COURSE DESCRIPTION

Ist Semester

Title of Course: Advance Transport Phenomena Course Code: CL501
L-T-P Scheme: 3-0-0 Course Credits: 3

Course Objective
The main aim of the course is to give an introduction to the mathematical foundation required for the analysis of fluid flow, heat transfer and mass transfer. The emphasis of the course will be on formulation of a given physical problem in terms of appropriate conservation equations, and obtaining a physical understanding of the associated phenomena.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the basic concepts of fluid mechanics, heat and mass transfer.
CO2	Understand overall balances for conservation of momentum, energy and mass.
CO3	Recognize and apply analogies among momentum, heat and mass transfer.
CO4	Analyze and solve the appropriate equations of change to obtain desired profiles for velocity, temperature and concentration.
CO5	Evaluate information obtained from solutions of the balance equations to obtain Engineering quantities of interest.
CO6	Develop mathematical expressions for complex problems.

Course Contents

UNIT 1: Preliminaries &Introduction
Vector and tensor algebra: Geometric view point, addition of vectors, multiplication by scalar, scalar product, cross product.
Analytical view point: kronecker delta, alternative unit tensor for cross product, cross product between two unit vector, vector operations in terms of components, vector addition, multiplication by scalar, scalar product between vectors, vectors product, identities for ε_{ijk}.
Vector Differential operations: Del operator, gradient of scalar, divergence of a vector, curl of a vector, Laplacian of a scalar, material derivative of a scalar.
Tensors: second order tensor, dyadic product, unit tensor, transpose of tensor, addition, dot product, double dot product, vector product, divergence of a tensor, trace, determinant.
Integral Theorems: Divergence theorem, curl theorem, Liebnitz rule.
Cylindrical coordinates: Del operator in cylindrical coordinates, derivatives of unit vectors.
Kinematics: Eulerian & Lagrangian view point, relationship between Eulerian and Lagrangian view points, Reynolds transport theorem, Motion near a point, relative velocity, vorticity tensor.

UNIT 2: Fluid Mechanics
Governing equations: conservation of mass, continuity equation, conservation of linear momentum, conservation of angular momentum, stress tensor, Cauchy's Ist and 2nd laws, Navier-Strokes equations, unidirectional flows, flow down an inclined surface, flow of generalized Newtonian fluid in cylindrical tube, flow with central plug region, tangential annular flow, velocity in the limit of narrow gap, flow due to wall suddenly set in motion, unsteady flow between parallel plates, two dimensional flows, stream function, stream lines, dimensional analysis approximation, dimensionless governing equations, creeping flow, velocity of particle falling from rest, flow in slow varying channels, in-viscid flow, potential flow past a cylinder, boundary layer theory, flow past a flat plate, converging flow, diverging flow, turbulent flow, transition to turbulence, turbulence models.

UNIT 3: Heat Transfer
Governing equations: energy balance equations, conservation of energy law, heat flux at any point, mechanical energy balance, constitutive equations for conduction, boundary conditions, steady state conduction through a composite wall, temperature profile in an electric wire, unsteady state conduction in a slab, heat conduction with generation in a slab, viscous dissipation, heat transfer from a cooling fin, forced convection in a pipe, macroscopic energy balance, free convection, free convection between vertical parallel plates, free convection near a heated vertical plate, free convection heat transfer from a vertical plate, dimensionless parameter for heat transfer, Radiation.

UNIT 4: Mass Transfer
Governing equations: species mass balance, Concentration, velocities and mass fluxes, constitutive equations, boundary conditions, Complete solutions: diffusion through a stagnant film, diffusion of gas with heterogeneous reaction, diffusion with homogeneous chemical reaction, diffusion into a falling liquid film, diffusion and reaction in a spherical droplet, diffusion and reaction in a porous catalyst pellet, Simultaneous heat and mass transfer, condensation in the presence of non-condensable gases.

Teaching Methodology:
This course is introduced to help students understand in detail transport phenomena. The entire course is broken down into following separate units: introduction to transport phenomenon, fluid mechanics, heat transfer, and mass transfer. Each unit includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2 to Unit-3, and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and around 30% from coverage of Test-2

Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Bird, R. B. , Stewart, W.E. and Lightfoot, E.N., 2002, "Transport Phenomena", 2nd Ed., John Wiley & Sons, New York.

Reference Books:

1. Slattery, J.C., 1981, "Momentum, Heat and Mass transfer", Krieger Pub.
2. Batchelor, G.K., 1967, "Introduction to Fluid Dynamics", Cambridge Uni. Press.
3. Pritchand, P.J., Fox, R.W., McDonald, A.T. and Leylegian, J.C., 2010, "Fox and McDonald's Introduction to Fluid Mechanics", 8th Ed., John Wiley & Sons.
4. Munson, R.B., Young, D.P. and Okiishi, T.H., Huebsch, W.W., 2008, "Fundamentals of Fluid Mechanics", 6th Ed., John Wiley & Sons, New York.
5. Tosun, I., 2007, "Modelling in Transport Phenomena – A Conceptual Approach", 2nd Ed, Elsevier Science & Technology Books.
6. Eduardo, C, 2009, "Heat Transfer in Processing Engineering", McGraw-Hill, New York.
7. White, F.M., 2010, "Fluid Mechanics", 6th Ed, McGraw-Hill, New York.

Title of Course: Process Modeling & Optimization **Course Code: CL502**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals with the mathematical modeling, simulation and optimization of various chemical processes.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the importance Process modeling and optimization.
CO2	Understand different types of mathematical modeling.
CO3	Apply simulation processes and techniques for various operations.
CO4	Analyzevarious optimization techniques.
CO5	Evaluate various processes after applying single and multi-variable optimization techniques
CO6	Develop the complete optimization and simulation of chemical process plants.

Course Contents

UNIT 1: Introduction

Mathematical models for chemical engineering systems: Fundamentals, introduction to fundamental laws. Examples of mathematical models of chemical engineering systems, constant hold up CSTRs, Gas pressurized CSTR, non-isothermal CSTR. Examples of single component vaporizer, Batch reactor, reactor with mass transfer, ideal binary distillation column, batch distillation with hold up.

UNIT 2: Classification of Mathematical modeling

Classification of mathematical modeling, static and dynamic models, the complete mathematical model, Boundary conditions, the black box principle. Artificial Neural Networks: Network training, Models of training, Network architecture, Back-propagation algorithm, ANN applications.

UNIT 3: Simulation of Chemical Processes

Computer Simulation: Simulation examples of Three CSTRs in series, Gravity Flow tank, Binary distillation column, Non-isothermal CSTR. Models for chemical reaction with diffusion in a tubular reactor, chemical reaction with heat transfer in a packed bed reactor, gas absorption accompanied by chemical reaction.

UNIT 4: Optimization Techniques for Single Variable

Introduction to process optimization; formulation of various process optimization problems and their classification. Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.Optimization of one dimensional function, unconstrained multi variable optimization. Bracketing methods: Exhaustive search method, Bounding phase method, Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic elimination method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Secant method, Cubic search method. Root-finding using optimization techniques.

UNIT 5: Optimization Techniques for Multivariable
Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method for multipliers, Sensitivity analysis and Direct search for constraint minimization: Variable elimination method, complex search method. Successive linear and quadratic programming, optimization of staged and discrete processes.

Teaching Methodology:

This course is introduced to help students understand basic concepts of modeling, simulation and optimization of chemical processes. The entire course is broken down into following separate units: Introduction, Classification of mathematical modeling, Simulation of chemical processes, Introduction to optimization, Optimization techniques for single and multi variable. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4&Unit-5 around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Luyben, William, Process Modeling, Simulation and Control for Chemical Engineers, McGraw Hill, New York, 1990.
2. B.V. babu, "Process Plant Simulation", Oxford University.
3. Crowe, C.M., Hamielec, A.E., Hoffman, T.W., Johnson, A.I., Woods, D.R. and Shannon, P.T., 1971, "Chemical Plant Simulation", Prentice Hall, Inc., Englewood Cliff, New Jersey.
4. Kalyanmoy D. "Optimization for engineering design", Prentice Hall of India.
5. T.F. Edgar and D.M. Himmelblau, 1989, "Optimization of chemical processes", McGraw Hill, International editions, chemical engineering series.

Reference Books:

1. G.S. Beveridge and R.S. Schechter, 1970, "Optimization theory and practice" McGraw Hill, New York.
2. Rekllitis, G.V., Ravindran, A, and Ragdell, K.M., 1983 "Engineering Optimization Methods and Applications", John Wiley, New York.

Elective –I

Title of Course: Process Dynamics & Control **Course Code: CL701**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
This course deals with the study and analysis of various control strategies used in chemical plants.

Learning Outcomes:

Course Outcome	Description
CO1	Describe advanced control strategies.
CO2	Understand the design of multivariable process control.
CO3	Apply method of decoupling control systems and model predictive control.
CO4	Analysis of sampled data control system.
CO5	Evaluate z-transform for stability analysis of sampled data systems.
CO6	Develop control strategy for heat exchangers, distillation column & reactors.

Course Contents

UNIT 1: Preliminaries
Review of basic concepts in process control: Laplace transformation, first order systems, second order systems & their dynamics, Open loop & closed loop control systems, frequency response of closed–loop systems, Bode diagram, stability criterion, Nyquist diagram, Tuning of controller settings.

UNIT 2: Advanced Control Systems
Introduction to multiple loop control systems, Cascade control, feed forward control, Inferential control, Adaptive & ratio control with chemical engineering applications.

UNIT 3: Multivariable Processes
Model based control; Multivariable control strategies; Model predictive control; Analysis of Dynamic Matrix Control (DMC) & Generalized Predictive Control (GPC) schemes; Controller tuning & robustness issues. Extensions to Constrained & Multivariable cases.

