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:

Exams		Marks	Coverage
P-1		15 Marks	**Based on Lab Exercises: 1-6**
P-2		15 Marks	**Based on Lab Exercises: 7-13**
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 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:

<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: 6-10</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 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.

2^{nd} 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: 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: Conventional and Non – Conventional Energy Engineering
Course Code: CL716
L-T-P Scheme: 3-0-0 **Course Credits: 3**

UNIT: 1 Fuels
Solid fuel: Coal classification, composition and basis, Coal mining, Coal preparation and washing. Combustion of coal and coke making, Action of heat on different coal samples, Different types of coal combustion techniques, Coal liquefaction, Direct liquefaction, Indirect liquefaction, Coal gasification.
Liquid fuel: Constitution of petroleum, Origin and Occurrence of crude. Evaluation of crude, Properties, testing and specifications of petroleum products- Octane no.; Reid vapor pressure; Flash point; Fire point; Smoke point; Pour point; Cloud point; Aniline point and Diesel index; Cetane no., Processing of Crude Petroleum - Atmospheric and Vacuum distillation, column control schemes, Cracking, Reforming, Vis-breaking, Delayed Coking, Liquid fuel from coal; Fischer Tropsch process, other synthetic liquid fuels Gaseous fuel: Introduction, Properties, Classification, Natural gas, Methane from coal mines, Producer gas, water gas, coal gas, Blast furnace gas, LPG, Gasification- coal, biomass, oil
UNIT: 2 Solar Energy Utilisation (Thermal)
Construction and performance analysis of solar flat plate collectors. Heat losses from FPC by radiation and natural convection, overall heat loss coefficient, collector efficiency factor, tilt factors, collector heat removal factor, Hottel-Willier-Bliss equation. Solar concentrating collectors : CPC, PTC, spherical paraboloids , modes of tracking, performance analysis, Salt gradient solar ponds: construction, operation, technical problems, Solar drying and dehumidification: Solar cabinet dryers, convective dryers.
UNIT: 3 Energy from Ocean, Wind, Tides and geothermal sources
OTEC power plants (closed cycle, open cycle, hybrid cycle), operation and technical problems, environmental impact, Tidal power, salinity power plants, Wind energy: Design and analysis of wind turbines, Geothermal systems: Hot water and dry steam systems, energy extraction principles.
UNIT: 4 Energy from biomass
Biomass utilisation: pyrolysis, gasification, anaerobic digestion (biogas production), Biodiesels: Manufacture and characteristics, Gasoho : Characteristics and manufacture , use of pervaporation technology, Synthetic liquid fuels from coal : F – T Process, Coal hydrogenation, MTOG process.
UNIT: 5 Nuclear Energy
Nuclear fission principles, types of nuclear reactors (BWR, PWR, PHWR, LMCR, GCR, FFR). Nuclear reactor analysis: four factor formula, resonance absorption, reactor buckling, multiplication factor, thermal utilisation coefficient, reflector saving, fast fission factor, optimum moderator to fuel ratio. Radioactive waste disposal.

Text Books:
1. Non-Conventional Energy Sources by G. D Rai, Khanna Publishers
2. Non-Conventional Energy Resources by B. H. Khan, McGraw Hill Education (India) Private Limited

3. Petroleum Refining Engineering: W. L. Nelson
4. Modern Petroleum Refining: B. K. B. Rao

Reference Books:

