COURSE DESCRIPTION

Ist Semester

Title of Course: Advance Transport Phenomena **Course Code: 14M11CL111**
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	Outline the basic concepts of transport phenomena.
CO2	Setup overall balances for conservation of momentum, energy and mass.
CO3	Recognize and apply analogies among momentum, heat and mass transfer.
CO4	Reduce and solve the appropriate equations of change to obtain desired profiles for velocity, temperature and concentration.
CO5	Utilize information obtained from solutions of the balance equations to obtain Engineering quantities of interest.
CO6	Reduce and solve appropriate macroscopic balances for conservation of momentum, energy and mass.

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 2^{nd} 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: 14M11CL112**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals with 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 Process modeling and optimization.
CO2	Understand different types of mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques.
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate 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: Introduction to Optimization

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.

UNIT 5: Optimization Techniques for Single Variable

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 6: 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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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. 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.

Title of Course: Chemical Reactor Analysis and Design **Course Code:** 21M11CL113
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. The course aims at understand the non-ideal flow, physical properties of solid catalysts, catalytic and non-catalytic heterogeneous systems.

Learning Outcomes:

Course Outcome	**Description**
CO1	To understand the mechanism of chemical kinetics for various types of reactions.
CO2	To design the reactors for homogeneous and heterogeneous reactions.
CO3	To analyze the non-ideality in the flow reactors.
CO4	To understand physical properties and preparation of solid catalysts.
CO5	Develop design equations for the heterogeneous reactors.
CO6	Apply 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.

Unit 6: Heterogeneous Process

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.

Unit 7: Non isothermal reactor design

General design procedure, optimum temperature progression, adiabatic operation, non adiabatic operation, semi batch reactors. Steady state and unsteady state operations in C.S.T.R and plug flow reactors, reactor stability with special reference to C.S.T.R. Introduction to optimization of chemical reactors.

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 ,Unit-4, Unit -5, and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-6, Unit - 7 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 of Course: Advance Separation Processes-I **Course Code: 14M11CL114**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
This course deals with 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 advanced separation processes.
CO2	Understand different of Physical-Chemical Phenomena
CO3	Describe the mass transfer process without chemical reaction.
CO4	Develop design equations for mass transfer equipment.
CO5	Apply principles for the selection of suitable mass transfer equipment for a given separation.
CO6	Demonstrate the complete design of mass transfer equipments.

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.

Elective –I

Title of Course: Wastewater Treatment **Course Code: 14M1GCL131**
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 equipments related water pollution control.
CO4	Develop rate expressions for different types of processes used in waste water treatment.
CO5	Apply appropriate equations for the design of water pollution control equipments.
CO6	Demonstrate the working of various equipments 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: Physical treatment methods
Screening, mixing and flocculation, gravity separation, settling, grit removal, sedimentation, flotation, aeration etc.

UNIT 4: Chemical treatment methods
Chemical coagulation, chemical precipitation, chemical oxidation, chemical neutralization.

UNIT 5: Biological treatment methods
Introduction to microbial metalbolism, bacterial growth and energetic, microbial growth kinetics, suspended growth and attached growth process, aerobic and anaerobic system.

UNIT 6: Natural treatment methods
Wetland treatment method, septic tank, infiltration and overland flow.

UNIT 7: Advanced treatment methods
Membrane filtration, adsorption, gas stripping, ion exchange, advanced oxidation processes etc.

UNIT 8: 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 ,Unit-4, Unit-5 & Unit-6 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-7 & Unit-8 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: 14M1GCL132**
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	Outline 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	Develop expressions for the estimating the efficiency of various air pollution control equipments.
CO5	Apply 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: 14M1GCL133**
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	Describe various cleaner production control techniques.
CO4	Develop cleaner 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.

2nd Semester

Title of Course: Advanced Separation Processes-II **Course Code: 14M11CL211**
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	Outline the importance of membrane separation processes employed in chemical industries.
CO2	Understand the types of process along with their applications.
CO3	Describe various membrane process utilized in different separation operations.
CO4	Develop various techniques for characterization of membranes.
CO5	Apply appropriate expressions that describes the complete transport process through membranes.
CO6	Demonstrate the preparation of 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.

UNIT 6: Polarization phenomenon and fouling:
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.

UNIT 7: Other separation Processes:
Pressure swing adsorption, reactive distillation, separation using surfactants, Cloud point extraction, Supercritical fluid extraction etc.

UNIT 8: Advanced analytical instruments:
Theory and working principle of UV-Vis spectrophotometer, HPLC, GC, LCMS, LPSA, DLS, SEM etc.

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, Polarization phenomenon and fouling, Other separation Processes, and Advanced analytical instruments. 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 , Unit-4 & Unit-5 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-6 , Unit-7 & unit-8 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.

Title of Course: Advanced Heat Transfer and Fluid Dynamics

Course Code: 21M11CL212

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

Course Objective

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

Learning Outcomes:

Course Outcome	Description
CO1	Able to understand the chemical process and process integration.
CO2	Ability to modify processes for minimization of heat, area, number of units and cost of chemical industries and allied industries.
CO3	Able to improve separations, heat transfer, mass transfer, mixing and integration of different process.
CO4	Ability to do pinch analysis and analyze heat exchanger network.
CO5	Understand the significance of heat exchange network in energy conservation.
CO6	Apply the principles of process integration in various industry related 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.

Title of Course: Environmental Engineering & Waste Management
Course Code: 14M11CL213
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
The aim of the course is to provide basic idea of environmental engineering and handling techniques of waste material.

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	Develop 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 Contents

UNIT 1: Nexus between energy, environment and development
Human population issues. Environmental ethics and environmental quality

UNIT 2: Types of pollution
Definition of pollution, Different types of pollution - Air, Water and soil and their local, regional and global aspects.

UNIT 3: Air pollution
Sources of air pollutants, their sources and behaviour in the atmosphere. Effects of air pollutants on humans, animals, plants and properties. Control approaches.

UNIT 4: Water pollution
Sources, consequences, control of water pollution

UNIT 5: Soil pollution
Sources and nature of soil pollution and its harmful effects. Environmental problems associated with noise pollution, oil pollution and radioactive pollution.

UNIT 6: Solid waste management principles
Sources and generation of solid waste, their nature and chemical composition. Their characterization and classification. Different methods of dispersal and management of solid wastes. Recycling of waste materials.

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: Nexus between energy, environment and development, Types of pollution, Air pollution, Water pollution, Soil pollution, and Solid waste management principles. 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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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. Mahajan S.P., "Pollution Control in Process Industries", Tata McGraw Hill Publishing Company Limited.
2. Peavy, H.S., Rowe, D.R., Tchobanoglous G., "Environmental Engineering", McGraw Hill 1985.
3. Metcalf et.al. "Waste Water Treatment, Disposal and Reuse", 3rd edition, Tata McGraw Hill.