UNIT 4: Applications
Examples for control of heat exchangers, distillation column & reactors.

UNIT 5: Use of Computers
Introduction to microprocessors & computer control of chemical processes.

Teaching Methodology:
This course is introduced to help students to learn about advanced control strategies, design control system for multivariable processes, and digital control system.The entire course is broken down into following separate units:Preliminaries, Advanced Control Systems, Multivariable Processes, Applications, and Use of Computers. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2& Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:
1. George Stephanopolous, “Chemical Process Control”, Prentice–Hall of India Pvt-Ltd., New Delhi, 1990.
2. Luyben and Luyben, 1996,”Essentials of Process Control”, McGraw-Hill.

Reference Books:
1. L.Ljung, 1987, “System Identification–Theory for the User”, Prentice Hall.
2. E.Camacho and C.Bordons, 1995. “Model Predictive Control in the Process Industry”.
3. B.G.Liptak, “Instrument Engineer’s Handbook”, Volume 1&2, CRC Press.

Title of Course: Advanced Heat Transfer and Fluid Dynamics

Course Code:CL702

L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The course aims deals with the understanding and application of heat and fluid dynamic concepts in various engineering problems.

Learning Outcomes:

Course Outcome	**Description**
CO1	Able to describe the basic concepts of heat transfer and fluid mechanics.
CO2	Understand various heat transfer mechanisms and fluid flow mechanisms
CO3	Apply various equations related to heat transfer and fluid flow.
CO4	Analyse various flow equations.
CO5	Evaluate various velocity profiles obtained in different flow patterns.
CO6	Develop flow equations for complex problems.

Course Contents

Unit - 1: Heat Transfer

Application of dimensional analysis to convection problems Heat Transfer in laminar turbulent and flow in closed conduits. Natural Convection heat transfer. Analogies between momentum heat and mass transfer. Heat transfer in packed fluidized beds. Condensing heat transfer co-efficients. Condensation of mixed vapours in presence of noncondensible cases. Boiling liquid heat transfer.

Unit - 2: Fluid Dynamics

Dimensional Analysis: Buckingham Pi-theorem, Rayleigh method, Geometric Kinematic and dynamic similarity, scale up numerical problems on pumps, drag force, and agitation. Differential Equation of fluid flow: Continuity equation for one dimensional and three dimensional flow. Derivation of momentum equation (Navier-Stoke's equation) for three dimensional flow.

Unit - 3: Laminar flow of viscous fluids

Effects of viscosity on flow, pressure gradient in steady uniform flow, Poseuille equation and friction factor, Reynolds number, velocity profiles in isothermal flow in circular tube and annuli and friction factor relations. Flow in infinite parallel plates and shear stress.

Unit - 4: Turbulent flow of viscous fluids

Prandtl mixing length theory, Reynolds equation for in compressible turbulent flow. Reynolds stresses Statistical theory of turbulence Measurement of turbulence, hot wire anemometer and its use in turbulence parameters. Turbulent flow in closed conditions: Logarithmic and universal velocity distribution for turbulent flow in smooth tubes. Friction factor for rough and smooth tubes.

Teaching Methodology:
This course is introduced to help students understand in detail the advanced concepts of heat transfer and fluid mechanics. The entire course is broken down into following separate units: heat transfer, fluid dynamics, laminar and turbulent flow of viscous fluids. Each unit includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	**Marks**	**Coverage**
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2,Unit-3, and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4, and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Holman J P, “Heat Transfer”, McGraw Hill Book Co. (1992).

2. Incropera F P and DeWitt D P, “Introduction to Heat Transfer,” 2nd Ed John Wiley New York (1996).

3. Knudsen, &Katz “Fluid Dynamics and Heat Trasnfer” McGrawHill Book Co.(1974)

Reference Books:

1. McCabe, Smith & Harriat, “Unit Operations of Chemical Engineering” McGraw HillBook Co. (1993)

2. Gupta,Santhosh K, “Momentum Transfer Operative” Tata McGraw Hill.

Elective –II

Title of Course: Separation Processes Course Code:CL703
L-T-P Scheme: 3-0-0 Course Credits: 3

Course Objective
This course deals with study and analysis of various mass transfer operations along with the design of mass transfer equipment.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the importance of separation processes.
CO2	Understand different of Physical-Chemical Phenomena
CO3	Apply the mass transfer principles for processes with chemical reactions and without chemical reactions.
CO4	Analyze the selection of suitable mass transfer equipment
CO5	Evaluate floor area / height requirements for various mass transfer equipment.
CO6	Develop the complete design of mass transfer equipment.

Course Contents

UNIT 1: Physical-Chemical Phenomena
Diffusivity and mechanism of mass transport, Equation of continuity and equation of change, Diffusion, Dispersion, Diffusivity measurements and prediction in non-electrolytes and electrolytes, Solubility of gases in liquids. Interphase mass transport, in two-phase system and in multi-component systems, Role of diffusion in reaction systems, Mass transfer theories – film, Higbie and surface renewal models and their application.

UNIT 2: Mass Transfer with and without Chemical Reaction
Fluid-fluid reaction involving diffusional transfer, Physical absorption and absorption accompanied by chemical reaction, Application of mass transfer to reacting systems. Residence time distribution analysis, Mass transfer coefficients, Determination and prediction in dispersed multi-phase contractors under conditions of free forced convection, prediction of mean drop/bubble size of dispersions.

UNIT 3: Selection-Classification of Mass Transfer Equipment
Choice of techniques, Selection of equipments for gaseous, particulate and liquidous effluent of various industries such as extractive hydro metallurgy, leaching of ores/leach liquors, Selection of equipment based on Mechanical/non-mechanical, Floor area/Height requirement considerations. Optimum energy/cost considerations.

UNIT 4: Design of Mass Transfer Equipment
Design and analysis of various mass transfer equipment involving multi-component, multi-phase situations, Design of multi component columns and process strippers, Selection of column diameter and height in stage-wise and differential column contactors.

Teaching Methodology:
This course is introduced to help students understand concepts of mass transfer processes. The entire course is broken down into following separate units:Physical-Chemical Phenomena, Mass Transfer with and without Chemical Reaction, Selection-Classification of Mass Transfer Equipment, and Design of Mass Transfer Equipment.Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2& Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:
1. Sherwood, T.K., and Wilke, C.R., 1975, “Mass Transfer”, McGraw-Hill Kogukusha Ltd.
2. Hanson, C., 1972, “Recent Advances in Liquid Extraction”, Pergamon Press, London.

Reference Books:
1. Bird, R.B., Stewart, W.E. and Lightfort, E.N., 1960, “Transport Phenomena”, John Wiley & Sons.
2. Welty J. R., Wicks, C.E., and Wilson R. E., 1976, “Fundamental of Momentum”, heat and Mass Transfer,John Wiley & Sons.

Title of Course: Chemical Reactor Analysis and DesignCourse Code: CL704
L-T-P Scheme: 3-0-0 Course Credits: 3

Course Objective

The course aims to understand the chemical kinetics for homogeneous and heterogeneous reactions and their applications in design of batch and flow reactors.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the basic concepts of homogeneous and heterogeneous reactions.
CO2	Understand the reaction mechanism and chemical kinetics.
CO3	Applyvarious kinetic models.
CO4	Analyze various flow patterns in the reactor.
CO5	Evaluate performance equations for the reactors.
CO6	Develop design equations for non-isothermal reactors.

Course Contents

Unit 1: Introduction

Kinetics of homogeneous and heterogeneous chemical and biochemical reactions, single and multiple reactions, order & molecularity, rate constant, elementary and non elementary reactions, review of design of single and multiple reactions in batch reactor, plug flow reactor, CSTR, and semi batch reactor, packed bed reactors and fluidized bed reactors.

Unit 2: Non Ideal Flow

Residence time distribution of fluid in vessel, mean residence time, models for non ideal flow, dispersion model, N tanks in series model, conversion in a reactor using RTD data.

Unit 3: Catalysts

Theories of heterogeneous catalysts, classification of catalysts, catalyst preparation, promoter and inhibitors, catalysts deactivation/poisoning.

Unit 4: Non Catalytic Fluid Solid Reactions

Kinetics and mass transfer, selection of model, PCM and SCM models, diffusion through gas film control, diffusion through ash layer control, chemical reaction control, reactor design.

Unit 5: Heterogeneous Process

Global rates of reaction, types of heterogeneous reactions, catalysis, the nature of catalytic reactions, mechanisms of catalytic reactions. Physical adsorption and chemisorptions, adsorption isotherms, rates of adsorption isotherm.Effect of intra pellet and mass transfer on reaction rate, effect of heat transfer on rate of reaction. Gaseous diffusion in single cylindrical pore. Mechanism and kinetics of heterogeneous reactions.

Teaching Methodology:
This course is introduced to help students understand in detail the advanced concepts of chemical reaction engineering. The entire course is broken down into following separate units: introduction, non-ideal flow, catalysts, heterogeneous reactors and non-isothermal reactors. Each unit includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	**Marks**	**Coverage**
Test-1	15 Marks	Based on Unit-1 and Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and Unit - 5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Levenspiel O., “Chemical Reaction Engineering”, 3rd Edition, John Wiley & Sons, Singapore, (19992.
2. Fogler H. S., “Elements of Chemical Reaction Engineering”,3rd Edition, Prentice Hall Inc., (1999).
3. 3. Smith J. M., “Chemical Engineering Kinetics”, 3rd Edition, McGraw Hill, (1981).

