.
4.	Present and apply the different fabrication processes for composite materials, including bonding, fastening, laminating, and finishing techniques.
5.	Perform design, construction, and fabrication of laminate parts, Define and use appropriate terminology as it relates to composite structure design and manufacturing.

Course Outcomes:

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

CO1	Classify the different type of polymeric composites and its applications.
CO2	Select different types of matrix and reinforcement materials.
CO3	Ability to select the process for fabrication of polymer composites.
CO4	Relate theoretical knowledge with typical products and its stress-strain behavior.
CO5	Aware of different testing and characterization of polymer composites.

SYLLABUS

Module I:
Polymer composite systems: Types of composites, reinforcements, Types of Resin. (8L)

Module II:
Natural fibre: Jute, sisal, cotton, hemp **Ceramic fibre:** silicon carbaide, zinc, Alumina, glass, **Synthetic fibre**: polyethylene, polyester, nylon, Kevlar. (8L)

Module III:
Thermoset, elastomer - resins (polyesters, epoxide, vinyl ester, phenol formaldehyde, polyimide, reinforced polyolefin, Semi crystalline and amorphous polymers - PEEK, PP, PEK, PBT, PC, ABC, nylon etc.) additives, reinforcements (particulate, fibrous, gaseous). (8L)

Module IV:
Processing techniques - open mould, hand layup spray up, vacuum bag moulding, pressure bag moulding, autoclave moulding, closed mould, SMC, DMC, RTM., Continuous manufacturing process - pultrusion, filament winding, centrifugal casting. Application (sandwich constructions - aircraft, racing cars, helicopter rotor blades etc.), Nano composites. (8L)

Module V:
Mechanical behaviour of composites. Deformation Behaviour of reinforced plastics, Types-reinforcement, matrix, Forms of fibre reinforcement in composites, Analysis of Continuous fibre composites, Deformation behaviour of a single ply or lamina, Deformation behaviour of Laminates, Analysis of multi-layer isotropic materials, Analysis of Non-symmetric laminates, Analysis of short fibre composites, Creep behaviour of fibre reinforced plastics, Fatigue behaviour of reinforced plastics, Impact behaviour of reinforced plastics. Bending buckling and vibration of laminated plates. Testing and joining of composite materials. (8L)

Books recommended:

TEXT BOOK

1. Dyson, R.W., "Engineering Polymers", Blackie, 1990. **(T1)**
2. Crawford, R.J., Plastics Engineering, Pergamon Press. **(T2)**

REFERENCE BOOK

1. Richardson, T., Composites – a design guide industrial press Inc., New York, 1987. **(R1)**

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

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

- Apply quality systems to composite manufacturing and product testing.
- Need more design problem on fibre orientation

POs met through Gaps in the Syllabus: **PO5, PO6**

<u>Topics beyond syllabus/Advanced topics/Design:</u>

POs met through Topics beyond syllabus/Advanced topics/Design:

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	2	1	3	1		1
CO2	2		2	2	1	3
CO3	2	1	3	2		2
CO4	2	1	2	1	1	1
CO5	2	1	1	1		1

< 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, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL509
Course title: Computer Aided Process Engineering
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: II/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To be able to learn basic concept of steady and unsteady state process simulation and preliminary flowsheet development.
2.	To learn model formulation and solution for continuous process with multiple unit.
3.	To be able to use commercial softwares for development of flowsheet for chemical processes.

Course Outcomes:

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

CO1	Formulate and Solve steady state operating conditions of a system with multiple unit operations with and without chemical reaction.
CO2	Model, Solve and Analyze transient behaviour of a chemical process.
CO3	Formulate and Compute vapor-liquid equilibrium of ideal and non-ideal liquid mixture.
CO4	Make use of Aspen software to develop and analyze different types of unit operations and unit processes.
CO5	Make use of Aspen software to develop and analyze a chemical process.

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 MATLAM/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 MATLAM/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. Stephenopolos, S., "Chemical process control", Prentice Hall of India, New Delhi, 1984.
2. Introduction to Chemical Engineering Computing, Bruce A Finlayson, JOHN WILEY & SONS, INC., PUBLICATION.

REFERENCE BOOK

1. DELANCEY, G., PRINCIPLES OF CHEMICAL ENGINEERING PRACTICE, Wiley, 2013.
2. DeCoursey, W.J., Statistics and Probability for Engineering Applications with Microsoft® Excel, Newnes, Elsevier, 2003.