Reference Books:

1. Davis M.L., Cornwell D.A., "Introduction to Environmental Engineering", 2nd edition McGraw Hill 1981.
2. Rao C.S., “Environmental Pollution Control Engineering", Wiley Eastern.

Title of Course: Process Dynamics & Control **Course Code: 14M11CL214**
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	Describe advanced control strategies.
CO2	Learn about the design of multivariable process control.
CO3	Describe method of decoupling control systems and model predictive control.
CO4	Outline of sampled data control system.
CO5	Apply z-transform for stability analysis of sampled data systems.
CO6	Study state-space methods.

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.

Elective II

Title of Course: Process Plant Simulation **Course Code: 14M1GCL231**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
Computer aided analysis of chemical process systems; classification and development of mathematical models to various chemical engineering systems; decomposition of networks; tearing algorithms; numerical methods for convergence promotion and solving chemical engineering problems; traditional & non-traditional optimization techniques; specific purpose simulation; dynamic process plant simulation; case study problems using professional software packages

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance of simulation in process plants.
CO2	Understand the concepts of mathematical modelling.
CO3	Describe various techniques of the solving different equations.
CO4	Develop various modular approaches used in process simulation.
CO5	Apply appropriate optimization techniques in different chemical processes.
CO6	Demonstrate the concept of dynamic simulation in process plants.

Course Contents

UNIT 1: Introduction
Introduction to Process Synthesis, Analysis, Design and Simulation

UNIT 2: Mathematical Modelling
Classification of Mathematical Modelling, Similarity Criteria, Variables, Parameters, etc.

UNIT 3: Chemical Systems Modelling
Modelling of various Chemical systems covering heat, mass, and momentum transfer, and reactions.

UNIT 4: Modular Approaches to Process Simulation
Sequential and Simultaneous Modular Approaches to be used in process plant simulation

UNIT 5: Equation Solving Approach
Partitioning, Decomposition, Disjointing, PTM, SWS-, Steward-, and Rudd-Algorithms, Sparcity, Direct Methods, Pivoting, Iterative methods, BTF, BBTF, Block Back Substitution, BTS, etc.

UNIT 6: Decomposition of Networks
Tearing Algorithms in decomposition of networks, digraph, MCN, signal flow graph, B&M Algorithm, BTA, K&S Algorithm, M&H-1 & -2 Algorithms, and related problems.

UNIT 7: Convergence Promotion
Convergence Promotion methods such as Newton's method, Direct substitution, Wegstein's method, Dominant Eigen value method, Quasi-Newton methods, Acceleration criterion, etc.

UNIT 8: Physical and Thermodynamic Properties
Sources and data banks of physical & thermodynamic properties, Modularity & Routing.

UNIT 9: Optimization Techniques
Importance & applications, limitations, types, methods, direct search routines, Lagrangian multiplier method, Gradient methods (Method of steepest descent & sequential simplex method); Non-traditional optimization techniques such as simulated annealing, genetic algorithms, differential evolution, etc.

UNIT 10: Specific Purpose Simulation
Case studies such as Casale converter for ammonia production, etc. on specific purpose simulation, and use of professional simulation packages.

UNIT 11: Dynamic Simulation
Case studies such as dynamic distillation modelling and simulation, etc. on Dynamic Simulation, and use of professional simulation packages.

Teaching Methodology:
This course is introduced to help students to learn about simulation and optimization techniques used in process plants. The entire course is broken down into following separate units: Mathematical Modelling, Chemical Systems Modelling, Modular Approaches to Process Simulation, Equation Solving Approach, Decomposition of Networks, Convergence Promotion, Physical and Thermodynamic Properties, Optimization Techniques, Specific Purpose Simulation, and Dynamic Simulation. 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 & Unit-3
Test-2	25 Marks	Based on Unit-4, Unit-5, Unit-6, Unit-7 & Unit-8 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-9, Unit-10 & Unit-11 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. Babu, B. V., 2004, "Process Plant Simulation", Oxford University Press, India.

Reference Books:

1. Onwubolu, G. C. and Babu, B. V., 2004, "New Optimization Techniques in Engineering; Springer-Verlag, Germany.
2. Luyben, W.L., 1990, "Process Modelling, Simulation and Control for Chemical Engineers", 2nd Ed., McGraw-Hill, New York.
3. Franks, R. G. E., 1972, "Modelling and Simulation in Chemical Engineering", John Wiley & Sons, New York.
4. Boyadjiev, C., 2010, "Theoretical Chemical Engineering: Modelling and Simulation", Springer Verlag, London.

Title of Course: Colloid & Interfacial Engineering **Course Code: 14M1GCL232**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

In this course students will study understand the phenomena occur in the colloids and the importance of colloids and role of interfacial engineering and study near the interface processes. Role of colloids in industry is also covered like drug delivery, paints and textile etc.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the basic concepts of colloids and interface.
CO2	Understand the concepts of Wetting, Contact Angle, and Adsorption.
CO3	Describe the importance of colloidal dispersion and surfactants.
CO4	Develop the phenomena to describe Interfaces in Motion
CO5	Apply appropriate mechanisms to explain the various transport phenomena.
CO6	Demonstrate the concept of dynamic interfaces and use of colloids in drug delivery.

Course Contents

UNIT 1: Fundamental of Interfacial Tension

Introduction to Interfacial Phenomena, Interfacial Tension: qualitative Considerations ,Interfacial Tension: Thermodynamic Approach, Vapour Pressure of a Drop, Interfacial Tension: Mechanical Approach, Locating the Dividing Surface, Density and Concentration Profiles , Equilibrium Shapes of Fluid Interfaces, Dimensions of a Sessile Drop , Shape of a Soap Film between Parallel Rings, Methods of Measuring Interfacial Tension, Capillary Rise in Air-Water and Oil-Water ,Surface Tension of Binary Mixtures , Surface Tension of Ideal Binary, Surface Tension of Regular Solutions, Surfactants, Solid-Fluid Interfaces

UNIT 2: Fundamentals of Wetting, Contact Angle, and Adsorption

Introduction ,Young's Equation , Work of Adhesion and Work of Cohesion, Phenomenological Theories of Equilibrium Contact Angles ,Acid-Base Interaction , Contact Angle , Hysteresis, Impurities on the Surface, Effect of Adsorption ,Surface Roughness ,Adsorption, Langmuir Adsorption Isotherm , The Brunauer-Emmett-Teller Isotherm , Density Profiles in Liquid Films on Solids, Characterizing Solid Surfaces

UNIT 3: Colloidal Dispersion

Introduction ,Attractive ,Electrical Interaction, Colloids of All Shapes and ,Combined Attractive and Electrical Interaction: DLVO ,Effect of Polymer Molecules on the Stability of Colloidal Dispersions , Kinetics of Coagulation

UNIT 4: Surfactants

Introduction ,Micelle Formation, Estimation of Micelle Aggregation Number and CMC, CMC of ,Variation of CMC for Pure Surfactants and Surfactant Mixtures , Other Phases Involving Surfactants, Cylindrical Micelles, Formation of Complexes between Surfactants and Polymers