Reference Books:

1. Hill C. G., “Chemical Engineering Kinetics and Reactor Design”, John Wiley, (1977).

2. Froment, G.F. and Bischoff, K. B., “Chemical Reactor Analysis and Design”, 2nd Edition, John Wiley and Sons, NY, (1990).

Title: Process modeling & Simulation lab **Code:CL601**
L-T-P scheme: 0-0-2 **Credit: 1**
Prerequisite: Students must have some knowledge about*numerical methods*.

Objective:

Use computer software and programming languages to solve complex chemical engineering systems.

Learning Outcomes:

Course Outcome	Description
CO1	Introduction of MATLAB, EXCEL, CHEMCAD, and POLYMATH.
CO2	Use of EXCEL to solve chemical engineering problems.
CO3	Use of MALAB to solve chemical engineering based problems.
CO4	To solve problems based on flow sheets using CHEMCAD
CO5	Solving problems on Flash Calculations, distillation columns, heat exchangers using CHEMCAD
CO6	Using polymath to solve basic chemical engineering problems.

Course Content:

LIST OF EXPERIMENTS

A) SECTION I: EXPERIMENTS ON MATLAB

1. Introduction to MATLAB
2. Problems on Euler's Method
3. Problems on Runge-Kutta Fourth Order Method
4. Problems on Newton-Rapson Method

B) SECTION II: EXPERIMENTS ON CHEMCAD

1. Overview of CHEMCAD and its Uses
2. CHEMCAD Products and Features
3. Introduction to CHEMCAD
4. Problems on Flow sheet
5. Problems on Flash Calculations, distillation columns, heat exchangers.

C) SECTION III: EXPERIMENTS ON POLYMATH

1. Introduction to Polymath
2. Problems on Linear Equations
3. Problems on Non-Linear Equations
4. Problems on Ordinary Differential Equations

Teaching Methodology:

This lab is introduced to help students to learn about process simulation software in case of chemical engineering. The entire course is broken down into following threesections: MATLAB, CHEMCAD, and POLYMATH. Each section gives knowledge about these softwares and how to implement them on chemical engineering problems.

Evaluation Scheme:

<table>
<tr><th colspan="2">Exams</th><th>Marks</th><th>Coverage</th></tr>
<tr><td colspan="2">P-1</td><td>15 Marks</td><td>Based on Lab Exercises: A-B</td></tr>
<tr><td colspan="2">P-2</td><td>15 Marks</td><td>Based on Lab Exercises: B-C</td></tr>
<tr><td rowspan="4">Day-to-Day Work</td><td>Viva</td><td>20 Marks</td><td rowspan="4">70 Marks</td></tr>
<tr><td>Demonstration</td><td>20 Marks</td></tr>
<tr><td>Lab Record</td><td>15 Marks</td></tr>
<tr><td>Attendance & Discipline</td><td>15 Marks</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">100 Marks</td></tr>
</table>

Learning Resources:

Study material of Process modeling & simulation lab (will be added time to time): Digital copy will be available on the JUET server.

Text Books:

1. Mathematical methods in Chemical Engineering, S. Pushpavanam, Prentice Hall of India 1998.
2. Mathematical methods in Chemical Engineering : Matrices and their Applications, N.R. Amundson Prentice Hall, 1966
3. Computational Methods in Chemical Engineering O.T. Hanna and O.C. Sandall
4. Mathematical Methods in Chemical and Environmental Engineering,, A.K. Ray and S.K. Gupta, Thomson Learning, 2004.
5. Applied Mathematics and Modelling for Chemical Engineers, R.G. Rice and D.D. Do, Wiley 1995.
6. Process Modeling, Simulation, and Control for Chemical Engineers, William L. Luyben, McGraw-Hill, 1996.
7. Fundamentals and Modeling of Separation Processes, C.D. Holland, Prentice Hall Inc. 1975.
8. Pratap, R., “Getting started with Matlab” Oxford university press.

Elective Lab - I

Title: Process Dynamics and Control Lab **Code:**CL801

L-T-P scheme:0-0-2 **Credit:** 1

Prerequisite: Students must be studying the course ***"Process Control"*** simultaneously.

Objective:

The main objective of this lab course is to provide the basic understanding of process dynamics, modes of control, and instrumentation.

Learning Outcomes:

Course Outcome	Description
CO1	Learn about the significance of process dynamics in process control.
CO2	Understand about working and calibration of instruments.
CO3	Describe valve characteristics.
CO4	Study of transient behaviour of closed loops.
CO5	Know about controller parameter tuning.
CO6	Demonstration of control of different process variables.

Course Content:

List of experiments:

1. Two Tank Interacting System
2. Two Tank Non-Interacting System
3. Measurement of Temperature using Thermocouple
4. Measurement of Temperature using RTD
5. Temperature Control Trainer using PID
6. Time Constant of Thermometer
7. Water Level Measuring Tutor
8. Dead Weight Pressure Gauge
9. Level Control Trainer using PID
10. Temperature Measurement using RTD
11. Study of PID Controller
12. Characteristics of Control Valve
13. Armfield Process Control Trainer

Teaching Methodology:

This lab is introduced to help students understand basic principles of Instrumentation and Process Control. The entire course is broken down into following separate sections: process dynamics, modes of control, and instrumentation. Each section includes some relevant experiments to help a student gain deeper understanding of the topic. This lab course is well complemented by a theory course under the name 'Instrumentation and Process Control' in the same semester that helps a student learn with hand-on experience.

Evaluation Scheme:

<table>
<tr><th colspan="2">Exams</th><th>Marks</th><th>Coverage</th></tr>
<tr><td colspan="2">P-1</td><td>15 Marks</td><td>Based on Lab Exercises: 1-6</td></tr>
<tr><td colspan="2">P-2</td><td>15 Marks</td><td>Based on Lab Exercises: 7-13</td></tr>
<tr><td rowspan="4">Day-to-Day Work</td><td>Viva</td><td>20 Marks</td><td rowspan="4">70 Marks</td></tr>
<tr><td>Demonstration</td><td>20 Marks</td></tr>
<tr><td>Lab Record</td><td>15 Marks</td></tr>
<tr><td>Attendance & Discipline</td><td>15 Marks</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">100 Marks</td></tr>
</table>

Learning Resources:

Study material of Instrumentation and Process Control Lab (will be added time to time): Digital copy will be available on the JUET server.

Text Books:

9. Luyben, W.L., "Process Modelling, Simulation and Control for Chemical Engineers", McGraw Hill International Edition, 1990.
10. Bequette W., "Process Control: Mathematical Modeling and Simulation and Control", Prentice Hall India., 2003
11. Stephanopolous, G., "Chemical Process Control" Prentice-Hall of India, 1990.
12. Coughaowr, "Process System Analysis and Control"
13. Riggs, J.B., "Chemical Process Control"
14. Marlin, T.E., "Process Control", McGraw Hill, 1995.

Reference Books:

1. Bentley, J.P., "Principles of Measurement Systems", Longmann, 1988
2. Liptak, B., "Instrumentation Engineers Hand Book", Butterworths Heinmann, 1995.
3. Nakra, B.C., and Chaudhury, K.K, "Instrumentation Measurement and Analysis", Tata McGraw Hill, 1985.
4. Considine, "Process/Industrial Instruments and Control Hand Book", McGraw Hill, 1993.
5. Patranabish, D., "Principles of Industrial Instrumentation." Tata McGraw Hill.

Title: Heat Transfer Operations Lab **Code:CL802**
L-T-P scheme: 0-0-2 **Credit: 1**
Prerequisite: Students must have a knowledge of heat transfer operations.

Objective:

The laboratory course is aimed to provide the practical exposure to the students with regard to the determination of amount of heat exchange in various modes of heat transfer including condensation & boiling.

Learning Outcomes:

Course Outcome	**Description**
CO1	Get familiar with the phenomena of heat transfer by conduction and determine thermal conductivity of liquid and solid.
CO2	Understand the significance of fin and determine fin efficiency.
CO3	Know about convection heat transfer and determine heat transfer coefficients in case of natural and forced convection.
CO4	Learn about radiation heat transfer and determine the emissivity of test plate.
CO5	Demonstrate the functioning of heat exchangers.
CO6	Describe the concepts of boiling and condensation.

Course Content:

Unit-1:
Lab Exercises based on conduction -
1. To determine the thermal conductivity of a liquid.
2. To determine the thermal conductivity of the composite wall.
3. To determine the thermal conductivity of metal bar.

Unit-2:
Lab Exercises based on fin –
1. To study the temperature distribution along of a pin fin under free and forced convection.

Unit-3:
Lab Exercises based on convection –
1. To find out the heat transfer coefficient of a vertical cylinder in natural convection.
2. To find out the heat transfer coefficient in forced convection.

Unit-4:
Lab Exercises based on radiation –
1. To find out the emissivity of a test plate.

Unit-5:
Lab Exercises based on heat transfer equipments –
1. To calculate overall heat transfer coefficient for double pipe heat exchanger.
2. To calculate overall heat transfer coefficient for shell and tube heat Exchanger.

Unit-6:

Lab Exercises based on boiling –

1. Determination of critical heat transfer coefficient for boiling.

Teaching Methodology:

This lab is introduced to help students understand basic principles of heat transfer and functioning of heat transfer equipments like double pipe heat exchanger, shell & tube heat exchanger, evaporator, etc. The entire course is broken down into following separate units:
conduction, convection, radiation, heat exchange equipments, evaporators, and boiling & condensation. Each section includes some relevant experiments to help a student gain deeper understanding of the topic. This lab course is well complemented by a theory course under the name Heat Transfer Operations in the same semester that helps a student learn with hand-on experience.