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

Gaps in the syllabus (to meet Industry/Profession requirements):
Process Optimization.
POs met through Gaps in the Syllabus: **PO4, PO5**

Topics beyond syllabus/Advanced topics/Design:
Molecular Simulation.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4, PO5, PO6**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignment/Simulation practice
CD3	Self- learning such as use of NPTEL materials and internets
CD4	Seminar

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	3	3	3	3
CO3	3	1	3	3	3	3
CO4	3	1	3	3	3	3
CO5	3	1	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, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4

COURSE INFORMATION SHEET

Course code: CL510
Course title: Chemical Engineering research Lab - I
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: II/05
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To study the different types of characterization techniques useful for chemical engineering.
2.	To understand the application of different analytical techniques.

Course Outcomes:

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

CO1	Determine the composition of solution.
CO2	Analyze the surface morphology of solid material.
CO3	Determine the surface structure of solid material.
CO4	Determine the composition of gas mixture.
CO5	Analyze the thermal behavior of material.

SYLLABUS

1. Characterization of organic sample by FTIR spectroscopy.
2. Determination of unknown concentration by UV-VIS Spectroscopy.
3. Study of Differential Scanning Calorimetric (DSC).
4. Study of Thermo Gravimetric Analysis (TGA).
5. Analysis by HPLC.
6. Determination of surface morphology by Scanning Electron Microscopy (SEM).
7. To study the diffraction pattern of material by Wide Angle X-Ray Diffraction (WAXRD).
8. Determination of surface area of porous sample by Physisorption technique [BET].
9. Determination of gas composition by GAS Chromatography technique.
10. Measurement of composition by AAS.

Books recommended:

TEXT BOOK

1. Material Characterization Techniques, Sam Zhang, Lin Li, Ashok Kumar, CRC Press, 2008.

REFERENCE BOOK

1. Characterization Techniques for polymer Nanocomposites, Edited by Vikas Mittal, Wiley-VCH, 2012.
2. Optical Techniques for Solid-State Materials Characterization, Rohit P. Prasankumar, Antoinette J. Taylor, CRC Press, 2011.

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

Gaps in the syllabus (to meet Industry/Profession requirements):
Composition analysis by Nuclear Magnetic Resonance (NMR).
POs met through Gaps in the Syllabus: **PO6**

Topics beyond syllabus/Advanced topics/Design:
Characterization techniques related to bio-chemical research.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignment/Simulation practice
CD3	Self- learning such as use of NPTEL materials and internets
CD4	Seminar

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	3	3	3	3
CO3	3	1	3	3	3	3
CO4	3	1	3	3	3	3
CO5	3	1	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, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4

COURSE INFORMATION SHEET

Course code: CL602
Course title: Advanced Separation Process
Pre-requisite(s): BE (Chemical Engineering)
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech..
Semester/Level: III/ 6
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:
This course will enable the students:

1.	To learn various advanced aspects of separation processes and the selection of separation processes.
2.	To understand the principles and processes of multicomponent distillation and absorption.
3.	To understand chromatography techniques and membrane separation processes.

Course Outcomes:

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

CO1	Calculate compositions of various species in multicomponent distillation.
CO2	Explain membrane distillation, Extractive Distillation, Salt Distillation, Pressure Swing Distillation.
CO3	Estimate multicomponent diffusion and mass transfer coefficients.
CO4	Learn basics of various membranes preparation and characterization techniques and solve separation problems related to membrane.
CO5	Explain and design gas-liquid contacting equipments.

SYLLABUS

Module I:

Multi Component Distillation, Selection of operating pressure, Equilibrium for Multi component System, Methods for Multi Component Distillation, Design of Batch Distillation for Multicomponent with Rectification with constant reflux & constant overhead component. (8L)

Module II:

Continuous distillation of multi component system, Energy Conservation in Distillation column, Advance topics in distillation. Distillation Curve Maps, Extractive Distillation, Salt Distillation, Pressure Swing Distillation, Homogeneous Azeotropic Distillation, Heterogeneous Azeotropic Distillation, Reactive Distillation, Supercritical Fluid Extraction. (8L)

Module III:

Diffusion in nonideal system and development of generalized Maxwell-Stefan formulation, Study of Generalized Fick's law, Estimation of binary and multicomponent Diffusion Coefficients, Study of interphase mass and energy transfer. Modeling and simulation of absorption and leaching process (8L)

Module IV:

Membrane Separation Techniques: Principles, characteristic, and classification of membrane separation processes; Membrane materials, structures, and preparation techniques; Membrane modules; Plant configurations. Membrane characterization: Pore size and pore distribution; Bubble point test; Challenge test; Factors affecting retentivity, concentration polarization, gel polarization, fouling, cleaning and regeneration of membranes. Mechanisms of separation: Porous membranes, dense membranes, and liquid membranes. Membrane separation models: Irreversible thermodynamics; Capillary flow theory; Solution diffusion model; Viscous flow models; Models for separation of gas (vapour) mixtures; Science and technology of microfiltration, reverse osmosis, ultrafiltration, nanofiltration, dialysis and electrodialysis, pervaporation, liquid membrane permeation, gas permeation. Membrane reactors: Polymeric, ceramic, metal and bio-membrane.