,Surface Films of Insoluble Substrates, Solubilisation and Micro emulsions , Phase Behaviour and Interfacial Tension for Oil-Water-Surfactant Systems, Effect of Composition Changes, Effect of Composition and Temperature on Optimal Salinity, Thermodynamics of Micro emulsions, Applications of Surfactants: ,Applications of Surfactants: Detergency, Chemical Reactions in Micellar Solutions and Micro emulsions

UNIT 5: Interfaces in Motion: Stability and Wave Motion

Background ,Linear Analysis of Interfacial Stability , Differential Equations, Boundary Conditions, Stability Condition and Wave Motion for Superposed ,Characteristics of Wave Motion for Free Interfaces ,Damping of Capillary Wave Motion by Insoluble Surfactants, Characteristics of Wave Motion for Inextensible Interfaces, Instability of Fluid Cylinders or Jets, Oscillating Jet , Surface Tension of Oscillating Jets , Stability and Wave Motion of Thin Liquid Films: Foams and Wet ability, Stability of a Liquid Film, Energy and Force Methods for Thermodynamic Stability of Interfaces , Energy Method for Stability of Superposed Fluids , charged interfaces

UNIT 6: Interfacial Stability for Fluids in Motion: Kelvin-Helmholtz

Instability , Kelvin-Helmholtz Instability for Air-Water System , Peak Heat Flux ,Waves on a Falling Liquid Film, Wave Motion on Falling Water Film

UNIT 7: Transport Effects on Interfacial Phenomena

Interfacial Tension Variation, Interfacial Species Mass Balance and Energy Balance , Interfacial Instability for a Liquid Heated from Below or Cooled from Above ,Conditions for Development of Marangoni Instability, Interfacial Instability during Mass Transfer , Other Phenomena Influenced by Marangoni Flow, Non equilibrium Interfacial Tensions , Effect of Surfactant Transport on Wave Motion ,Stability of Moving Interfaces with Phase Transformation, Characteristics of Interfacial Instability during Solidification, Stability of Moving Interfaces with Chemical Reaction , Intermediate Phase Formation , Transport Related Spontaneous Emulsification , Interfacial Mass Transfer Resistance, Other Interfacial Phenomena Involving Dispersed Phase Formation

UNIT 8: Dynamic Interfaces

Introduction , Surfaces , Basic Equations of Fluid Mechanics, Flow Past a Droplet , Asymptotic Analysis , Dip Coating, Spherical Drop Revisited , Surface Rheology, Drainage of Thin Liquid Films , Dynamic Contact Lines , Slip ,Thin and Ultrathin Films.

UNIT 9: Colloids in Drug Delivery

Surfactants and block copolymers in drug delivery, Application of colloids in drug delivery, Micelles: multifunctional nano-carrier for colloidal drug delivery, colloids in aerosol drug delivery systems, colloidal carrier for drug delivery in dental tissue engineering, classification and application of colloidal drug delivery system

Teaching Methodology:

This course is introduced to help students to learn about interfacial engineering. The entire course is broken down into following separate units: Fundamental of Interfacial Tension, Fundamentals of Wetting, Contact Angle, and Adsorption, Colloidal Dispersion, Surfactants, Interfaces in Motion: Stability and Wave Motion, Interfacial Stability for Fluids in Motion: Kelvin-Helmholtz, Transport Effects on Interfacial Phenomena, Dynamic Interfaces, and Colloids in Drug Delivery. 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 , Unit-4, Unit-5 & Unit-6 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-7, Unit-8 & Unit-9 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. Miller, C. A. and Neogi, P., 2008, "Interfacial Phenomena Equilibrium and Dynamic Effects", 2nd Ed., CRC, New York.
2. Saw, D. J., 2000, "Introduction to Colloid and Surface Chemistry", 4th Ed, Butterworth Heinemann, New York.
3. Fanun, M., 2010, "Colloids in Drug Delivery", CRC Press, Boca Raton.
4. Berg, J. C., 2009, "An Introduction to Interfaces and Colloids: The Bridge to Nanoscience", World Scientific.
5. Binks , B. P., 2006, "Colloidal Particles at liquid interface", Cambridge Uni. Press, USA

Title of Course: Advances in Process Control **Course Code: 14M1GCL233**
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 basic concepts of process control.
CO2	Understand the concepts of advanced controllers.
CO3	Describe the significance of SISO and MIMO.
CO4	Develop the expressions used in automatic controllers.
CO5	Apply the use of digital computers in field of process control.
CO6	Demonstrate the concept of ANN and Fuzzy Logic applied to chemical processes.

Course Contents

UNIT 1: Introduction to process control

Dynamic and steady state processes, development of block diagram and its reduction, PID control algorithm. routh stability criteria, bode plots, root locus

UNIT 2: Introduction to Advanced Controllers

Feed forward, ratio controller, cascade, controller, adaptive controller, inferential controller.

UNIT 3: SISO and MIMO

Review of Single Input Single Output (SISO) Control; Model Based Control; Multivariable control strategies Internal Model Control Preliminaries & Model Predictive Control; Model forms for Model Predictive Control.

UNIT 4: Automatic controllers

Analogue & digital signals, process actuators & control equipment; Electronic, Controllers, Operational amplifier, Electronic controller input & output, PID & on- off control models, Microprocessors, General architecture, Algorithms, Application in Chemical Process Control.

UNIT 5: Process control using digital computers

Characteristics & performance of control computer , signals –types, Signal transmission , Analog feedback control systems; The direct digital control concept, Advantages of DDC , Computer process interface for data acquisition & control , Computer control loops.

UNIT 6: ANN and Fuzzy Logic

Introduction to computer control using artificial neural network (ANN) & fuzzy logic applied to chemical processes. Examples of advanced control applied to a small unit in a process plant.

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: Introduction to process control, Introduction to Advanced Controllers, SISO and MIMO, Automatic controllers, Process control using digital computers, and ANN and Fuzzy Logic. 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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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, 1990, "Chemical Process Control", Prentice –Hall of India PvtLtd., New Delhi.
2. Peter Harriott, 1977, "Process control ", Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

Reference Books:

1. G.K.McMillan and D.M.Consdine, 1999, "Process/ Industrial Instruments and controls Handbook ", McGraw-Hill.
2. B.G.Liptak, "Instrument Engineer's Handbook"-Volume 1&2, CRC Press.
3. Emanule and S. Savas, 1965, "Computer Control of Industrial Processes", McGraw-Hill London.