Evaluation Scheme:

Exams		Marks	Coverage
P-1		15 Marks	**Based on Lab Exercises: 1-5**
P-2		15 Marks	**Based on Lab Exercises: 6-10**
Day-to-Day Work	Viva	20 Marks	**70 Marks**
	Demonstration	20 Marks	
	Lab Record	15 Marks	
	Attendance & Discipline	15 Marks	
Total		**100 Marks**	

Learning Resources:

Study material of Heat Transfer Operations Lab – I (will be added time to time): Digital copy will be available on the JUET server.

Text book:

1. McCabe, W.L., Smith, J.C. and Harriott, P., “Unit operations of Chemical Engineering”, 6th ed, Tata McGraw Hill, New Delhi, 2001.

Reference books:

2. Brown, G.G., “Unit Operations”, CBS Publishers, New Delhi, 1995.
3. Kern, D.Q., “Process Heat Transfer” McGraw Hill, New delhi, 1965
4. Kreith, F., Bohn, M.S., “Principles of Heat transfer”, 6th edition, Thomson Learning, 2001
5. Holman, J.P., “Heat Transfer”, 9th edition, McGraw Hill, 2001.

Title: Separation Processes Lab **Code: CL803**

L-T-P scheme: 0-0-2 **Credit: 1**

Objective:

Objective of designing of this course is to develop the fundamental understanding of basic mass transfer processes associated in chemical and allied industries.

Learning Outcomes:

Course Outcome	**Description**
CO1	Outline various solid-fluid, fluid-fluid mass transfer operations.
CO2	Understand the importance of operations such as absorption, distillation etc.
CO3	Describe various modes of operations for these operations.
CO4	Develop material and energy balance equations for all separation processes.
CO5	Apply operating line equations to enable the design various mass transfer equipments.
CO6	Demonstrate the working of all the mass transfer equipments.

Course Content:

LIST OF EXPERIMENTS:

1. To determine diffusion coefficient or diffusivity, of given liquid (acetone) in air by using ARNOLD's cell.
2. To find the absorption efficiency of the mechanical agitator vessel.
3. To verify Rayleigh's Equation by carrying out differential distillation of Binary Mixture.
4. To determine the effective interfacial area a, as a function of the superficial liquid velocity, $V_{L,}$ in a packed column using the theory of Gas Absorption accompanied by fast chemical reaction.
5. To study the operation of a packed bed batch rectification column under constant or total reflux condition.
6. To carry out steam distillation.
7. Wetted Wall Column.
8. Diffusion coefficient of solid in air.
9. Rotary Dryer.

Teaching Methodology:

This course is introduced to help students understand basic principles of mass transfer along with the design of mass transfer equipment like absorption column, distillation column etc. This lab course helps a student learn and discuss the technical details of the underlying technologies.

Evaluation Scheme:

Exams		**Marks**	**Coverage**
P-1		15 Marks	**Based on Lab Exercises: 1-6**
P-2		15 Marks	**Based on Lab Exercises: 7-9**
Day-to-Day Work	Viva	20 Marks	**70 Marks**
	Demonstration	20 Marks	
	Lab Record	15 Marks	
	Attendance & Discipline	15 Marks	
Total		**100 Marks**	

Learning Resources:

Study material of Mass Transfer Operations Lab (will be added time to time): Digital copy will be available on the JUET server.

Text Book:

[1] Laboratory Manual available in Lab
[2] Study material available in related folder of Server
[3] Treybol, R.E., “Mass-Transfer Operations”, 3rd ed., McGraw Hill, New Delhi, 1981.
[4] Dutta, B. K., “ Principles of Mass Transfer and Separation Processes”, 4th ed., PHI, New Delhi, 2010

Reference Books/Material:

1. Cussler, E.D., "Diffusion Mass Transfer in Fluid Systems", Cambridge Univ. Press, Cambridge, 1984.
2. Foust, A.S., "Principles of Unit Operations", 2nd ed., Wiley, New York, 1980.
3. Geankopolis, C.J., "Transport Processes and Unit Operations", 3rd ed., Prentice Hall India, New Delhi, 1993.
4. Smith, B.D., "Design of Equilibrium Stage Processes", McGraw Hill, New York, 1980

Title: Chemical Reaction Engineering Lab **Code:**CL804

L-T-P scheme:0-0-2 **Credit:** 1

Objective: The objective of this course is the successful design and operation of chemical reactors**.**

Learning Outcomes:

Course Outcome	**Description**
CO1	Outline the significance of chemical reactors in various process industries.
CO2	Understand different reaction mechanisms along with kinetic expressions for homogeneous reactions.
CO3	Describe different types of reactors for carrying out reactions.
CO4	Develop performance equations for reactors such as batch, PFR and CSTR.
CO5	Apply material and energy balance equations for the design of reacors
CO6	Demonstrate the working of all the reactors

Course Content:
LIST OF EXPERIMENTS:

1. To study a non-catalytic homogeneous reaction in a plug flow reactor (PFR).

2. To study a non-catalytic homogeneous reaction in a coil type plug flow reactor under ambient conditions.

3. To study a non-catalytic homogeneous reaction in a CSTR under isothermal conditions.

4. To study a second order saponification reaction (between Ethyl acetate and NaOH) in a Semi Batch Reactor under isothermal condition (i.e. at a fixed temperature).

5. To study a non-catalytic homogeneous reaction in an isothermal Batch Reactor.

6. To study a non-catalytic homogeneous second order liquid phase reaction in a CSTR under ambient conditions.

7. To study the performance of a cascade of three equal volumes CSTRs in series for the saponification of Ethyl acetate with NaOH.

8. To study a non-catalytic homogeneous reaction in a series arrangement of PFR and CSTR.

Teaching Methodology:

This course is introduced to help students understand basic principles of different types of reactors along with their design employed in the chemical industries for carrying out homogeneous reactions. This lab course helps a student learn and discuss the technical details of the underlying technologies.

Evaluation Scheme:

<table>
<tr><th colspan="2">Exams</th><th>Marks</th><th>Coverage</th></tr>
<tr><td colspan="2">P-1</td><td>15 Marks</td><td>Based on Lab Exercises: 1-5</td></tr>
<tr><td colspan="2">P-2</td><td>15 Marks</td><td>Based on Lab Exercises: 6-8</td></tr>
<tr><td rowspan="4">Day-to-Day Work</td><td>Viva</td><td>20 Marks</td><td rowspan="4">70 Marks</td></tr>
<tr><td>Demonstration</td><td>20 Marks</td></tr>
<tr><td>Lab Record</td><td>15 Marks</td></tr>
<tr><td>Attendance & Discipline</td><td>15 Marks</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">100 Marks</td></tr>
</table>

Learning Resources:

Study material of Chemical Reaction Engineering Lab (will be added time to time): Digital copy will be available on the JUET server.

Text Book:

[1] aboratory Manual available in Lab
[2] Study material available in related folder of Server
[3] Levenspiel , O., “Chemical Reaction Engineering”, John Wiley and Co. (latest edition)
[4] Smith, J. M., “Chemical Engineering Kinatics”, McGraw Hill (Latest edition)
[5] Laidler, K. J., “Chemical Kinetics” Tata McGraw Hill, 1973

Reference Books/Material:

1. Haugen, O. A., and Watson, K. M., "Chemical Process Principles" part-3, "Kinetics and Catalysis", John Wiley, 1964
2. Hill, C. G., "Chemical Reaction Engineering"
3. Walas, "Reaction Kinetics for Chemical Engineers", Tata McGraw Hill, 1959
4. Sharma, M. M., and Daraiswami, L. K., "Heterogeneous Reactions" vol.-1, John Wiley.

2nd Semester

Title of Course: Fluidization Engineering **Course Code: CL503**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The course aims to provide an insight into fluidization phenomena and its use in industrial applications.

Learning Outcomes:

Course Outcome	Description
CO1	Describe fluidization phenomena, fluidized beds, and their industrial applications.
CO2	Understand laws and equations associated with packed bed.
CO3	Apply the properties of various fluidized beds
CO4	Analyze heat & mass transfer phenomena in fluidized bed.
CO5	Evaluate various flow models used for bubbling beds
CO6	Design a fluidized bed for different flow conditions and regimes.

Course Contents

UNIT 1: Introduction

Phenomena of fluidization, Behaviour of a Fluidized Bed, Comparison with other contacting methods, Advantages and Disadvantages of Fluidized Beds for Industrial Operations, Fluidization Quality, Selection of a Contacting Mode for a given Application.

UNIT 2: Fluidization and Mapping of Regimes

Characterization of Fixed Beds of Particles, Fluidization without Carryover of Particles: Minimum Fluidizing Velocity, Pressure Drop-versus-Velocity Diagram, Effect of Pressure and Temp. on Fluidized Behaviour, Sintering and Agglomeration of Particles at High Temperature. Type of Gas Fluidization with and without Carryover, Turbulent and Churning Fluidization, Pneumatic Transport of Solids, Fast Fluidization, Voidage Diagrams for all Solid Carryover, Regimes, The Mapping of Fluidization Regimes.

UNIT 3: Bubbles in Dense Beds

Single Rising Bubbles: Rise Rate of Bubbles, Evaluation of Models for Gas Flow at Bubbles, The Wake Region and the Movement of Solids at Bubbles, Solids within Bubbles. Coalescence and Splitting Bubbles: Interaction of Two Adjacent Bubbles, Coalescence, Bubble Size and Bubble Frequency, Splitting of Bubbles and Maximum Bubble Size, Bubble Formation above a Distributor, Slug Flow

UNIT 4: Bubbling Fluidized Beds
Emulsion Movement for small and Fine Particles, Emulsion Movement for Large Particles, Emulsion gas flow and Voidage, Effect of Pressure on Bed Properties, Estimation of Bed Properties: Gas Flow in the emulsion phase, Bubble Gas Flow, Bubble Size and Bubble growth, Bubble Rise Velocity, Beds with Internals, Physical Models: Scale up and scale down.