(8L)

Module V:

Advances in Absorption - Criteria for selection of packed tower, tray tower, Spray chamber, Venturi Scrubber etc. Design of Falling Film Absorption, Design of Spray Chamber Design of Venturi Scrubber, Advantage of Falling Film Absorber. (8L)

Books recommended:

TEXT BOOK

1. Introduction to Process Engineering and design by S.B.Thakore & B.I. Bhatt. **(T1)**
2. Chemical Engineering Handbook 7th edition by R.H.Perry & Green D. **(T2)**

3. Mass Transfer Operation 3rd Edition by R.E.Treybal. **(T3)**
4. B.D. Smith, Design of Equilibrium Staged Processes, McGraw Hill. **(T4)**
5. Van Winkle , Distillation, McGraw Hill. **(T5)**

REFERENCE BOOK

1. B.D. Smith, Design of Equilibrium Staged Processes, McGraw Hill. **(R1)**
2. Van Winkle, Distillation, McGraw Hill. **(R2)**

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

Gaps in the syllabus (to meet Industry/Profession requirements):
Multicomponent absorption and Non-isothermal absorption.
POs met through Gaps in the Syllabus: **PO5, PO6**

Topics beyond syllabus/Advanced topics/Design:
Detailed design of separation process Equipments such as distillation column.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignments/Seminar
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	2	1	1
CO2	1	1	2	1	1	3
CO3	3	1	2	3	1	3
CO4	3	1	3	3	3	3
CO5	3	1	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

Programme Elective-III

COURSE INFORMATION SHEET

Course code:	**CL631**
Course title:	Composite Manufacturing Technology
Pre-requisite(s):	**CH101, PH111, MA103**
Co- requisite(s):	**Nil**
Credits:	L: 03 T: 00 P: 00
Class schedule per week:	**03**
Class:	**M. Tech**
Semester / Level:	**III/06**
Branch:	**Chemical Engineering**
Name of Teacher:	

Course Objectives:

This course enables the students:

1.	To impart the fundamentals of polymer composites and its applications.
2.	To know about manufacture, properties and application of polymer and fibre.
3.	Explain the basic properties, characteristics and constituents of composite materials.
4.	Present and apply the different fabrication processes for composite materials, including bonding, fastening, laminating, and finishing techniques.
5.	Perform design, construction, and fabrication of laminate parts, Define and use appropriate terminology as it relates to composite structure design and manufacturing.

Course Outcomes:

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

CO1	Classify the different type of polymeric composites and its applications.
CO2	Select different types of matrix and reinforcement materials.
CO3	Ability to select the process for fabrication of polymer composites.
CO4	Relate theoretical knowledge with typical products and its stress –strain behavior.
CO5	Aware of different testing and characterization of polymer composites.

SYLLABUS

Module I:

Polymer composite systems: Types of composites, reinforcements, Types of Resin. (8L)

Module II:

Natural fibre: Jute, sisal, cotton, hemp **Ceramic fibre:** silicon carbaide, zinc, Alumina, glass, **Synthetic fibre**: polyethylene, polyester, nylon, Kevlar. (8L)

Module III:

Thermoset, elastomer - resins (polyesters, epoxide, vinyl ester, phenol formaldehyde, polyimide, reinforced polyolefin, semi crystalline and amorphous polymers - PEEK, PP, PEK, PBT, PC, ABC, nylon etc.) additives, reinforcements (particulate, fibrous, gaseous). (8L)

Module IV:

Processing techniques - open mould, hand lay up spray up, vacuum bag moulding, pressure bag moulding, autoclave moulding, closed mould, SMC, DMC, RTM., Continuous manufacturing process - pultrusion, filament winding, centrifugal casting. Application (sandwich constructions - aircraft, racing cars, helicopter rotor blades etc.), Nano composites. (8L)

Module V:

Mechanical behaviour of composites. Deformation Behaviour of reinforced plastics, Types-reinforcement, matrix, Forms of fibre reinforcement in composites, Analysis of Continuous fibre composites, Deformation behaviour of a single ply or lamina, Deformation behaviour of Laminates, Analysis of multi-layer isotropic materials, Analysis of Non-symmetric laminates, Analysis of short fibre composites, Creep behaviour of fibre reinforced plastics, Fatigue behaviour of reinforced plastics, Impact behaviour of reinforced plastics. Bending buckling and vibration of laminated plates. Testing and joining of composite materials. (8L)

Books recommended:

TEXT BOOK

1. Dyson, R.W., "Engineering Polymers", Blackie, 1990. **(T1)**
2. Crawford, R.J., Plastics Engineering, Pergamon Press. **(T2)**

REFERENCE BOOK

1. Richardson, T., Composites – a design guide industrial press Inc., New York, 1987. **(R1)**

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

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

- Apply quality systems to composite manufacturing and product testing.
- Need more design problem on fibre orientation

POs met through Gaps in the Syllabus: **PO5, PO6**

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	2	1	3	1		1
CO2	2		2	2	1	3
CO3	2	1	3	2		2
CO4	2	1	2	1	1	1
CO5	2	1	1	1		1

< 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, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code:	**CL 632**
Course title:	**Polymer Physics**
Pre-requisite(s):	CH101, PH111, MA103
Co- requisite(s):	
Credits:	L:03 T:00 P:00
Class schedule per week:	**03**
Class:	**M. Tech.**
Semester/Level:	**III/06**
Branch:	**Chemical Engineering**
Name of Teacher:	

Course Objectives:
This course enables the students to:

1.	Learn the fundamental knowledge on the physics of polymer materials, their volume and surface properties;
2.	knowledge on polymer materials with special properties, obtained by various physical and chemical methods, and of their performances;
3.	ability to use analysis techniques to identify the properties of polymer materials of interest in modern applications;
4.	work in a team for solving experimental and technological issues; identify and use bibliographic resources for continuous formation
5.	To familiarize with recent advances in the field of Polymer Physics

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

CO1	account for different descriptions of size and shape of a polymer, and being able to predict phase properties and aggregate structure from the chemical properties and structure of the monomers, using the Flory-Huggins theory.
CO2	account for the molecular theory of rubber elasticity and apply this on relevant problems.
CO3	apply phenomenological theory to characterise linear viscoelastic materials. account for the origin of deformation and fracture of polymeric materials from a molecular basis.
CO4	suggest and motivate choice of polymeric materials in different products and practical applications, especially regarding rheology and strength.
CO5	Analyze viscoelastic properties of polymer materials and validate the properties in terms of models available in literature.

SYLLABUS

Module I:

A single ideal chain; mean-square end-to-end distance, radius of gyration. Gaussian chain. freely jointed chain. worm-like chain, stretching and confinement, structure factor, excluded volume, solvent quality, theta-temperature. Polymer solutions: Flory Huggins Theory, osmotic pressure. Polymer solutions: scaling laws for good solvents, concentration fluctuation and correlation length. Polymer solutions: Size of a polymer in semi-dilute solutions, poor solvents and phase separation, fractionation. (8L)

Module II:

Measurements of polymer sizes in solution: osmotic pressure, light scattering, intrinsic viscosity, size-exclusion chromatography. Polymer melts / concentrated solutions, SANS studies of chain dimensions and of correlation hole. Polyelectrolytes. Debye-Huckle theory, Donnan equilibrium. Rubber elasticity; gels. Polymer thermodynamics: phase behavior of polymer blends; stability and metastability. Dynamics of polymeric liquids: phenomenology and constitutive equations, Maxwell model. Rouse theory: equations of motion, normal modes, time-temperature superposition. (8L)

Module III:

Diffusion & viscoelasticity, experimental tests of Rouse theory. Zimm theory: hydrodynamic interactions, free-draining and non-draining limits, pre-averaging approximation, experimental tests. Reptation theory: tube model; primitive chain, reptation dynamics. The glass transition; free volume theory. End-teethered chains: polymer brushes, self-assembly and order-disorder transitions of di-block copolymers. Liquid crystalline polymers, polymer crystallization. (8L)

Module IV:

Linear Viscoelasticity: Boltzmann Superposition Principle, Empirical models for linear viscoelasticity, Relaxation Spectrum, Dynamic Response, Time temperature superposition, Polymeric Yield and Ductility. (8L)

Module V:

Measurement of viscosity: Rotational and sliding surface viscometer, capillary & slit rheometers - sources of error and their corrections. Rheo-optics & molecular orientation, Effects of Molecular structure on Rheological properties. Rheology of multi- phase systems, Reacting systems, liquid crystal polymer. (8L)

Books recommended:

TEXT BOOK

1. Text Book of Physical Chemistry ; S. Glasstone, Mc millan and Co. 1962, New Delhi, 2nd Ed. 1962. **(T1)**
2. Introduction to Physical Polymer Science, L.H. Sperlings, John Wiley and Sons. New York, 3rd Ed. 2001. **(T2)**