Title of Course: Applied Optimization & Operations Research
Course Code: 14M1GCL234
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 basic concepts of Optimization techniques
CO2	Understand the applications of various optimization techniques in various chemical processes.
CO3	Describe the significance of mathematical programming.
CO4	Develop the expressions used in dynamic programming
CO5	Apply the use of Pert, and Cpm in evaluation of projects.
CO6	Demonstrate the concept of basic elements of the Quening model

Course Contents

UNIT 1: Optimization techniques

Function, Analysis and numerical methods for single variable and multivariable system, constrained optimization Problems

UNIT 2: Application of optimization

Heat transfer and energy conservation, Separation techniques, Fluid flow systems, Chemical Reactor design

UNIT 3: Mathematical programming

Introduction, Linear Programming, Solution by simplex method, Duality, Sensitivity analysis, Dual simplex method, Integer Programming, Branch and bound method, Integer Programming, Branch and bound method

UNIT 4: Dynamic programming

Elements of DP models, Bellman's optimality criteria, Recursion formula, solution of multistage decision problem by DP method

UNIT 5: Pert, Cpm

Network representation of projects, critical path calculation, construction of the time chart and resource levelling, Probability and cost consideration in project scheduling, Project control

UNIT 6: Elements of queuing theory

Basic elements of the Quening model, M/M/I and M/M/C Quenes

UNIT 7: Elements of reliability theory

General failure distribution, for components, Exponential failure distributions, General model, Maintained and non-maintained systems.

Teaching Methodology:
This course is introduced to help students to learn about Applied Optimization & Operations Research used in chemical plants. The entire course is broken down into following separate units: Optimization techniques, Application of optimization, Mathematical programming, Dynamic programming, Pert, Cpm, Elements of queuing theory, and Elements of reliability theory. 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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5, Unit-6 & Unit-7 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. Edgar, T.F. and D.M. Himmelblau, 1989, “Optimization of Chemical Processes ", McGraw Hill Book Co., New York.
2. Hamdej A. Taha, 1982, “Operations Research, an introduction ", Macmillan Publishing Co., Third Edition.

Reference Book:

1. Narayan Bhatt, 1972, “Elements of Applied Stochastic Processes ", John Wiley and Sons.

3rd Semester

Elective III

Title of Course: Petroleum Refinery Operations **Course Code: 14M1GCL331**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
The objective of this course is to trend the student about the origin and formation petroleum and petroleum products.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance of petroleum refining.
CO2	Understand the origin and composition of petroleum.
CO3	Describe the applications of various refinery products along with their feedstock.
CO4	Develop various techniques employed in the refining operations.
CO5	Apply various technologies such as catalytic cracking, coking, and other treatment processes to meet the specifications of the end product.
CO6	Demonstrate the complete working of a petroleum refinery.

Course Contents

UNIT 1: Petroleum Refining
Pre-treatment and Distillation, Stripping, Rerunning, Stabilization and Light End Removal, Super fractionation, Azeotropic Distillation and Extractive Distillation.

UNIT 2: Thermal Cracking
Introduction, Thermal Cracking, Visbreaking, Coking, Delayed Coking, Fluid Coking and Flexi coking

UNIT 3: Catalytic Cracking
Introduction, Fixed Bed processes, Moving Bed processes, Fluid Bed processes, Reaction chemistry of FCC, Mechanism and Kinetics, Process Variables: Feedstock Quality, Feedstock preheating, Feedstock Pressure, Feedstock Conversion, Reactor Temperature, Recycle Rate, Space Velocity, Catalyst Activity, Catalyst Oil Ratio, Regenerator Temperature, and Regenerator Air Rate, Catalysts for Cracking

UNIT 4: Hydro treating

Introduction, Hydrosulphurization: Process configuration, Reaction chemistry and Kinetics, Down flow Fixed Bed Reactor, Up flow expanded Bed Reactor, De-metallization Reactor (Guard Bed Reactor), Catalysts, Distillate Hydro-sulfurization, Residuum Hydro-desulphurization, Ultra low sulphur Diesel.

UNIT 5: Hydrocracking
Introduction, Processes and Process Design: Reaction chemistry and Kinetics, CANMET, Gulf HDS, H-G Hydrocracking, H-Oil. IFP Hydrocracking, Isocracking, LC fining, MAK, HDC, Microcat RC, Mild Hydrocracking, MRH, RCD, Unibon (BOC), Residfining, Residue Hydro conversion, Unicracking, Veba, Combi-Cracking.

UNIT 6: Next Generation Processes
Introduction, Thermal (Carbon Rejection) Processes: Asphalt Coking Technology Process, Comprehensive Heavy Ends reforming Refinery Processes, Deep Thermal Conversion Process, ET – II Process, Eureka Process, Fluid Thermal Cracking Process, High Conversion Soaker Cracking Process, Catalytic Cracking Processes: Asphalt Residue Treating Process, Heavy Oil Treating Process, Reduced Crude Oil Conversion Process, Residual Fluid Catalytic Cracking Process, Shell FCC Process, S&W Fluid Catalytic Cracking Process, Hydrogen Addition Processes, Asphaltenic Bottoms Cracking Process, Hydrovisbreaking (HYCAR) Process, Solvent Processes: Deasphalting Process, Deep Solvent Deasphalting Process, Demax Process.

UNIT 7: Product Improvement
Desulfurization and Heteroatom Removal: Hydrotreating, Hydrogen Sulphide Removal, Reforming: Thermal Reforming, Catalytic reforming, Dehydrogenation, Catalysts, Reformulated Gasoline and other oxygenates like MTBE and others.

UNIT 8: Isomerization, Alkylation and Polymerization
Process Types, Chemistry, Commercial Processes, Catalysts

UNIT 9: Hydrogen Production
Introduction, Feed stocks, Process Chemistry, Commercial Processes: Heavy Residue Gasification and Combined Cycle Power Generation, Hybrid Gasification Process, Hydrocarbon Gasification, Hydro Process, Shell Gasification (Partial Oxidation) Process, Steam Methane Reforming, Steam Naphtha Reforming, Synthesis Gas Generation, Texaco Gasification (Partial Oxidation) Process, Catalysts, Hydrogen Purification

UNIT 10: Alternative sources of Petroleum based applications
Hydrogen production and Fuel cells, Gas to Liquid Fuels, First & Second Generation Bio fuels.

Teaching Methodology:

This course is introduced to help students understand the basic structure of any petroleum refinery along with the various processes used in the refining of petroleum. The entire course is broken down into following separate units: Origin formation and composition of petroleum, Refinery products, Fractionation of petroleum, Treatment techniques, Petrochemicals feedstock. 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 & Unit-3
Test-2	25 Marks	Based on Unit-4 , Unit-5, Unit-6 & Unit-7 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-8, Unit-9 & Unit-10 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.B. Rao, "Modern Petroleum Refining Processes", Oxford & IBH Publishing Pvt. Ltd.
2. C.S. Hsu and P.R. Robinson, "Practical Advances in Petroleum Processing", Springer Publications.

Reference Books:

1. W.L. Nelson, "Petroleum Refinery Engineering", McGraw-Hill International.
2. G.N. Sarkar, "Advanced Petroleum Refining", Khanna Publishers.

Title of Course: Polymer Science & Engineering **Course Code: 14M1GCL333**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

In this course, the basic concepts of polymerization techniques, kinetics, several properties of polymers with structures and upcoming applications will be dealt with. The present course aims to help the students in selection of the polymerization technique, required by the industries. This course also gives and exposure to the students in the field of advancement of the course through projects related to recent research topics.