UNIT 5: Flow Models for Bubbling Beds
General Interrelationship among Bed Properties, Simple Two-phase Model, K-L Model with its Davidson Bubbles and Wakes. Turbulent Fluidized Beds, Experimental Findings, Fast Fluidization, The Freeboard Entrainment Model Applied to Fast Fluidization, Design Considerations, Pressure Drop in Turbulent and Fast Fluidization.

Teaching Methodology:
Students will be able to understand how to design fluidized bed applications in the chemical process industry. The entire course is broken down into following separate sections: packed beds, fluidized beds, bubbles in dense phase, application and design aspects. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:
1. Kunii, D and Levenspiel, O., "Fluidization Engineering", 2nd Edition, ButterworthHeinemann, Elsevier.

Reference Books:

1. Wen-Ching Yen, 1999, “Fluidization, Solid Handling and Processing: Industrial Application”, Noyes publication. 2. M. Kwauk, 1994, “Fast Fluidization”, Vol 20, Advances in chemical Engineering, Academic Press. 3. L. G. Gibilaro, 2011, “Fluidization Dynamics”, Butterworth-Heinemann.

Title of Course: Membrane Separation Processes **Course Code: CL504**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
The aim of the course is to provide basic idea about the modern separation processes.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the importance of membrane separation processes employed in chemical industries.
CO2	Understand the types of process along with their applications.
CO3	Apply various membrane process utilized in different separation operations.
CO4	Analyze various techniques for characterization of membranes.
CO5	Evaluate appropriate expressions that describes the complete transport process through membranes.
CO6	Develop various synthetic membranes used in process industries.

Course Contents

UNIT 1: Introduction:
Separation processes, introduction to membrane science and technology; classification of membranes and membrane based processes; membrane materials: ceramic membrane, polymeric membrane, composite membrane liquid membrane

UNIT 2: Preparation of Membranes:
Preparation of polymeric, ceramic and composite membranes by different methods. Advantage and disadvantages of various methods. Controlling pore size, porosity etc. of membrane during preparation.

UNIT 3: Characterization of Membranes:
Determination of pore size, pore size, thickness, permeability, membrane resistance, ionic character, mechanical, thermal, chemical resistance etc. by various methods and analysis of results by various methods.

UNIT 4: Module and process design:
Introduction, plate and frame model, spiral wound module, tubular module, capillary module, hollow fibre model, comparison of module configurations.

UNIT 5: Transport in Membranes:
Theory and applications of membrane processes: micro filtration, ultra filtration, nano filtration, reverse osmosis, electrodyalysis, dialysis, pervaporation, gas separations, membrane distillation and ion exchange membranes.Concentration polarization, turbulence promoters, pressure drop, gel layer model, osmotic pressure model, boundary layer resistance model, concentration polarization in diffusive membrane separations and electro dialysis, membrane fouling, methods to reduce fouling, compaction

Teaching Methodology:

This course is introduced to help students understand the design and applications of various membranes employed in various separation processes.The entire course is broken down into following separate units:Introduction, Preparation of Membranes, Characterization of Membranes, Module and process design, Transport in Membranes,. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. J. Seader and Henley, "Separation Processes", Wiley Publishers, 1998.
2. R.W. Baker, Membrane Technology and Applications, John Wiley & Sons Ltd, 2004.
3. B.K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall of India Private Limited, 2007.

Elective –III

Title of Course: Wastewater Treatment **Course Code: CL705**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
This course deals with various types of treatment methods for waste water coming from various sources.

Learning Outcomes:

Course Outcome	Description
CO1	Outline various types of water pollutants.
CO2	Understand the causes of water pollution along with their harmful effects.
CO3	Describe various equipment related water pollution control.
CO4	Analyze rate expressions for different types of processes used in waste water treatment.
CO5	Evaluate appropriate equations for the design of water pollution control equipment.
CO6	Develop the design of various equipment related to waste water treatment.

Course Contents

UNIT 1: Waste water types and pollutants
Definitions, types of waste water, industrial wastewater, municipal wastewater, Wastewater flow rates data calculations. Classification, sources and effect of water pollutant on human being and ecology, eutrophication, dissolved oxygen depletion, natural aeration.

UNIT 2: Sampling, measurements & standards of water quality
Physical impurity: TDS, suspended solids, colour, taste and odour, temperature, Turbidity. Chemical impurity: chlorides, fluoride, metals, alkalinity, DO, nitrogen, phosphorous, hardness, MLSS, ML VSS etc. Biological impurity: BOD, COD, TOC, pathogens etc.

UNIT 3: Treatment methods
Screening, mixing and flocculation, gravity separation, settling, grit removal, sedimentation, flotation, aeration etc. Chemical coagulation, chemical precipitation, chemical oxidation, chemical neutralization. Introduction to microbial metalbolism, bacterial growth and energetic, microbial growth kinetics, suspended growth and attached growth process, aerobic and anaerobic system.

UNIT 4: Advanced treatment methods
Membrane filtration, adsorption, gas stripping, ion exchange, advanced oxidation processes etc.

UNIT 5:Design of wastewater treatment plant
Wastewater reclamation and reuse, effluent treatment and disposal

Teaching Methodology:
This course is introduced to help students understand principles of application of wastewater treatment technologies in process industries. The entire course is broken down into following separate units:Waste water types and pollutants, Sampling, measurements & standards of water quality, Physical treatment methods, Chemical treatment methods, Biological treatment methods, Natural treatment methods, Advanced treatment methods, and Design of wastewater treatment plant. Each section includes multiple topics to help a student gain deeper understanding of the subject.
Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:
1. Metcalf et al. "Waste Water Treatment, Disposal and Reuse", 4th edition, Tata McGraw Hill.

Title of Course: Air Pollution Control **Course Code: CL706**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
The aim of the course is to provide details of air pollution and their control technologies.

Learning Outcomes:

Course Outcome	Description
CO1	Describe various air pollutants present in the atmosphere.
CO2	Understand the causes of air pollution and their harmful effects.
CO3	Describe various air pollution control equipments.
CO4	Analyze the efficiency of various air pollution control equipments.
CO5	Evaluate appropriate equations for the design of air pollution control equipments.
CO6	Demonstrate the working of various equipments related to air pollution control and monitoring.

Course Contents

UNIT 1: Sources and effect of air pollution
Sources of air pollution-stationary and mobile, fugitive emissions, secondary pollutants; Effects of air pollution in regional and global scale, air pollution episodes; Emission factors, inventory and predictive equations. Atmospheric meteorology, wind profiles, turbulent diffusion, topographic effects, separated flows, temperature profiles in atmosphere, inversions, plume behavior.

UNIT 2: Air quality monitoring
Objectives, time and space variability in air quality; air sampling design, analysis and interpretation of air pollution data, guidelines of network design in urban and rural areas. Stack monitoring. Air pollution standards and indices.

UNIT 3: Air pollutants and modeling-Basic concepts
Dispersion of air pollutants and modeling- Basic concepts, inversion layer and mixing height, atmospheric stability classes, theory and application of acoustic sounding (SODAR) technique. Box model, The Gaussian dispersion model-point, area and line sources. Prediction of effective stack height-physics of plume rise, Holland's equation, Brigg's equation, etc. Modification of Gaussian dispersion models; indoor air quality models.

UNIT 4: Review of general principles of air pollution control
Design and operation of gravity settling chambers, Design and operation of cyclones. Design and operation of wet dust scrubbers-column scrubbers, jet scrubbers, vortex scrubbers, rotating disc scrubbers, and venturi scrubbers. Design and operation of fabric filters. Design and operation of electrostatic precipitators, Design and operation of mist separators-baffled mist

separators, pressure separators. Control devices for gaseous pollutants with special emphasis on absorption, adsorption and mass transfer consideration, and combustion, control of motor vehicle emissions, indoor air pollution control.

Teaching Methodology:
This course is introduced to help students understand various types of air pollutants present in the atmosphere along with their control techniques. The entire course is broken down into following separate units:Sources and effect of air pollution, Air quality monitoring, Air pollutants and modeling-Basic concepts, and Review of general principles of air pollution control. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2& Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Air Pollution Control Engineering, Vol. 1, Wang. Lawrence K.; Norman C.; Hung, Yung-Tse (Eds.) Human Press, 2004.
2. Air Pollution Control Technology Handbook by Karl B. Schnelle, Charles A. Brown.

Title of Course: Cleaner Technology **Course Code: CL707**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
This course is designed to explain the concepts of cleaner production and minimize pollution.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance Cleaner technology.
CO2	Understand different of sustainable development models.
CO3	Apply various cleaner production control techniques.
CO4	Analyzecleaner production project along with its implementation.
CO5	Apply principles to evaluate the cleaner production project alternatives.
CO6	Demonstrate the concept of Life cycle assessment & environmental management systems

Course Contents

UNIT 1: Sustainable development
Sustainable development – Indicators of Sustainability – Sustainability Strategies. Barriers to Sustainability – Industrial activity and Environment – Industrialization and sustainable development – Industrial Ecology.

UNIT 2: Cleaner production control
Definition – Importance- Historical evolution – Benefits – Promotion – Barriers – Role of Industry, Government and Institutions – Environmental Management Hierarchy – Source Reduction techniques – Process and equipment optimization, reuse, recovery, recycle, raw material substitution – Internet information & Other CP Resources. Cleaner Production (CP) in Achieving Sustainability – Prevention versus Control of Industrial Pollution – Environmental Policies and Legislations – Regulation to Encourage Pollution Prevention and Cleaner Production.