REFERENCE BOOK

1. Melt Rheology and its role in Plastic Processing, John F. Dealy & Kurt F. Wissburn, Kluwer Academic Publishers, 1999. **(R1)**
2. Viscoelastic Properties of Polymers, John D. Ferry, 3rd edition, John Wiley & Sons, 1980. **(R2)**

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

<u>Gaps in the syllabus (to meet Industry/Profession requirements) :</u>
Industry oriented problems solving topics not covered.
POs met through Gaps in the Syllabus: **PO5**

<u>Topics beyond syllabus/Advanced topics/Design:</u>

POs met through Topics beyond syllabus/Advanced topics/Design:

<u>COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	2			3
CO2	3		2		1	3
CO3	3		2	2		3
CO4	3	1	2	2	1	3
CO5	3	1	2	2	1	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, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code:	**CL633**
Course title:	**Polymer Product Manufacturing Technology**
Pre-requisite flow chart:	CH101, PH111, MA103
Co-requisite:	
Credits:	L: 03 T: 00 P: 00
Class schedule per week:	**3**
Class:	**M.Tech.**
Semester / Level:	**III/6**
Branch:	**Chemical Engineering**
Name of Teacher:	

Course Objectives:

This course enables the students:

1	Understanding: Outline the steps of specific process to manufacture a specific product, identify the various parts of the machine and explain the function of it.
2.	Apply: Solve numerical problems on simple flow analysis for polymers during a specific processing, interpretation and analysis of rheological data using models for non-Newtonian fluids.
3.	Predict: the reasons behind specific product defect and propose probable solutions specific to processing technique.

Course Outcomes:

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

CO1	Understanding: Choose the methods of product manufacture with given plastic material for the specific use.
CO2	Analyze: Identify the defects in plastic products, interpret the product quality in terms of machine parameters and suggest professional engineering solutions as remedies which will be sustainable and economical.
CO3	Apply: Apply most modern technology to modify the process variables on existing machine to manufacture a specific plastic/ rubber/composite product.
CO4	Create: optimize the design for manufacturing specific product, handle projects related to development of new products.
CO5	Design: design and develop polymer product with defined structural properties.

SYLLABUS

MODULE- I
Compression moulding –Process description, various parts of the machine, Types of moulds, analysis of melt flow inside a mould, Advantages and limitations of compression moulding, Materials used- with and without reinforcement, Manufacturing of specific products-shoes, sheets. [8L]

MODULE II:
Extrusion: Extruder variuos parts of the machine Classification-single screw, twin screw (co and counter rotating type), Flow analysis: pressure flow, leak flow, drag flow, influence of polymer properties, Technology of product manufacturing: dies used for Pipe, films, Tapes. [8L]

MODULE III:
Injection moulding–Effect of mould cooling on product quality, ejection, Part cooling analysis, Reaction Injection Moulding-process description, materials used, product defects and its remedies. [8L]

MODULE IV:
Pultrusion- process description, Materials used-resin, reinforcement, Classification, Machinery, defects, remedies, **Blow moulding**- process description, Materials used-resin, reinforcement, Classification, Machinery, defects, remedies, Analysis of product quality. [8L]

MODULE V:
Calendering- process description, Materials used-resin, reinforcement, Classification, Machinery, defects, remedies classification, flow analysis, **Rotomoulding**- process description, Materials used-resin, reinforcement, Classification, Machinery, defects, remedies classification. [8L]

Books recommended:

TEXT BOOK

1. Plastics Engineering, Crawford, R.J., Pergammon Press. **(T1)**
2. Polymer Extrusion, Chris Rauwendaal, Hanser, 1994. **(T2)**
3. Plastics Product Design and Process Engineering, H. Belofsky, Hanser, 1995. **(T3)**
4. Blow Moulding Handbook, Rosato, D.V. and Rosato D.V., Hanser, 1989. **(T4)**
5. Plastic Extrusion Technology, Hensen, Hanser, 1997. **(T5)**
6. Polymer processing,D.H.Morton-Jones,Chapmman & Hall, New York,1989. **(T6)**

REFERENCE BOOK

1. Principles of Polymer Processing, Tadmor, Z and Gogos, C.G., John Wiley and Sons, 1982. **(R1)**
2. Plastics: Product Design and Process Engineering, Belofsky, H., Hanser Pub. 1995. **(R2)**
3. Fundamentals of Polymer Processing, Middleman, Mc Graw Hill, 1979. **(R3)**
4. Rotational Moulding Technology, R.J Crawford and J.L.Throne, William Andrew publishing, 2002. **(R4)**
5. Thermoforming, J.L.Throne, Hanser, 1987. **(R5)**

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

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

- Lack of coverage on Product development based on specific material and techniques.
- Troubleshooting of various processing technology.