1. Petroleum Refining Technology & Economics: J.H. Gary & G.E. Handwerk
2. Fuels & Combustion: Samir Sarkar

Title of Course: Energy Management and Circular Economy Course Code: CL717
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit 1
Energy Management – Definitions and significance – objectives –Characterizing of energy usage – Energy Management program – Energy strategies and energy planning Energy Audit – Types and Procedure – Optimum performance of existing facilities – Energy management control systems – Computer applications in Energy management.
Unit 2
Energy conservation – Principles – Energy economics – Energy conservation technologies – cogeneration – Waste heat recovery – Combined cycle power generation – Heat Recuperators – Heat regenerators – Heat pipes – Heat pumps.
Unit 3
Pinch Technology Energy Conservation Opportunities – Electrical ECOs – Thermodynamic ECOs in chemical process industry – ECOs in residential and commercial buildings – Energy Conservation Measures.
Unit 4
Recognize, explain and discuss how materials and energy flow through our economic system. Apply a systems approach to developing circular economy models to keep materials and energy at their highest value.
Unit 5
Recognise and distinguish between strategies to achieve a more circular economy, including resource and waste management, eco-efficiency, clean production, industrial ecology, and how technology such as big data facilitates this. Understand how to apply life cycle approaches to quantifying environmental impacts of products or systems, including embodied energy.
Text Books:
1. Energy Management in Industry: David Thorpe, 2013, ISBN 9780367787431, Routledge.
2. The Circular Economy, 1st Edition, Mika Sillanpaa, Chaker Ncibi, ISBN: 9780128152683, 2019, Elsevier.
Reference Books:
1. Waste Management as Economic Industry Towards Circular Economy Ghosh, Sadhan Kumar (Ed.), 1st ed. 2020, XIV, 203 p. Springer.
2. Strategic Management and the Circular Economy Marcello Tonelli, Nicolo Cristoni, 1st Edition, 2019, ISBN 9780367514563, Routledge.
3. Waste to Energy in the Age of the Circular Economy: Best Practice Handbook 978-92-9262-480-4, Asian Development Book Bank, 2020.

Title of Course: Solar Energy **Code: CL718**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit 1

Energy Resources and Solar Spectrum World and Indian energy scenario, Global solar resources. Physics of the Sun - Energy balance of the earth, energy flux, solar constant for earth, green house effect. Solar radiation on the earth, Measurement of solar radiation – 16 Pyranometer, Pyrheliometer, Sunshine recorder. Solar time - Local apparent time (LAT), equation of time (E). Solar radiation geometry, Estimation of Sunshine hours at different places in India. Calculation of total solar radiation on horizontal and tilted surfaces. Prediction of solar radiation availability.

Solar thermal power plants - Parabolic trough system, distributed collector, hybrid solar-gas power plants, solar pond based electric-power plant, central tower receiver power plant.

Unit 2

Solar Cell Fundamentals, Photovoltaic effect - Principle of direct solar energy conversion into electricity in a solar cell. Semiconductor properties, energy levels, basic equations. Solar cell, p-n junction, structure. I-V characteristics of a PV module, maximum power point, cell efficiency, fill factor, effect of irradiation and temperature. Commercial solar cells – Production process of single crystalline silicon cells, multi crystalline silicon cells, amorphous silicon, cadmium telluride, copper indium gallium diselenide cells. Design of solar PV systems and cost estimation. Case study of design of solar PV lantern, standalone PV system - Home lighting and other appliances, solar water pumping systems. Classification - Central Power Station System, Distributed PV System, Standalone PV system, Grid Interactive PV System, small system for consumer applications, Hybrid solar PV system, Concentrator solar photovoltaic. System components - PV arrays, inverters, batteries, charge controls, net power meters. PV array installation, operation, costs, reliability. PV System Applications

Unit 3

Stationary collectors- FPC- CPC- ETC- Sun tracking concentrating collectors- PTC- PDR- HFCFresnel collectors- Solar thermal power plants- Solar chimney power plant- Solar pond- Solar water heater- Solar cooker- Types- SODISThermal energy storage- Solar cooling- Limitations of solar thermal energy.

Fundamentals of solar collectors as devices to convert solar energy to heat. Nonconcentrating low temperature flat-plate and evacuated tube collectors. Design and structures of collectors for heating liquids and air. Performances of Flat Plate Collectors, Solar Concentrating Collectors and its performance, applications of solar collectors.

Unit 4

Modeling and analysis of solar systems Mathematical Modeling Mathematical modeling overview – Types, stages, choosing the modeling equations, levels of analysis, steps in model development, solving and testing of models. Software Tools Overview of effective tools for solar energy systems - RET Screen - Evaluation of the energy production and savings of renewable energy and energy efficient technologies, TRNSYS - Dynamic simulation of solar heating and cooling systems, GREENIUS - Simulation, design and analysis of solar thermal electric and photovoltaic systems, PVSYST - Sizing, simulation and analysis of photovoltaic systems. Energy Optimization, Case studies of energy system optimization – Application - Analysis and design of solar thermal and photovoltaic systems.

Text Books:

1. Sukhatme .K, Suhas P.Sukhatme., "Solar energy: Principles of thermal collection and storage", Tata McGraw Hill publishing Co. Ltd, 8th edition, 2008.
2. Garg. H. P., Prakash .J, "Solar energy fundamentals and applications", Tata McGraw Hill publishing Co. Ltd, 2006.
3. Yogi D. Goswami, Frank Kreith, Jan F.Kreider., "Principle of solar engineering", 2nd edition, Taylor and Francis, 2nd edition, 2003.