UNIT 3: Cleaner production project development & implementation
Overview of CP Assessment steps and Skills, Preparing for the Site Visit, Information gathering, and Process Flow Diagram, Material Balance, CP Option Generation Technical and Environmental Feasibility analysis.

UNIT 4: Evaluation
Economic valuation of alternatives – Tool Cost Analysis – CP Financing – Establishing a Program – Organizing a Program – Preparing a Program Plan – Measuring Progress Pollution Prevention and Cleaner Production Awareness Plan – Waste audit Environmental Statement.

UNIT 5: Life cycle assessment & environmental management systems
Elements of LCA – Life Cycle Costing – Eco Labeling – Design for the Environment – International Environmental Standards – Iso 14001 – Environmental audit. Industrial applications of CP, LCA, EMS and Environmental Audits.

Teaching Methodology:

This course is introduced to help students understand concepts of Cleaner Technology. The entire course is broken down into following separate units:Sustainable development, Cleaner production control, Cleaner production project development & implementation, Evaluation, and Life cycle assessment & environmental management systems.Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1
Test-2	25 Marks	Based on Unit-2& Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Prasad Modak, C. Visvanathan and Mandar Parasnis, "Cleaner Production Audit Environmental System Reviews, No. 38, Asian Institute of Technology, Bangkok, 1995.
2. World Bank Group' Pollution Prevention and Abatement Handbook – Towards Cleaner Production "World Bank and UNEP", Washington D.C., 1988.
3. Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards (Eco-Efficiency in Industry and Science) (Hardcover) by Jeroen B. Guinee (Editor) Kluwer Academic Publishers.

Elective –IV

Title of Course: Mutiphase Contactors **Course Code: CL708**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
In the course, detailed analysis of multiphase contactors like packed bed, fluidized bed, trickle bed etc. is covered. This course also deals the design modelling of multiphase reactors; separator and their dynamics will be studied.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the importance of multiphase reactors
CO2	Understand different types multiphase contactors used in the industries.
CO3	Apply the basic principles of mathematical modelling for industrial fixed bed reactors
CO4	Analyze various design equations employed for the reactor design.
CO5	Evaluate the performance of Industrial Fixed Bed Catalytic Reactors
CO6	Develop the complete design of various multiphase contactors.

Course Contents

UNIT 1: Mathematical Models for Gas-Liquid-Solid Reactors
Models based on effectiveness of contact, with no external mass transfer resistances (models for trickle-bed reactors) , Reactor performance based on residence-time distribution , Model when reactant present in both liquid and vapour phases ,Models for non-isothermal trickle-bed reactors, Models which include external mass-transfer effects, Models for threephase slurry reactors, Models for the packed-bubble-column gas- liquid reactors.

UNIT 2: Fixed Bed Catalytic Reactors
Systems and mathematical models, general concepts, outline of the procedure for model building, basic principles of mathematical modelling for industrial fixed bed reactors.

UNIT 3: Practical Relevance of Bifurcation, Instability and Chao in Catalytic Reactors
Sources of multiplicity: isothermal multiplicity, concentration multiplicity, thermal multiplicity, multiplicity due to reactor configuration, quantitative discussion of the multiplicity phenomenon, bifurcation and stability, steady state analysis and dynamic analysis.

UNIT 4: Optimization of The Performance of Industrial Fixed Bed Catalytic Reactors
Objective functions, optimal and suboptimal temperature control policies, optimization of reversible reactions, Pontryagin maximum principle and simple optimality criterion for exothermic reversible reaction, modelling, simulation and optimization of industrial fixed bed

catalytic reactors, case studies: mathematical modelling of high/low temperature watergas shift converter, modeling of ammonia converters, precise modeling of industrial steam reformers and methanators.

UNIT 5: Design of Multiphase Reaction Processes
Multiphase Reaction Processes and Chemical Engineering, Reason for Adopting Multiphase Reactors.

Teaching Methodology:
This course is introduced to help students understand basic concepts and design of multiphase contactors. The entire course is broken down into following separate units:Mathematical Models for Gas-Liquid-Solid Reactors, Fixed Bed Catalytic Reactors, Practical Relevance of Bifurcation, Instability and Chao in Catalytic Reactors, Optimization of The Performance of Industrial Fixed Bed Catalytic Reactors, Design of Multiphase Reaction Processes. Each section includes multiple topics to help a student gain deeper understanding of the subject.
Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4& Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Elnashie, S.S.E.H. and Elshishini, S.S., 1993, "Modelling, Simulation, and Optimization of Industrial Catalytic Reactors", Gordon and Breach Science Publishers, Amsterdam
2. Ranade, V.V., Chaudhary, R. and Gunjal, P.R., 2011, "Trickle Bed Reactors: Reactor Engineering & Applications", Elsevier.
3. Shah, Y.T., 1979, "Gas –Liquid-Solid Reactor Design", McGraw-Hill, New York.
4. Tominaga, H. and Tamaki, M., 1997, "Chemical Reaction and Reactor Design", John Wiley & Sons, New York.

Title of Course: Catalysis & Surface Chemistry **Course Code: CL709**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Contents
Course Objective
This course deals with surface chemistry of catalyst, methods for catalyst preparation, reaction mechanism and their characterization. Case studies of preparation of several important industrial catalysts.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance ofcatalysis.
CO2	Understand the kinetics of catalyzed reactions.
CO3	Apply various adsorption isotherms to determine the kinetics of a reaction.
CO4	Analyze the properties of various catalysts.
CO5	Evaluate the use of heterogeneous catalysts.
CO6	Demonstrate the application of homogeneous catalysis with transition metal complexes

UNIT 1: History of Catalysis
Introduction, Industrial Catalysis, Catalytic Processes In The Oil Refinery, Total Isomerization Process of Paraffins, Isotacttic Polypropylene, Catalysts For Automotive Pollution Control.

UNIT 2: Chemical Kinetics of Catalyzed Reactions
Rate Expression (Single Site Model), Rate Determining Step, Adsorption Isotherms, Rate Expression (Other Models), Initial Rate Expressions, Temperature Dependency, Sabatier Principles – Volcano Plot.

UNIT 3: Bonding And Elementary Steps In Catalysis
Bonding, Bonding To Transition Metal Surfaces, Chemical Bonding In Organometallic Coordination Complexes And On Surfaces of Transition Metal Compounds, Elementary Steps In Organometallic Complexes, Creation of A Vacant Site, Coordination Of The Substrate, Insertions And Migrations, Β-Elimination And Deinsertion, Oxidative Addition, Reductive Elimination, Α-Elimination Reactions, Cyclometallation , Activation Of Substrate Towards Nucleophilic Attach, Σ-Bond Metathesis, Heterolytic Cleavage of Dihydrogen, Elementary Reaction Steps On Surfaces: Metal Catalysed Reactions, Mechanism of The Reaction on Oxides, Catalysis By Solid Acids.

UNIT 4: Heterogeneous Catalysis
Synthesis Gas Reactions, Fischer-Tropsch Synthesis of Hydrocarbons, Modification of The Catalyst By Alloying Metals And By Using Promoters And Supports, HydroDehydrogenation Reactions on Metals, Catalytic Oxidation.

UNIT 5: Homogeneous Catalysis with Transition Metal Complexes
Rhodium Catalyzed Hydroformylation: Rhodium Based Hydroformylation, Ligand Effects, Phosphine Effects, Ligand Effects In Rhodium Catalyzed Hydroformylation, The Characterization of Intermediates, Zirconium Catalyzed Polymerization Of Alkenes : Supported Titanium Catalysts ,Isotactic Polypropylene ,The Cossee-Arlman Mechanism , Homogeneous Versus Heterogeneous Catalysts , Site Control Versus Chain-End Control ,Chain-End Control: Syndiotactic Polymers , Chain-End Control: Isotactic Polymers ,Sitecontro1: Recent history Site Control: Isotactic Polymers Asymmetric Hydrogentation: Cinnamic Acid Derivatives, Naproxenandibuprofen , Binapcatalysis

Teaching Methodology:
This course is introduced to help students understand basic concepts of catalysts used in the industries. The entire course is broken down into following separate units:History of Catalysis, Chemical Kinetics of Catalyzed Reactions, Bonding And Elementary Steps In Catalysis, Heterogeneous Catalysis, Homogeneous Catalysis with Transition Metal Complexes. Each section includes multiple topics to help a student gain deeper understanding of the subject.
Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Book:

1. J.A. Moulijn, J. A., Leeuwen, P.W.N.M. V. and Santen, R.A. V., 1993, "Studies in Surface Science and Catalysis Vol. 79: CATALYSIS: An Integrated Approach to Homogeneous, Heterogeneous and Industrial Catalysis", Elsevier, Netherlands.