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

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Industrial visits/in-plant training
CD5	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	1	1	3
CO2	2	1	3	2	1	3
CO3	3	1	3	3	2	3
CO4	3	1	3	3	3	3
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, CD5
CO2	CD1, CD2, CD5
CO3	CD1, CD4, CD5
CO4	CD2, CD3, CD5

COURSE INFORMATION SHEET

Course code: **CL634**
Course title: **Polymer Rheology**
Pre-requisite(s): **Macromolecular Science, Polymer Technology**
Co- requisite(s):
Credits: **L: 03 T:00 P:00**
Class schedule per week: **03**
Class: **M. Tech.**
Semester/Level: **III/6**
Branch: **Chemical Engineering**
Name of Teacher:

Course Objectives

This course enables the students:

1.	To provide the student with an understanding of deformation and flow of polymeric materials such as polymeric liquids, suspensions, melts, colloids, foams, gels, etc.
2.	To understand mechanical behaviour of polymeric materials under applied load for short term and long-term flow behavior of polymer melts.
3.	An ablity to perform experimental techniques for measuring the rheological properties.

Course Outcomes

After the completion of this course, students will be:

CO1	An ability to apply knowledge of mathematics, science and engineering.
CO2	Attain the knowledge in flow behaviour of polymers.
CO3	Acquire knowledge in handling rheological instruments and ability to design and conduct experiments, as well as analyze and interpret data.
CO4	Able to describe the viscoelastic behavior of polymers with respect to their chemical structures.
CO5	To construct a corresponding master curve from the experimental data, which can be used to predict the material response at different temperatures, times, and/or frequencies.

SYLLABUS

Module I:

Introduction and Basic concept of Rheology, classification of fluids, Newtonian and non-Newtonian fluids-Viscosity Models, Yield stress fluids, thixotropic fluids - Structural model, Shear Flow, Dependence of viscosity with temp, pressure, shear stress, shear rate etc. Fluid flow through pipe, parallel plates, slit channel, Annulus Flow. [8L]

Module II:

Viscoelasticity – effect of rate of strain, temperature and time on mechanical behaviour of polymeric materials. Viscoelastic models – stress strain response of spring and dashpot, Maxwell element, Voigt kelvin element – response to creep and stress relaxation, three and four-parameter model. Viscosity of polymer melts– Normal stress, die-swell and melt fracture, Weissenberg effect, Elongational fluid flow. [8L]

Module III:

Measurement of rheological properties: Rotational and capillary rheometers, capillary & slit rheometers - sources of error and their corrections. torque rheometers, Mooney viscometer. [8L]

Module IV:

Dynamic mechanical properties, Complex viscosity, Boltzmann Superposition principle, time temperature superposition, Relaxation spectrum, WLF equation. Applications of rheology to polymer processing (injection moulding, extrusion and blow moulding). [8L]

Module V:

Molecular theories of Prediction of linear behaviour, Rouse Model, Bueche Ferry law. Theories of Entangled Melts, Reptation, Doi Edwards Theory, Curties- Bird Model. Rheo-optics & molecular orientation. Effects of Molecular structure on Rheological properties. Rheology of multiphase systems, Reacting systems, liquid crystal polymers. [8L]

Books recommended:

TEXT BOOK

1. Dynamics of Polymeric Liquids, Bird RB, Armstrong RC and Hassager O, John Wiley & Sons, 1987. **(T1)**
2. J.A.Brydson, Flow properties of polymer melts, life books, London, 1978. **(T2)**
3. R.J. Crawford, Plastics Engineering, Butterworth – Heinemann, Oxford, 1998. **(T3)**
4. P.N.Cogswell, Polymer Melt Rheology, A guide for Industrial Practice, George Godwin. **(T4)**
5. John M. Dealy and Kurt F. Wissburn, Melt rheology and its role in plastics processing, Chapman, London, 1995. **(T5)**

REFERENCE BOOK

1. Richard C. Progelhof and James L. Throne, Polymer Engineering Principles, Hanser Publishers, New York, 1993. **(R1)**
2. R.S. Lenk, Polymer Rheology, Applied Science, London, 1978. **(R2)**
3. J.D. Ferry, Viscoelastic Properties of Polymers, john Wiley & Sons, New York, 1986. **(R3)**
4. Chang Dae Han. Rheology in Polymer Processing, Academic Press, New York, 1976. **(R4)**
5. The Structure and Rheology of Complex Fluids, Larson RG, Oxford University Press, 1999. **(R5)**
6. Rheology and Non-Newtonian Fluids, Irgens F, Springer, 2014. **(R6)**

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:

POs met through Topics beyond syllabus/Advanced topics/Design:

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	1	1	3
CO2	2		3	2	2	3
CO3	3		3	3	2	3
CO4	2	1	3	2	1	3
CO5	2	1	3	2	1	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, CD3
CO5	CD1,CD2,CD3