Learning Outcomes:

Course Outcome	Description
CO1	The outline, outcomes and attributes provide students with learning experiences that help in still deep interests in learning of Polymer Engineering. It develops broad and balanced knowledge and understanding of the Polymer Engineering concepts, principles, and theories.
CO2	Describe the real world problems, challenges in current scenario. It is micro-specialization paper for the Chemical Engineering students.
CO3	Develop in students the ability to apply the knowledge and skills they have acquired to the solution of specific theoretical and applied problems of the world.
CO4	Identify and use of various techniques for resolving the world problem and in project management.
CO5	Apply experimental demonstration and validation by using various techniques given in theorem, principles as explained in lectures.
CO6	Demonstrate students with the knowledge and skill base that would enable them to undertake further studies in the Polymer Engineering and related areas or in multidisciplinary areas that help develop a range of generic skills that are relevant to wage employment, self-employment and entrepreneurship.

Course Contents

UNIT 1: Introduction to Polymer science

Classification of polymers, polymer structure, molecular weight, chemical structure and thermal transition.

UNIT 2: Synthesis of Polymers

Step growth polymerization: condensation polymerization, non-condensation polymerization, kinetics of step growth polymerization, Chain growth polymerization: free radical polymerization & its kinetics, Anionic polymerization and its kinetics, Cationic polymerization and its kinetics, Copolymerization & its kinetics, Coordination polymerization and its kinetics.

UNIT 3: Polymerization Techniques
Bulk polymerization, solution polymerization, suspension polymerization & Emulsion polymerization

UNIT 4: Solution properties and molecular weight determination
Solution properties, membrane osmometry, vapor pressure osmometry, end group analysis, light scattering method, intrinsic-viscosity Measurement, sedimentation transport, gel-permeation chromatography.

UNIT 5: Solid-state properties of polymers
Amorphous state, chain entanglements & reputation, glass transition, crystalline state, crystalline melting temperature, crystallization kinetics, techniques to determine crystallinity.

UNIT 6: Thermal transition & properties
Fundamental thermodynamic relationship, thermal transition in polymeric material, determination of T_g by dilatometry and calorimetry.

UNIT 7: Mechanical properties
Test to determine mechanical performance in polymers, Static test: tensile, shear, Transient test: creep test, stress relaxation, impact & cyclic test.

UNIT 8: Viscoelasticity
Introduction to viscoelasticity, Dynamic-mechanical analysis, Mechanical models of viscoelastic behaviour.

UNIT 9: Polymer Rheology
Introduction to Polymer Rheology, Analysis of Simple Flows, Rheometry.

Polymer degradation, stability and environmental issues
Thermal degradation oxidative & UV-stability, management of plastics in environment.

Polymer additives
Fillers, plasticizers, stabilizers, colorants, flame retardant.

Commercial polymers
Thermoplastics, Thermosetting polymers, Elastomers, Vulcanization

Engineering and specialty polymers
Self-study

UNIT 10: Polymer processing

Extrusion, moulding, spinning calendaring, coating.

Teaching Methodology:
This course planned in 3 lectures each week. The course content divided in two 42 lectures. The lectures will be conducted in both manner white board and Power Point presentation. At the end of this course student will be able to understand the concept of Polymer Engineering and able to apply in further study and research.

Evaluation Scheme:

Exams	Marks	Coverage
Test-1	15 Marks	Based on Unit-1, Unit-2 & Unit-3
Test-2	25 Marks	Based on Unit-4, Unit-5, Unit-6 & Unit-7 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-8, Unit-9 & Unit-10 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. Fried, J.R., 1995, "Polymer Science and Technology", Prentice Hall of India, New Delhi.

Reference Books:

1. Bill Meyer, F. W. Jr, 1994, "Textbook of Polymer Science", 3rd Ed., John Wiley & Sons, New York.
2. Rudin, A., 1999, "Polymer Science and Engineering", 2nd Ed., Academic Press, USA.
3. Gowarikar, V.R., 1986, "Polymer Science", Ist Ed, New Age International (P), ltd.

Title of Course: Combustion Processes **Course Code: 14M1GCL334**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The purpose of this course is to provide theoretical knowledge about combustion process, flames and various combustion applications in process industries.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance of combustion
CO2	Understand different types of combustion processes.
CO3	Describe various types of flames produced during combustion.
CO4	Develop various models to describe different types of flames.
CO5	Apply principles of modeling in flames.
CO6	Demonstrate the use of combustion in Boilers and Furnaces.

Course Contents

UNIT 1: Combustion Fundamentals

Introduction, Energy Sources, Fuels, Fuel cells, Combustion Stoichiometry and Thermochemical Calculations, Chemical Kinetics and Equilibrium: Kinetic theory of gases, Chemical kinetics, Reaction kinetics, Equilibrium composition and temperature, Conservation, energy and equilibrium equations, Transport Phenomena, and Modelling of Real gases, Transport properties of multi-component mixtures, Combustion Generated Air Pollution, Pollutants Formation and Oxidation Kinetics, Pollutant Emissions Reduction Techniques.

UNIT 2: Laminar Premixed Flames

Introduction, Flammability limits, Laminar flame stabilization, Flame temperature, Burning velocity of a premixed flame, Stationary methods, Propagation methods, Ignition, Theory and Kinetics of laminar Premixed Flames, Simple Fuels – N_2-O_2 Flames, Hydrogen-oxygen-nitrogen flames, Hydrogen-H_2O-CO-O_2-N_2 flames, Methane-oxygen-nitrogen flames, Natural gas-air flames, Generalization of Flame Characteristics, Effect of Fuel Type and Additives on Emissions and Flame Characteristics.

UNIT 3: Turbulent Premixed and Diffusion Flames

Characteristics of Diffusion Flames, Turbulent Burning, Turbulence Models, Interaction between Turbulence and Chemical Kinetics, Flame Stabilization, Turbulent Premixed Flames

UNIT 4: Characteristics of Turbulent Confined Diffusion Flames

Mixing and Flow Fields of Jets, Swirling Flows in Combustion Systems, Flow and mixing in Cold Models, Characteristics of Confined Flames, Emission and Combustion Modelling in Flames.

UNIT 5: Combustion, Heat Transfer, Emission in Boilers and Furnaces
Steam Boilers, Tangentially-Fired Furnaces (TFFs), Fluidized-Bed Furnaces (FBFs)

Teaching Methodology:

This course is introduced to help students understand concepts of combustion in various chemical equipments. The entire course is broken down into following separate units: Combustion Fundamentals, Laminar Premixed Flames, Turbulent Premixed and Diffusion Flames, Characteristics of Turbulent Confined Diffusion Flames, and Combustion, Heat Transfer, Emission in Boilers and Furnaces. 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. Fawzy El-Mahallawy, Saad El-Habik Fundamental and technology of combustion: 2002, Elsevier.