Reference Books:

1. Tiwari. G.N, "Solar energy: Fundamentals, Design, Modeling and Applications", CRC Press Inc., 2002.
2. Artur V.Kilian, "Solar Collectors: Energy Conservation, Design and Applications", Nova Science Publishers Incorporated, 2009

Elective –V

Title of Course: Energy Optimization and Process IntensificationCode:CL719
L-T-P Scheme: 3-0-0 Course Credits: 3

Unit 1
Basic concept and introduction, Challenges faces by process industries ,Paradigm shift of chemical business ,Background of energy and process optimization in industry ,Five ways to improve energy efficiency, Four key element for continuous improvement , Theory of energy intensity, Definition of process energy intensity, Concept of fuel equivalent ,Energy intensity for a total site, Benchmarking energy intensity, Data extraction from historian, Convert all energy usage to fuel equivalent, Energy balance, Energy performance index method, Key indicators and targets, Define key indicators, Set up targets for key indicators, Economic evaluation of key indicators, Implementing key indicators into energy dashboard.
Unit 2
Heat exchanger Distillation system performance assessment Basic concept and calculations, Understanding performance criteria –U values, Understanding pressure drop, Improving heat exchanger performance, Heat exchanger fouling assessment, Fouling mechanism, Fouling mitigation, Fouling resistance calculations, A cost based model for clean cycle optimization, Energy loss assessment, Energy loss audit, Energy loss evaluations, Brainstorming, Energy audit report
Distillation system assessment
Distillation operating window, Distillation efficiency, Understanding operating window, Typical capacity limit, Distillation system optimization, Define a base case, Building process simulation, Tower efficiency assessment, Tower optimization basis, Energy optimization for distillation system, Overall process optimization.
Unit 3
Boiler, Deaerator, Steam turbine, Let down valve, Steam desuperheater, Steam flash drum, Steam trap, Steam distribution loss, Establishing steam balance, Guidelines for generating steam balance, A working example of generating steam balance, A practical examples for generating steam balance, Verify steam balance.
Unit 4
Process optimization in industry. Collect online data for the whole operation cycle, Determine the true benefit from process variation, Map the whole process in cost term, How to detect opportunities for optimization Common tools available to exploit those opportunities.

Text Books:
1. Energy and process optimization for the process industries by Frank (Xin X) Zhu (Wiley, ISBN 978-1-118-10116-2)
2. Process Heat Transfer – D. Q. Kern (McGraw-Hill)

Title of Course: Nuclear EnergyCode:CL720
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit 1: Introduction
Scope of nuclear energy (fission and fusion energy), typical reactions Basics Concepts: Binding Energy of a nuclear reaction, mass energy equivalence and conservation laws, nuclear stability and radioactive decay, radioactivity calculations. Interaction of Neutrons with Matter: Compound nucleus formation, elastic and inelastic scattering, cross sections, energy loss in scattering collisions, polyenergetic neutrons, critical energy of fission, fission cross sections, fission products, fission neutrons, energy released in fission, γ-ray interaction with matter and energy deposition, fission fragments.
Unit 2: The Fission Reactor
The fission chain reaction, reactor fuels, conversion and breeding, the nuclear power resources, nuclear power plant & its components, power reactors and current status. Reactor Theory: Neutron flux, Fick's law, continuity equation, diffusion equation, boundary conditions, solutions of the DE, group diffusion method, Neutron moderation (two group calculation), one group reactor equation and the slab reactor Health Hazards: radiation protection & shielding.
Unit 3: Nuclear Fusion
Fusion reactions, reaction cross-sections, reaction rates, fusion power density, radiation losses, ideal fusion ignition, Ideal plasma confinement & Lawson criterion. Plasma Concepts: Saha equation, Coulomb scattering, radiation from plasma, transport phenomena Plasma Confinement Schemes: Magnetic and inertial confinement, current status.
Unit 4: Nuclear Power Plant
Waste Management and Safety Nuclear Power Plant, Nuclear power plant safety systems, Nuclear Accidents- consequences– case study, criteria for safety, Nuclear Waste management, International Convention on safety aspects, radiation hazards and their prevention.
Unit 5: Nuclear Policy and Regulations
Atomic Energy Act, India's Nuclear Energy Programme, Indian nuclear energy policy, International Atomic Energy Agency [IAEA] International Nuclear Energy Policies and Regulations, Weapons proliferation NPT, safe guards to prevent nuclear proliferation, Indian Nuclear deal and 123 agreement and present Status of International Nuclear Co-operation.
Text Books:
1. Samuel Glasstone and Alexander Sesonske "Nuclear Reactor Engineering" Third Edition
2. John K. S. and Richard E. F. (2007); Fundamentals of Nuclear Science and Engineering, Second Edition, CRC Press
Reference Books:
1. Raymond M and Keith E. H. (2014); Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Seventh Edition, Butterworth-Heinemann
2. Bodansky D. (2008); Nuclear Energy: Principles, Practices and Prospects, Second Edition, Springer.