COURSE INFORMATION SHEET

Course code: **CL635**
Course title: **DIE AND MOLD DESIGN**
Pre-requisite(s):
Co- requisite(s):
Credits: L: 03 T: 00 P: 00
Class schedule per week: **03**
Class: **M. Tech**
Semester / Level: **III/06**
Branch: **Chemical Engineering**
Name of Teacher:

Course Objectives

This course enables the students:

1.	To learn about the design of injection mould and its various parts.
2.	To learn about the design of compression & transfer mould and its various parts.
3.	To learn about the design of blow mould and its various parts.
4.	To learn about the design of extrusion dies and its various parts.
5.	To understand the concept of different types of mould fabrication & selection of materials for various parts of mould.

Course Outcomes

After the completion of this course, students will be:

CO1	Able to understand about design of various types of moulds such as injection, compression, blow moulding and extrusion dies.
CO2	Able to develop knowledge in selection of mould for different processing techniques such as injection, compression, blow and extrusion process.
CO3	Able to list the various parts of moulds and its design.
CO4	Able to understand about different types of mould fabrication.
CO5	Able to design a mould or die for a new product.

Syllabus

MODULE 1:
Injection mould design: Introduction – different types of injection moulds, basic mould elements. Methodological mould design. Computation of number of cavities, cavity layout. Selection of parting line. Feed system – design of sprue, runner & gate, Cooling systems, Ejection systems, Mould venting, Mould Alignment, Lifting and clamping. Mechanical Design, Strength of cavities, Support pillar, screws in molds. (8L)

MODULE 2:
Compression & Transfer Mould design: Types of compression moulds, loading chamber design, heater types & calculation, pressure pad area calculation. Transfer moulds: Types of transfer molds, design of pot and plunger, Feed system, Ejection method, cull pick up. (8L)

MODULE 3:
Blow Mould design: Types of blow mould, Mould material selection, Parting line, neck, pinch off design, parison design, flash trimming, mould venting, mould cooling, mould alignment. (8L)

MODULE 4:
Extrusion die design: Introduction – different types of die exit cross sections: Circular, slit, annular, profile. (8L)

MODULE 5:
Mould fabrication: Selection of materials for moulds and dies. Steels for moulding tools and their treatment. Selection of materials for various parts of mould like cavity, core, back plates, push back pin, guide pin, guide bushes, ejector elements, etc. Selection of materials for various parts of Dies. Outline of method of fabrication: Lathe, milling, grinding, drilling, EDM, shaping, etc., (8L)

Text books:

(1) Injection Mold Design, R.G.W. Pye, George Godwin. (**T1**)
(2) How to make Injection molds, Menges/Mohren, Hanser, 1993. (**T2**)
(3) Production Technology, R.K. Jain, S. Chand & Co., 1991. (**T3**)
(4) Blow Molding Handbook, D.V. Rossato, Hanser, 1989. (**T4**)
(5) Extrusion Dies for Plastics and Rubber, W. Michaeli, Hanser, 1992. **(T5**)

Reference books:

(1) Plastic Mold Engineering Handbook, Dubois & Rribble, Chapman & Hal, 1987. (R1)
(2) P.S. CRACKNELL and R.W DYSON, “Hand Book of Thermoplastics – Injection Mould Design”, Chapman & Hall, 1993. (R2)
(3) Mold Engineering, Herbert Rees, Hanser, 1995. (R3)
(4) Laszlo Sors and Imre Balazs, “Design of Plastics Moulds and Dies”, Elsevier, Amsterdam Oxford – Tokyo – NY, 1989. (R4)

Course Evaluation:
Individual assignment, Quiz, Mid and End semester examinations.

Gaps in the syllabus (to meet Industry/Profession requirements):
Design of Molds (case studies) for solving industrial problems.
POs met through Gaps in the Syllabus: **PO4; PO5**

Topics beyond syllabus/Advanced topics/Design:
Advanced Mold design related to industrial problems.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4; PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignments/Seminars
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	2	2	3	2	2
CO2	3	2	3	3	2	2
CO3	3	2	2	3	2	2
CO4	3	2	2	3	2	2
CO5	3	2	2	3	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
CO2	CD1, CD2, CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL614
Course title: Process Integration
Pre-requisite(s): CL308, CL210
Co- requisite(s):
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester /Level: III/06
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1	To learn the concept of Process Intensification.
2	To apply the techniques of intensification to a range of chemical processes and process Equipment's.