Title of Course: Environmental Management **Course Code: 14M1GCL335**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide basic idea about the environmental pollution, their possible treatment methods and Conventional and non-conventional energy resources.

Learning Outcomes:

Course Outcome	Description
CO1	Outline different types of pollutants.
CO2	Understand the causes of pollution and their harmful effects.
CO3	Describe various sources of air and water pollutants.
CO4	Develop different methods for the management of solid, liquid and gaseous polutants
CO5	Apply appropriate techniques for the control of pollution in different fields.
CO6	Demonstrate the concept of Conventional and non-conventional energy resources

Course Contents

UNIT 1: Introduction to different types of pollution

Air, Water and soil and their local, regional and global aspects. Sampling and analysis techniques, Human population issues, Environmental ethics and environmental quality.

UNIT 2: Air pollution

Sources of air pollutants, their sources and behaviour in the atmosphere, Effects of air pollutants in humans, animals, plants and properties. Control approaches

UNIT 3: Water pollution

Sources, consequences, control of water pollution. Sources and nature of soil pollution and its harmful effects. Environmental problems associated with noise pollution, oil pollution and radioactive pollution.

UNIT 4: Solid waste

Sources and generation of solid waste, their nature and chemical composition. Their characterization and classification. Different methods of dispersal and management of solid wastes. Recycling of waste materials, Impact assessment, National and International regulations, ISO series.

UNIT 5: Conventional and non-conventional energy resources

Bio gas, Solar Power, wind power, life cycle analysis, Environmental audit, Sustainable development, Case studies

Teaching Methodology:

This course is introduced to help students understand concepts of environmental management. The entire course is broken down into following separate units: Introduction to different types of pollution, Air pollution, Water pollution, Solid waste, and Conventional and non-conventional energy resources. 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. Deneves, "Air Pollution Control Engineering", McGraw hill, 1999.
2. Jr. W.C. Blackman, "Basic Hazardous Waste Management", CRC Press.
3. K.L. Mulholland, J.A. Dye, "Pollution Prevention: Methodology, Technologies and Practices", Wiley.

Elective IV

Title of Course: Fluidization Engineering **Course Code: 14M1GCL332**
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	Outline about fluidization phenomena, fluidized beds, and their industrial applications.
CO2	Study laws and equations associated with packed bed.
CO3	Understand the fluidization in detail.
CO4	Explain bubble formation, heat & mass transfer in fluidized bed, and introduction to the design aspects of fluidized beds.
CO5	Application of fluidization in conveying.
CO6	Discuss about advanced fluidization.

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: Industrial Applications of Fluidized Beds

Coal Gasification, Gasoline from other Petroleum Fractions, Gasoline from natural and Synthesis Gases, Synthesis Reactions, Metallurgical and Other Processes, Physical Operations, Cracking of Hydrocarbons, Combustion and Incineration, Carbonization and Gasification and Reactions Involving solids, Bio-fluidization.

UNIT 3: 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 4: 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 5: 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 6: Flow Models for Bubbling Beds
General Interrelationship among Bed Properties, Simple Two-phase Model, K-L Model wit its Davidson Bubbles and Wakes

UNIT 7: High Velocity Fluidization
Turbulent Fluidized Beds, Experimental Findings, Fast Fluidization, The Freeboard Entrainment Model Applied to Fast Fluidization, Design Considerations, Pressure Drop in Turbulent and Fast Fluidization.

UNIT 8: Circulation Systems
Circuits for the Circulation of Solids, Finding Required Circulation Rates, Flow of Gas-Solid Mixtures in down comers: Downward discharge from a Vertical Pipe, Moving Bed Down flow, Fluidized Down flow, Fluidized Down flow in Tall Down comers. Flow in Pneumatic Transport Lines: Vertical Up flow of Solids, Horizontal Flow, Safe Gas Velocity for Pneumatic Transport, Pressure Drop in Pneumatic Transport, Pressure drop in Bends, Practical Considerations

UNIT 9: Design of Fluidized bed Reactors
Design of catalytic and non-catalytic fluidized bed reactors.

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, pneumatic and hydraulic conveying, three phase fluidization, and multistage fluidization. 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, Unit-4, Unit-5, & Unit-6 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-7, Unit-8 & Unit-9 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: Mutiphase Contactors **Course Code: 14M1GCL336**
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	Outline the importance Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

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.

UNIT 6: Model Description of Multiphase Processes
Governing Equations for State Variables of Each Phase, Dispersed Phase Modelling and Population Balance, Relationship between the Multi-stage Cell model and the Continuous model.

UNIT 7: Mechanical and Morphological Variety of Each Phase and Contacting Mode
Parameters Relations between Parameters, Behaviour of an Isolated Particle (Solid Particle, Bubble and Droplet), Behaviour of Multi-particle Systems, Behaviour of Solid Dispersed Systems, Mass Transfer Volumetric Coefficient and Gas Exchange Coefficient, eddy diffusivity, The importance of the State of the Interface.

UNIT 8: Concepts of Multiphase Reaction Processes
Alternatives to the State of the Interface, Systems with Flat Interfaces, Systems with One or More Phases Dispersed, Systems with Stabilized Dispersions, Systems with Forced Mechanical Dispersion, Contacting Systems with a Porous Material.

UNIT 9: Options for Reacting Systems and Reactor Structures
Batch/Semi-batch (Semi-continuous) / Continuous, Entrained Flow/Separate Flow, Complete Mixing / Incomplete Mixing / Plug Flow, Co-current/ Counter current /Cross Current, Uniform Reactions/Zone Reactions/Surface Reactions, Micro Mixing/Macro Mixing, and Molecular Diffusion/Eddy Diffusion, Statics/ Dynamics/ Stability.

UNIT 10: Development and Scale-Up of Multiphase Reactors
The Nature of Development and Scale-up Issues, Methodology of Development and Scaleup.

UNIT 11: Dynamics of the Gas-Liquid Suspended-solid Column
Introduction, Hydrodynamics, Gas, liquid , and solid holdups, Axial dispersion in the gas, liquid, and solid phases, Gas-liquid interface mass transfer, Liquid- sol id mass transfer, Wall mass transfer in the slurry column, Heat transfer.

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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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: 14M1GCL337**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

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 Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

Course Contents

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 Catalysed 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

UNIT 6: Preparation of Catalyst Supports and Zeolites
Introduction ,Preparation of Silica Gel Catalyst Supports , Preparation of Silica Gel , Preparation of Alumina Catalyst Supports , Preparation of and , Structure of And ,Zeolite Synthesis , Synthesis of Zeolite A , Synthesis of Zeolite Y , Synthesis of Mordenite , Synthesis of ZSM-5 , Catalyst Shaping: Introduction , Spray Drying ,Granulation , Pelletization , Extrusion , Oil-Drop Method/Sol-Gel Method .

UNIT 7: Preparation of Supported Catalysts
Introduction, Selective Removal, Application On A Separately Produced Support, Support Surface Chemistry, Impregnation, Deposition-Precipitation.