Title of Course: Pinch Technology in Process IndustryCode:CL721
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit : 1
Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram. Overview of Pinch Technology: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology. Key steps of Pinch Technology: Concept of ΔTmin, Data Extraction, Targeting, Designing, Optimization-Supertargeting Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve. Targeting of Heat Exchanger Network: Energy Targeting, Area Targeting, Number of units targeting, Shell Targeting and Cost targeting.
Unit: 2
Designing of HEN: Pinch Design Methods, Heuristic rules, stream splitting, and design of maximum energy recovery (MER). Use of multiple utilities and concept of utility pinches, Design for multiple utilities pinches, Concept of threshold problems and design strategy. Network evolution and evaluation-identification of loops and paths, loop breaking and path relaxation.
Unit: 3
Design tools to achieve targets, Driving force plot, remaining problem analysis, diverse pinch concepts, MCp ratio heuristics. Targeting and designing of HENs with different ΔTmin values, Variation of cost of utility, fixed cost, TAC, number of shells and total area with ΔTmin Capital-Energy trade-offs. Process modifications-Plus/Minus principles, Heat Engines and appropriate placement of heat engines relative to pinch. Heat pumps, Appropriate placement of heat pumps relative to pinch. Steam Rankin Cycle design, Gas turbine cycle design, Integration of Steam and Gas turbine with process. Refrigeration systems, Stand alone and integrated evaporators. Heat integrations and proper placement of Reactors for batch Processes as well as continuous processes.
Unit: 4
Case studies on heat integration by pinch technology

Text Books:
1. Shenoy U. V.; "Heat Exchanger Network Synthesis", Gulf Publishing Co.
2. Smith R.; "Chemical Process Design", McGraw-Hill.
3. Linnhoff B., Townsend D. W., Boland D, Hewitt G. F., Thomas B. E. A., Guy A. R., and Marsland R. H.; "A User Guide on Process Integration for the Efficient Uses of Energy", Inst. of Chemical Engineers.
Reference Books:
1. Ian C. Kemp, Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy, 2nd Edition, ISBN: 9780750682602, Butterworth-Heinemann, 2016.

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”

3^{rd} Semester

Elective –VI

Title of Course: Fuel Cell and BatteryCode:CL722
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit 1
Introduction of fuel cells and battery; history; basic structure and characteristic of fuel cells and batteries; overview of electrode process; application; advantage and disadvantage.
Unit 2
Thermodynamics and electrochemical kinetics – Potential and kinetic of cells; kinetic of electrode reaction; mass transfer by migration and diffusion; Nernst Equation, Open Circuit Voltage; Reactions in Concentrated Solutions; Faradic reaction; Butler-Volmer Equation, electrocatalysis; electrochemical phase transformation; homogeneous and Heterogeneous charge transfer; Diffusion.
Unit 3
Fuel Cell – Introduction; basic components; working principle; Performance and dependency of different parameters; different type of fuel cells (alkaline, phosphoric acid, proton exchange and solid state fuel cell etc); fuelling problem; catalyst used in fuel cells; prospect of direct methanol production fuel cell; application; competing technology for transportation; fuel cell fuel cycles.
Unit 4
Battery – Introduction, components, working principle, important practical parameters, principle for voltage, current and capacity determination; different type of batteries (primary/secondary – lead acid; NiCd, Lithium and sodium-ion battery, metal sulfur battery, lithium/sodium air battery); materials used in lithium/sodium ion batteries, different type of electrolytes; applications, challenges and future aspect; supercapacitor.
Unit 5:
Impedance and Circuit model – Introduction; dynamic of equivalent circuit; Electrochemical Impedance spectroscopy (EIS); Nyquist diagram; Bode diagram, charge transfer resistance, Warburg resistance, impedance of electrode (batteries, supercapacitor and fuel cell); transport in solid and porous structure and their chemical kinetics based on non- equilibrium thermodynamics.
Text Books:
1. Electrochemical Method, Fundamentals and Application by Allen J. Bard and Larry R. Faulkner.
2. Fuel Cell Handbook by EG&G Technical Services, Inc
3. Advance Batteries by Robert A. Huggins