Course Outcomes:

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

CO1	Assess the importance and limitations of process intensification.
CO2	Explain the principles of intensified technologies/Equipments such as compact heat exchanger, Higee reactors, Reactive absorption, Reactive distillation.
CO3	Plan for research in new energy systems, materials and process intensification.
CO4	Explain basics of pinch technology and its application.
CO5	Explain and design of heat exchanger networks.

SYLLABUS

Module I:

Introduction to Process Intensification and Process Integration (PI). Areas of Application and Techniques available For PI, Onion Diagram, Process Integration in Chemical Industries, Formulation of a Design Problem, Chemical Process Design and Integration, Hierarchy of Chemical Process Design and Integration, Continuous and Batch Processes, New Design and Retrofit, Approaches to Chemical Process Design and Integration, Process Control. (8L)

Module II:

Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology. Key steps of Pinch Technology: Concept of ΔT_{min}, Data Extraction, Targeting, Designing, Optimization-Super targeting. Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve. (8L)

Module III:

Targeting of Heat Exchanger Network, Designing of Heat Exchanger Networks, Hot Composite Curve, Cold Composite Curve, Problem Table Algorithm, Grand Composite Curve, Area Targeting by Uniform Bath formula and Unit Targeting by Euler's formula, Heuristics for Pinch Design, Maximum Energy Recovery Design, Evolution of Network. (8L)

Module IV:

Choice of Idealized reactor model and reactor performance. Reactor configurations: Temperature Control, Gas-Liquid and Liquid Reactors, Choice of Reactors. Heat Integration characteristics of reactors, Appropriate placements of reactors. Use of GCC for Heat Integration of reactor. (8L)

Module V:

Distillation sequencing, Heat Integration characteristics of Distillation column, appropriate placement of distillation column, various configurations for heat integration of distillation column.

(8L)

Books recommended:

TEXT BOOK

1. Chemical Process Design and Integration Robin Smith, John Wiley and Sons. Ltd., New Delhi, 2005. **(T1)**

2. Product & Process Design Principles Warren D. Seider, J. D. Seader and Daniel R. Lewin, Wiley Publication. **(T2)**

REFERENCE BOOK

1. Heat Exchanger Network Synthesis U. V. Shenoy, Gulf Publication. **(R1)**

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Case Studies related to industrial problems.
POs met through Gaps in the Syllabus: **PO5**

Topics beyond syllabus/Advanced topics/Design:
Use of commercial software for solving industrial problems.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4, PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
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	1	1	3
CO2	3	1	3	1	1	3
CO3	3	1	3	2	1	3
CO4	3	1	3	2	2	3
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, CD3
CO2	CD1, CD2 CD3
CO3	CD1, CD2, CD3
CO4	CD1, CD2, CD3
CO5	CD1, CD2, CD3

COURSE INFORMATION SHEET

Course code: CL603
Course title: Chemical Engineering research Lab - II
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: III/06
Branch: Chemical Engineering
Name of Teacher:

Course Objectives:

This course will enable the students:

1.	To gather the basic knowledge of different research fields which included in the domain of chemical engineering.

Course Outcomes:

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

CO1	Prepare the supported metal oxide catalyst.
CO2	Prepare the membrane and study its property.
CO3	Analyze the basic principle of electrolysis.
CO4	Build the basic knowledge of biochemical engineering.
CO5	Analyze the kinetic of hydrocarbon reactions.

SYLLABUS

1. Preparation of supported Metal Oxide Catalyst.
2. Preparation of UF membrane by phase inversion method and its characterization.
3. Metal recovery from Dilute solution by Electrochemical Method.
4. Bioethanol preparation.
5. Biodiesel Preparation.
6. Studies on energy storage using phase change material.
7. Transient analysis of Plate Heat Exchanger.
8. Waste water treatment by Phenton's Reagent.
9. Glycerol dehydration by reactive distillation.
10. Determination of calorific value by Bomb Calorimeter.

Books recommended:

TEXT BOOK

1. Material Characterization Techniques, Sam Zhang, Lin Li, Ashok Kumar, CRC Press, 2008.

REFERENCE BOOK

1. Characterization Techniques for polymer Nanocomposites, Edited by Vikas Mittal, Wiley-VCH, 2012.
2. Optical Techniques for Solid-State Materials Characterization, Rohit P. Prasankumar, Antoinette J. Taylor, CRC Press, 2011.

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

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

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	Y	Y	Y	Y	Y
Semester End Examination	Y	Y	Y	Y	Y

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors
CD2	Assignment/Simulation practice
CD3	Self- learning such as use of NPTEL materials and internets
CD4	Seminar

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	3	3	3	3
CO3	3	1	3	3	3	3
CO4	3	1	3	3	3	3
CO5	3	1	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, CD4
CO2	CD1, CD2, CD3, CD4
CO3	CD1, CD2, CD3, CD4
CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4