UNIT 8: Catalyst Characterization with Spectroscopic Techniques
Introduction ,Aim of Catalyst Characterization ,X-Ray Diffraction (XRD) ,Electron Microscopy ,Temperature Programmed Techniques ,Surface Spectroscopy ,Infrared Spectroscopy ,Extended X-Ray Absorption Fine Structure (Ems) ,Techniques , Mossbauer Spectroscopy.

UNIT 9: The Use of Adsorption Methods for the Assessment of the Surface Area and Pore Size Distribution of Heterogeneous Catalysts
Introduction ,Physical Adsorption, Adsorption Isotherms , Classification of Pore Sizes , Porosity of Porous Substances , The Yardstick In The Determination of Surface Areas , The Langmuir Adsorption Isotherm (Monolayer Adsorption) And The Bet Equation (Multilayer Adsorption) ,The Concept of A Standard Isotherm ; The T Method , Microporosity , Hysteresis Loops , The Corrected Kelvin Equation.

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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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.

4th Semester

Elective V

Title of Course: Process Engineering **Course Code: 14M1GCL431**
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 Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

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.

UNIT 4: Simulation to assist in process creation
Principles of steady state flow sheet – simulation, principles of batch process simulation

UNIT 5: 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 6: 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

UNIT 7: Synthesis of Separation Trains

Feed separation systems, phase separation of reactor effluent, industrial separation operations, criteria for selection of separation methods, selection of equipment, sequencing of ordinary distillation columns for the separation of nearly ideal fluid mixtures, Sequencing of operations for the separation of non-ideal fluid mixtures, separation systems for gas mixtures, separation sequencing for solid-fluid systems

UNIT 8: Heat and Power Integration

Minimum utility targets, networks for maximum energy recovery, minimum number of heat exchangers, threshold approach temperature, optimal approach temperature, Heat integrated distillation trains

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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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 operation processes
Course Code: 14M1GCL432
L-T-P Scheme: 3-0-0 **Course Credits: 3**
Course Objective
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 Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

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 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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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: 14M1GCL433**
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 Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

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, Fire fighting 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
HAZOP, HAZAN and such methods. Safety Review & other methods, examples. Safety Audit.

UNIT 6: Risk assessment
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.

UNIT 7: Accident investigations
Learning from accidents Methods of investigating and diagnosing. Aids for recommending case studies of well-known accidents such as Flixburough. Bhopal etc.

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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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.

Title of Course: Nanotechnology and applications **Course Code: 14M1GCL434**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
The aim of the course is to provide core aspects of the physical sciences which are relevant to nanotechnology e.g. Electronic, optical, magnetic, structural and chemical properties.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

Course Contents

UNIT 1: Introduction to nanotechnology
Definition, history of nanotechnology. Properties in nanoscale: Extensive and Intensive properties, change in physical properties like colour, melting point, electrical, magnetic, and mechanical. Crystal structure; free electron theory of metals; band theory of solids; metals and insulators; semiconductors: classification, electrons and holes, transport properties; size and dimensionality effects - quantum wells.

UNIT 2: Synthesis of nano materials
Synthesis of nano materials, different approaches of synthesis (physical techniques and Chemical Techniques. Equipment and processes needed to fabricate nano devices and structures.

UNIT 3: Thin Films and Thick Films
Deposition of thin film and thick films, Physical vapour Deposition (PVD) and Chemical Vapour Deposition

UNIT 4: Characterization techniques of nano-materials
SEM, STM, AFM, XRD etc. Electronic, Magnetic, Optical, Chemical and Mechanical properties of nano materials.

UNIT 5: Applications of different nano-materials in Chemical and Environmental engineering
Discovery, preparation, properties, applications of carbon nanotubes. Inorganic nanowires, Biological and bio-inspired materials, Metallic nano materials, Different shape nano materials.

Nanomaterial based biosensors: bio functionalization of nano materials, advantages over other sensors, Field effect transistor based biosensors. Application in cholesterol, blood sugar, single virus detection: Semiconductor nanoparticles and Quantum dots. Application of quantum dots. Application of nanoparticles in catalysis.

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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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. Introduction to Nanotechnology, Poole, Charles P. Owens, Frank J., New York: John Wiley & Sons, 2003. Nanotechnology basic science and emerging technologies by Kannangar, UNI of NSW Press.
2. M.Di Ventra, S.Evoy and Jr. J. R. Heflin, Introduction to Nanoscale Science and Technology, (Eds.), Springer, 2004.
3. Jr. C. P. Poole, F. J. Owens, Introduction to Nanotechnology, Wiley, 2003.

Title of Course: **Energy Management and Audit** **Course Code:** 21M1GCL438

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

Course Objective

The course discusses about the energy scenario, energy conservation and its importance, energy strategy for the future, energy conservation act-2001 and its features, Kyoto protocol and global warming. The students would learn about the concepts of energy management & audit.

Learning Outcomes:

Course Outcome	**Description**
CO1	Students will be able to understand the current energy scenario along with energy management and strategies.
CO2	Students will be able to take action on energy planning.
CO3	Students will acquire the knowledge of financial management.
CO4	Students will be able to analyze the data for energy monitoring and targeting.
CO5	Student will be able to analyze project management.
CO6	Student will be able to perform energy audit.

Course Contents

Unit – 1: Energy Scenario

Commercial and Non-Commercial Energy, Primary Energy Resources, Commercial Energy Production, , Energy Needs of Growing Economy, Long Term Energy Scenario, Energy Pricing, Energy Sector Reforms, Energy and Environment: Air Pollution, Climate Change, Energy Security, Energy Conservation and its Importance, Energy Strategy for the Future, Energy Conservation Act-2001 and its Features. Kyoto Protocol. Global warming.

Unit – 2: Energy Management & Audit

Definition, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments.

Unit – 3: Energy Action Planning

Key elements, Force field analysis, Energy policy purpose, perspective, Contents, Formulation, Ratification, Organizing - location of energy management, Top management support, Managerial function, Roles and responsibilities of energy manager, Accountability. Motivating-motivation of employees: Information system designing barriers, Strategies; Marketing and communicating-training and planning.

Unit – 4: Financial Management

Investment-need, Appraisal and criteria, Financial analysis techniquesSimple pay back period, Return on investment, Net present value, Internal rate of return, Cash flows, Risk and sensitivity analysis; Financing options, Energy performance contracts and role of ESCOs

Unit – 5: Project Management

Definition and scope of project, Technical design, Financing, Contracting, Implementation and performance monitoring. Implementation plan for top management, Planning Budget, Procurement Procedures, Construction, Measurement & Verification.

Unit – 6: Energy Monitoring and Targeting

Defining monitoring & targeting, Elements of monitoring & targeting, Data and information-analysis, Techniques -energy consumption, Production, Cumulative sum of differences (CUSUM).