Reference Books:
1. Handbook of Batteries by David Linden and Thomas B. Reddy
2. Fundamentals Of Electrochemistry by V. S. Bagotsky

Title of Course: Membrane Technology in Environmental Pollution ControlCode:CL723
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit 1
Membrane materials, membrane-based processes and membrane modules.
Introduction to membrane-based technology, application potentials of micro, ultra, nano, reverse osmosis, forward osmosis and other integrated membrane processes in water treatment, bio separation, biofuel production, air pollution control, green chemical production.
Unit 2
Introduction to modelling membrane separation, modelling microfiltration, ultrafiltration, nanofiltration, reverse osmosis, forward osmosis, membrane distillation and integrated processes.
Unit 3
Introduction to Membrane-based technologies in air pollution control. Membrane technology in controlling particulates, and gaseous pollutants (SOx, NOx, CO2, CO).
Unit 4
Membrane-based technologies in groundwater treatment, surface water treatment, industrial wastewater treatment, turning waste to wealth through membrane technology, closed loop wastewater treatment using multistage membrane separation.
Unit 5
Introduction to development of green technology using membranes, green chloralkali production, green biofuel production, green biochemical production. Process intensification through membrane technology, analysis of space intensification, energy reduction, eco-friendly production through adoption of membrane technology.

Text Books:
1. Membrane-based Technologies for Environmental Pollution control, Parimal Pal, Elsevier Sci.
Reference Books:
1. Industrial Water Treatment Process Technology, Parimal Pal, Elsevier
2. Groundwater Arsenic Remediation: Treatment Technology & Scale Up, Parimal Pal, Elsevier Sci.

Title of Course: Air Pollution Control and Solid Waste Management **Code:CL724**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Unit 1: Air Pollution
Air Pollution: Sources, Health Hazards, global warming & climate change. Role of Atmosphere in dispersion, Plume behaviour. Dispersion problems and Stack Design (Tutorial): Control devices- ESP, Venturi scrubber, gravity separator, filters. Design Problems (Tutorial), Abatement of gaseous pollutants & VOCs.

Unit 2: Relevant Regulations
Municipal solid waste (management and handling) rules; hazardous waste (management and handling) rules; biomedical waste handling rules; flyash rules; recycled plastics usage rules; batteries (management and handling) rules.

Unit 3: Municipal Solid and Hazardous Waste Management – Fundamentals
Sources; composition; generation rates; collection of waste; separation, transfer and transport of waste; treatment and disposal options

Characterization of waste; compatibility and flammability of chemicals; fate and transport of chemicals; health effects.

Unit 4: Treatment Techniques of Solid and Hazardous Waste
Chemical treatment processes for MSW (combustion, stabilization and solidification of hazardous wastes); physicochemical processes for hazardous wastes (soil vapour extraction, air stripping, chemical oxidation); ground water contamination and remediation. Composting; bioreactors; anaerobic decomposition of solid waste; principles of biodegradation of toxic waste; inhibition; co-metabolism; oxidative and reductive processes; slurry phase bioreactor; in-situ remediation.

Unit 5: Landfill design
Landfill design for solid and hazardous wastes; leachate collection and removal; landfill covers; incineration

Text Books:

1. Basic Environmental Technology- Jerry A. Nathanson.
2. Environmental Pollution Control Engineering – C.S. Rao,
3. John Pichtel Waste Management Practices CRC Press, Taylor and Francis Group 2005.
4. LaGrega, M.D. Buckingham, P.L. and Evans, J.C.
5. Hazardous Waste Management, McGraw Hill International Editions, New York, 1994.

Reference Books:

1. Richard J. Watts, Hazardous Wastes - Sources, Pathways, Receptors John Wiley and Sons, New York, 1997.

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