<u>Elective –V</u>

Title of Course: Process Engineering **Course Code: CL710**
L-T-P Scheme: 3-0-0 **Course Credits: 3**
Course Objective
This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Learning Outcomes:

Course Outcome	**Description**
CO1	Outline the importance of Process engineering.
CO2	Understand the concepts of process invention.
CO3	Apply the techniques for process creation.
CO4	Analyze various process synthesis options.
CO5	Evaluate heat addition to reactors, heat exchangers and furnaces.
CO6	Create reactor design and reactor network synthesis

Course Contents

UNIT 1: Product and Process Invention
Objectives, design Opportunities, steps in product and process design, environmental protection, safety considerations, engineering ethics, role of computers

UNIT 2: Molecular Structure Design
Objectives, Introduction, Property Estimation, Optimization to locate molecular structure

UNIT 3: Process Creation
Preliminary database creation ,Preliminary process synthesis, Development of base case design, Generalization of the Resolution Based Synthesis procedure for development of flow sheet for a chemical plant.Principles of steady state flow sheet – simulation, principles of batch process simulation

UNIT 4: Heuristics for process synthesis
Raw materials and chemical reactions, distribution of chemicals, separations, heat removal from and addition to reactors, heat exchangers and furnaces, pumping, compression, pressure reduction, vacuum, and conveying of solids

UNIT 5: Reactor Design and Reactor Network Synthesis

Reactor models, Stoichiometry, extent of reaction, equilibrium, kinetics, ideal kinetic reaction models – CSTRs and PFRs, reactor design for complex configurations, reactor design using the attainable region

Teaching Methodology:

This course is introduced to help students understand basic concepts of process engineering and design. The entire course is broken down into following separate units:Product and Process Invention, Molecular Structure Design, Process Creation, Heuristics for process synthesis, Reactor Design and Reactor Network Synthesis.Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Book:

1. Seider, W. D., Seader, J.D., Lewin, D. R., Widagdo, S., 2008, “Product & Process Design Principles Synthesis Analysis & Evaluation”, 3rd Ed., John Wiley & Sons, New York.

Reference Books:

1. Douglas, J.M., 1988, “Conceptual Design of Chemical Processes”, 1st Ed, McGraw-Hill, New York.
2. Kumar, A., 1981, “Chemical Process Synthesis & Engineering Design”, McGraw-Hill, New Delhi.
3. Rudd, D. F. and Watson, C.C., 1968, “Strategy of Process Engineering”, John Wiley& Sons, New York.

4. Murphy, R., 2005, Introduction to Chemical Processes: Principles, Analysis, Synthesis”, 1st Ed, McGraw-Hill, New York.
5. Smith, R. M., 2005, “Chemical Process Design & Integration”, John Wiley & Sons, New York.
6. Kemp, I.C., 2007, “Pinch Analysis and Process Integration, Second Edition: A User Guide on Process Integration for the Efficient Use of Energy”, 2nd Ed., Butterworth-Heinemann.

Title of Course: Conceptual Design of selected separation processes
Course Code: CL711
L-T-P Scheme: 3-0-0 **Course Credits: 3**

At end of the course students should be able analyse economic feasibility and therefore design chemical and mechanical aspects of various types of separation process.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance of design of separation processes.
CO2	Understand the strategy for process synthesis and analysis
CO3	Apply conceptual design methods to draw a flow sheet
CO4	Analyze to find out the best flow sheet.
CO5	Evaluate the design of various chemical processes.
CO6	Demonstrate the complete conceptual design of various separation processes.

Course Contents

UNIT 1: Strategy for process synthesis and analysis
Creative aspects of process design, a hierarchical approach to conceptual design

UNIT 2: Engineering economics
Cost information required, estimating capital and operating cost, total capital investment and total product cost, time value of money, measures of process profitability

UNIT 3: Developing a conceptual design and finding best flow sheet
Input information and batch versus continuous, Input output structure of the flow sheet: design variable, overall material balance and stream costs, process alternatives, recycle structure of the flow sheet: recycle material balance, heat effects, equilibrium limitation, recycle economical and cost

UNIT 4: Design of chemical processes
Design of distillation tower, Azeotropic system, solvent extraction, membrane separation, reactive distillation, absorption

Teaching Methodology:
This course is introduced to help students understand basic concepts of design of selected separation processes. The entire course is broken down into following separate units:Strategy for process synthesis and analysis, Engineering economics, Developing a conceptual design and finding best flow sheet, Design of chemical processes. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. B. K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall of India Private Limited, 2007.
2. James M douglas: conceptual design of chemical process, Mcgraw Hill Book company.

Title of Course: Safety & Hazards analysis and assessment Course Code: CL712
L-T-P Scheme: 3-0-0 Course Credits: 3

Course Objective

The purpose of this course is to familiarize with safety, health and Hazard issues in the operation of a chemical plant.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance of safety in chemical plants.
CO2	Understand accident prevention and hazard analysis techniques.
CO3	Identify and apply the process safety responsibilities.
CO4	Analyze the psychological approach to process safety.
CO5	Learn the legislations pertaining to safety in chemical industries
CO6	Develop the complete HAZOP analysis of a process.

Course Contents

UNIT 1: Introduction and Concepts of Safety

Definitions. Types of Accidents. Causes and direct & indirect effects of accidents, Types of damages. Role of safety considerations in chemical plant design & operations. Protective & safety equipment's. Measure of Risk. Liabilities of accidents Laws. Rules, Regulations (concerning safety in chemical process plant) for the prevention of accident. Managerial aspects of safety, General aspects of post disaster mitigation and management within an organization & in society at large.

UNIT 2: Toxicology and industrial hygiene

Typical toxins and their biological effects. Outline of their ingestion to and elimination from biological systems. Toxicological Parameters -Their definitions and outline of the measurement methods. Evaluation of exposure to toxicants and its impact. Source Models - Release & flow of toxic gases & liquids, flashing liquids, boiling liquids, etc. Dispersion Models - factors affecting dispersion and their modeling. Design & Equipment for prevention of toxic release in chemical plants. Management of toxic release scenario.

UNIT 3: Fires and explosion

The fire triangle and factors contributing to fire & explosions. Definition. Relevant material characteristics & properties. Concepts of Ignition, Ignition Energy. Phenomena and Source of Ignition auto ignition, auto oxidation, adiabatic compression, electrostatic ignition, role of fuel sprays, mists, dusts on ignition process. Explosions - various types & conditions for their occurrence. Inerting & Purging of equipment, Ventilation of rooms, Control of static electricity process control systems, Sprinkler systems, Firefighting systems

UNIT 4: Relief and relief systems

Definitions. Relief requiring scenarios. Relief types & locations. Relief systems, various options and their sizing and applications for single and multiphase flows. Deflagration venting for dust & vapour explosions.

UNIT 5: Hazard identifications and Risk assessment

HAZOP, HAZAN and such methods. Safety Review & other methods, examples. Safety Audit.Review of probability theory in respect of failures, coincidences etc. Leading to unsafe situation. Concepts of event trees & fault trees. Analysis of trees for risk assessment, its advantages & disadvantages for simple examples of application of Risk Assessment technique.

Teaching Methodology:

This course is introduced to help students understand basic concepts of safety and hazards in chemical processes. The entire course is broken down into following separate units:Introduction and Concepts of Safety, Toxicology and industrial hygiene, Fires and explosion, Relief and relief systems, Hazard identifications and Risk assessment. Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Crowl, D. Y., Louvar, J. F., "Chemical Process Safety Fundamentals with Applications", Prentice Hall, Englewood, 1990.
2. Pandya, C. L., "Hazards in Chemical Units", Oxford ISH 1991.
3. Pandya, C. L., "Risk in Chemical Units" Oxford IBH 1994.

ELECTIVE LAB - III

Title: Environmental Engineering Lab **Code: CL805**

L-T-P scheme:0-0-2 **Credit: 1**

Prerequisite: NIL

Objective: The objective of this course is to give the students a basic idea of the different types of pollution in the environment. This course also gives them the idea about how to handle environmental pollution problems.

Learning Outcomes:

Course Outcome	**Description**
CO1	Outline different types of pollutants.
CO2	Understand the causes of pollution and their harmful effects.
CO3	Describe various equipments related to air pollution and water pollution control.
CO4	Implement expressions for the estimating the efficiency of various air pollution control equipments.
CO5	Apply appropriate equations for the design of water pollution control equipments.
CO6	Demonstrate the working of various equipments related to pollution control.

COURSE CONTENT:

1. pH, Turbidity, Electrical Conductivity
2. Acidity and Alkalinity
3. Total Hardness, Calcium and Magnesium
4. Solids (total, suspended and dissolved)
5. Settleable solids (by Imhoff Cone)
6. Optimum coagulant dose (Jar Test)

7. Dissolved oxygen
8. Biochemical oxygen demand
9. Chemical oxygen demand (COD)
10. Gas liquid mass transfer characteristics (aeration apparatus)
11. Softening or demineralization of water (ion exchange column)

Teaching Methodology:

This course is introduced to help students understand basic principles of air and water pollution along with the design of air pollution and water pollution control equipment. The entire course is broken down into following separate units: Introduction, Air pollution, Water pollution and Noise pollution. Each section includes multiple topics to help a student gain deeper understanding of the subject. This lab course is well complemented by a theory course under the name Environmental Engineering in the same semester that helps a student learn and discuss the technical details of the underlying technologies.

Evaluation Scheme:

<table>
<tr><th colspan="2">Exams</th><th>Marks</th><th>Coverage</th></tr>
<tr><td colspan="2">P-1</td><td>15 Marks</td><td>Based on Lab Exercises: 1-7</td></tr>
<tr><td colspan="2">P-2</td><td>15 Marks</td><td>Based on Lab Exercises: 8-11</td></tr>
<tr><td rowspan="4">Day-to-Day Work</td><td>Viva</td><td>20 Marks</td><td rowspan="4">70 Marks</td></tr>
<tr><td>Demonstration</td><td>20 Marks</td></tr>
<tr><td>Lab Record</td><td>15 Marks</td></tr>
<tr><td>Attendance & Discipline</td><td>15 Marks</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">100 Marks</td></tr>
</table>

Learning Resources:

Study material of Environmental Engineering Lab (will be added time to time): Digital copy will be available on the JUET server.

TEXT BOOKS

1.Laboratory Manual available in Lab

2.Study material available in related folder of Server

3.Rao C.S., “Environmental Pollution Control Engineering”, Wiley Eastern.

4.Davis M.L., Cornwell D.A., “Introduction to Environmental Engineering”, 2/e McGraw Hill-1991.

5.Mahajan S.P., “Pollution Control in Process Industries”, Tata McGraw Hill Publishing Company Ltd.

6.Peavy, H.S., Rowe, D.R., Tchobanoglous G., “Environmental Engineering”, McGraw Hill 1985.

7.Master, G.M., “Introduction to Environmental Engineering & Science”, Prentice Hall of India.

REFERENCE BOOKS / Material:

1. Metcalf et. al., “Waste Water Treatment, Disposal & Teuse”, 3/e, Tata McGraw Hill.
2. Chandalia S.B., Rajgopal D., “Environmental Perspectives of Chemical Industries”

Semester III

Elective –VI

Title of Course: Bioprocess Principles **Course Code: CL713**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
This course deals with the principles of various bioprocesses and study of bioreactors.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the importance of various bioprocesses.
CO2	Understand the process of cell cultivation.
CO3	Apply enzyme kinetics and cell kinetics.
CO4	Analyze various enzymatic processes.
CO5	Design various bioreactors.
CO6	Develop the complete downstream processing operations.

Course Contents

UNIT 1: Introduction
Fermentation processes, general requirements of fermentation processes, an overview of aerobic and anaerobic fermentation processes and their application in industry, Medium requirements for fermentation processes - examples of simple and complex media, Design and usage of commercial media for industrial fermentation. Sterilization: Thermal death kinetics of micro-organisms, Batch and Continuous Heat-Sterilization of liquid Media, Filter Sterilization of Liquid Media and Air.

UNIT 2: Enzyme technology
Enzymes: Classification and properties, Applied enzyme catalysis, Kinetics of enzyme catalytic reactions, Microbial metabolism, Metabolic pathways, Protein synthesis in cells. Stoichiometry and Kinetics of substrate utilization and Biomass and product formation: Stoichiometry of microbial growth, Substrate utilization and product formation-Batch and Continuous culture, Fed batch culture Recovery and purification of products.

UNIT 3: Bioreactor
Bioreactor and product recovery operations: Operating considerations for bioreactors for suspension and immobilized cultures, Selection, scale-up, operation of bioreactors – Mass transfer in heterogeneous biochemical reaction systems; Oxygen transfer in submerged

fermentation processes; oxygen uptake rates and determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen transfer. Heat transfer processes in biological systems.

UNIT 4: Control in Bioprocesses

Introduction to Instrumentation and Process Control in Bioprocesses: Measurement of physical and chemical parameters in bioreactors - Monitoring and control of dissolved oxygen, pH, impeller speed and temperature in a stirred tank fermenter.

Teaching Methodology:

This course is introduced to help students understand basic concepts of various bioprocesses. The entire course is broken down into following separate units:Introduction, Enzyme technology, Bioreactor, Control in Bioprocesses.Each section includes multiple topics to help a student gain deeper understanding of the subject.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1& Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Shuler, M. L., and Kargi, F., 2002, “Bio-process engineering", 2nd Edition, Prentice Hall of India, New Delhi.
2. Bailey, J. E., and Ollis, D. F., 1986, “Biochemical Engineering Fundamentals", 2nd Ed., McGraw-Hill Publishing Co. New York.

Reference Book:

1. Stanbury, P., Whitakar, A., and Hall, S. J., 1999, "Principles of Fermentation Technology" 2nd Ed., Elsevier-Pergamon.

Title of Course: Bio-separations Course Code: CL714
L-T-P Scheme: 3-0-0 Course Credits: 3

Course Objective
This course deals with the principles of various bio-separation processes.

Learning Outcomes:

Course Outcome	Description
CO1	Describe the importance of bioseparations.
CO2	Understand the concepts of purification.
CO3	Apply various techniques for purification.
CO4	Analyze various mechanisms employed in the separation processes.
CO5	Design various equipment used for doing bio-separations.
CO6	Develop the strategy for process control of bio-separations.

Course Contents
UNIT 1: Introduction
Bio separations: an overview, Analytical methodologies, separation and purification methods.

UNIT 2: Purification and Analysis by HPLC
Analysis of protein impurities in pharmaceuticals derived from recombinant DNA, Basic chromatographic terms and concepts, the chemical structure of polypeptide and protein, Physicochemical Factors That Underpin Ligate Interactions with Polypeptides and Proteins in HPLC Separation Systems , Strategic Considerations behind the HPLC Separations, Specific Physicochemical Considerations on the Individual Chromatographic Modes, The Effect of Temperature and the Thermodynamics of Polypeptide- or Protein-Ligate Interactions

UNIT 3: Capillary Electrophoresis of Compounds of Biological Interest
Introduction, Capillary Zone Electrophoresis, Migration Behaviour of Peptides and Proteins, Modifications of Fused Silica Capillaries, Effect of Temperature on Separations, Strategy for Protein Separations, Capillary Gel Electrophoresis, Micellar Electro kinetic Chromatography, Capillary Electro chromatography

UNIT 4: Processing Plants and Equipment
Introduction, Industries Using Bio separations, Process-Scale Bio separations, Process-Scale Considerations

UNIT 5: Process Control of Bio separation Processes
Need for Process Control in Bio separations, Brief Overview of Current Control Methods, Application Examples, Opportunities for Continuing Development

Teaching Methodology:
This course is introduced to help students understand basic concepts of bio-separations. The entire course is broken down into following separate units:Introduction, Purification and Analysis by HPLC, Capillary Electrophoresis of Compounds of Biological Interest, Processing Plants and Equipment, Process Control of Bio separation Processes. Each section includes multiple topics to help a student gain deeper understanding of the subject.
Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:
Tutorials and study material (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:
1. S, Ahuja, "Handbook of Bio separations", volume 2, Academic Press.

Title: Cement TechnologyCode: CL715

L-T-P scheme:3-0-0 **Credit: 3**

Course Objective : After completion of this course, a student will be familiar with the cement raw materials, cement manufacturing technologies, energy trends related to cement manufacture and quality aspects of different cement varieties.

Learning Outcomes:

Course Outcome	Description
CO1	Outline of cement manufacturing.
CO2	Understand the processes of cement manufacture.
CO3	Describe production process of wet, semi wet, dry with pre-heater and dry with pre-calciner.
CO4	Develop the understanding of conversion of raw materials to cement.
CO5	Identify the quality control aspects in cement.
CO6	Demonstrate the principles of heat and mass transfer in cement manufacture.

Course Content:

Unit 1:INTRODUCTION

What is cement, importance of cement in construction, usage of lime in construction. Ancient constructions around the world.

Unit 2: CEMENT MANUFACTURE

History of development of cement, all the processes of cement manufacture, wet, semi-wet, semi-dry and dry process, various unit operations in cement manufacture.

Behive kilns, vertical shaft kilns, long wet process kilns, long dry process kilns, LEPOL Kilns, pre-heater kilns and pre-heater- pre-calcinator dry process kilns. Their developments and transformation into modern kilns.

Unit 3: RAW MATERIALS & RAW MIX DESIGN

Raw materials for cement manufacture and their quality requirements, calcareous and argillaceous materials. Corrective raw materials, sweetner and mineralizers. Quality requirements of industrial and agricultural wastes for utilization in cement manufacture.

Different types of limestone: limestone, aragonite, marl and dolomite, classification of limestone, different types of clay: Kaolinite, montmorrilonite, shale and illite, other corrective materials: laterite, iron ore, pyrite cinder and bauxite. Utilization of calcareous, argillaceous and siliceous industrial wastes for cement manufacture.

Unit 4: CEMENT CLINKER

Clinker minerals, absorption of various constituents in phases. Bouge's calculation, phase diagrams. Polymorphs of alite and belite.Chemical reactions during clinkerization, role of minor constituents in clinkerization, thermochemistry of clinker formation. Microscopic examination of cement minerals.

Unit 5: TYPES OF CEMENTS

Varieties of cement being manufactured in the country and their classification. Physical and chemical properties of cement.

Teaching Methodology:

This course is introduced to help the students to understand raw material collection procedures, Quality control norms to be followed during cement manufacture.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-4 & Unit-5 and around 30% from coverage of Test-2
Assignment	10 Marks	
Tutorials	5 Marks	
Quiz	5 Marks	
Attendance	5 Marks	
Total	**100 Marks**	

Learning Resources:

Tutorials and lecture slides on raw material collection, specification requirements, physical tests, quality control norms (will be added from time to time): Digital copy will be available on the JUET server.

Text Books:

1. Cement Engineers' Handbook, Labahn and Kohlhaas, Bauverlag GMBH, Berlin.
2. The Rotary Cement Kiln, K. Perey, Edward Arnold.
3. Cement Data Book, All volumes, W. H. Duda, Verlag GmBH, Berlin.
4. Reports of VDZ Congress, 1993, 2002.
5. Cement International, No. 3/2003, No. 6/2003, VDZ, Germany
6. BIS Specifications on Cement.
7. NCB Guide Norms for Cement Plant Operations, Fifth Edition, 2005, National Council for Cement and Building Materials, New Delhi.
8. Quality Control in Cement Manufacture, NCB publication, 1995.
9. The Chemistry of Cement and Concrete, F M Lea, Edward Arnold (Publishers) Ltd.,Great Britain.

Reference books:

[1] Proceedings of Selected International Seminars on Cement

[2] Innovation in Portland Cement Manufacturing, J I Bhatty, F M Miller and S H Kosmatka, Portland Cement Association, USA.

[3] Advances in Cement Technology, S N Ghosh,Tech Books International, New Delhi