Teaching Methodology:
This course is introduced to help students understand in detail the advanced concepts of energy management. The entire course is broken down into following separate units: energy scenario, energy management and audit, energy action planning, financial management, project management and energy monitoring and targeting. 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 ,Unit-4, and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5, Unit - 6 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. Capehart, Barney L., Wayne C. Turner and William J. Kennedy, “Guide to Energy Management” , Third Edition, Fairmont Press, Atlanta, GA, 2000

2. Albert Thumann and D. Paul Mehta “Handbook of Energy Engineering”, by. 4th ed. Lilburn, GA: Fairmont Press; 1997

3. Loftness, Robert L. “Energy Handbook.” 2d ed. New York: Van Nostrand Reinhold Co., 1984.

Reference Books:

1. Turner W. “Energy Management Handbook”, Ed., John Wiley &. Sons, New York, 1982

2. Lapedes, DN “Encyclopedia of Energy”, McGraw-Hill, New York, (1976).

Elective VI

Title of Course: Advanced Process Synthesis **Course Code: 14M1GCL435**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective
This course deals with detailed synthesis of process flow sheets using computational packages like CHEMCAD, ASPEN PLUS etc. It also deals with optimization of process flow sheets and control analysis.

Learning Outcomes:

Course Outcome	Description
CO1	Outline the importance Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

Course Contents

UNIT 1: Heuristics for Process Synthesis
Objectives, Introduction, Raw Materials and Chemical Reactions, Distribution of Chemicals: Inert species, purge streams, recycle to extinction, selectivity, Reactive Separations, Optimal conversion, Separations: separation involving liquid and vapor, mixtures, separation involving solid particles, heat removal from and addition to reactors, heat exchanger and furnaces, pumping, compression, pressure reduction, vacuum, and conveying of solids, changing the particle size of solids and size separation of particles, removal of particles from gases and liquids.

UNIT 2: Reactor Design and Reactor Network Synthesis
Reactor design for complex configuration, reactor network design using the attainable region, construction of the attainable region, the principles of reaction invariants.

UNIT 3: Synthesis of separation trains
Sequencing of operations for the separation of non-ideal fluid mixtures, Heuristics for determining favourable sequences, complex and thermally coupled distillation columns, sequencing of operation for the separation of Non ideal fluid mixtures: azeotropy, residue curves, computing azeotropes for multi component mixtures, heterogeneous distillation, pressure swing distillation, membranes, absorbers, auxiliary separators, reactive distillation, separation train synthesis, Separation systems for gas mixtures, separation sequencing for solid-fluid systems.

UNIT 4: Reactor- separator-recycle networks

Introduction, locating the separation section with respect to the reactor section, trade off in processes involving recycle.

UNIT 5: Heat and Power Integration

Network for maximum energy recovery: mixed integer linear programming, Minimum number of heat exchangers: stream splitting, Optimal temperature approach, superstructures for minimization of annual costs, Heat integrated distillation trains: impact of operating pressure, multiple effect distillation, heat engines and heat pumps: positioning heat engines and heat pumps, optimal design.

UNIT 6: Mass Integration

Introduction, minimum mass separating agents: approach to phase equilibrium, concentration interval method, composite curve methods, mass exchange networks for minimum external mass separating agents, minimum number of mass exchangers, breaking mass loops.

UNIT 7: Optimization of process flow sheets

Introduction, general formulation of the optimization, classification of optimization problems, linear programming, nonlinear programming, optimization algorithm, flow sheet optimization: case studies.

UNIT 8: Integration of process design and process control

Introduction, control system configuration, classification of process variables, selection of controlled output variables, selection of manipulated variables, selection of measured variables, degree of freedom analysis, qualitative plant wide control system, qualitative plant wide control system synthesis.

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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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. Seider, W. D., Seader, J.D. ,Lewin, D. R., Widagdo, S., 2008, "Product & Process Design Principles Synthesis Analysis & Evaluation", 3nd Ed., John Wiley & Sons, New York.

Reference Books:

1. Rudd, D.F., Powers, G.J., and Siirola, J.J., 1973, "Process Synthesis", Prentice Hall, Englewood Cliffs, N.J...
2. Floudas, C.A., 1995, "Nonlinear and Mixed Integer Optimization: Fundamentals and Applications", Oxford University Press, New York.
3. Shenoy, U.V., 1995,"Heat Exchange Network Synthesis: Process Optimization by Energy and Resource Analysis", Gulf Publishing Company, Houston, Texas.
4. Douglas, J.M., 1988, "Conceptual Design of Chemical Processes", 1st Ed, McGrawHill, New York.
5. Kumar, A., 1981, "Chemical Process Synthesis & Engineering Design", McGraw-Hill, New Delhi
6. Rudd, D. F. and Watson, C.C., 1968, "Strategy of Process Engineering", John Wiley& Sons, New York.
7. Murphy, R., 2005, Introduction to Chemical Processes: Principles, Analysis, Synthesis", 1st Ed, McGraw-Hill, New York.
8. Smith, R. M., 2005, "Chemical Process Design & Integration", John Wiley & Sons, New York.
9. 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: Bioprocess Principles **Course Code: 14M1GCL436**
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 Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

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 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 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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: 14M1GCL437**
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 Process modeling and optimzation
CO2	Understand different types mathematical modeling.
CO3	Describe the simulation processes and techniques.
CO4	Develop various optimization techniques
CO5	Apply principles of optimization techniques to single and multi variable.
CO6	Demonstrate the complete optimization and simulation of chemical process plants.

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

UNIT 6: Economics of Bio separation Processes
Drugs Market and Sales, Applications of Models and Flow Sheets in Bio separation Economics.

Evaluation Scheme:

Exams	**Marks**	**Coverage**
Test-1	15 Marks	Based on Unit-1, Unit-2
Test-2	25 Marks	Based on Unit-3 & Unit-4 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-5 & Unit-6 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 Technology **Code:** 21M1GCL439

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

Course Objective

The purpose is to familiarize the students with basics of cement raw materials , raw mix design, clinker manufacturing technologies, cement types, energy trends and waste utilization in cement.

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:DIMENTIONS OF CEMENT INDUSTRY

Indian cement industry, benchmarks with respect to thermal and electrical energy consumption, various groups and cement companies in India, world scenario. Future prospects of cement industry.

Unit 4: 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 5: MINING OF LIMESTONE

Geological assessment of limestone deposits and various methodologies used for limestone mining and haulage of limestone. Safety in mining operations, mines rehabilitation.

Mining techniques: Blasting, ripping and surface mining and different methods used for limestone haulage: usage of dumpers, belt conveyors and rope ways.

Unit 6: SIZE REDUCTION

Size reduction machinery: crushers such as Jaw crusher, gyratory crushers, impact crushers, roll crushers and cone crushers; Grinders such as hammer mills, ball mills, roll presses & vertical roller mills.

Unit 7: MATERIAL HANDLING

Various material handling equipments used in cement plants. Mechanical and pneumatic equipments and their energy requirements. Logistic arrangements for cement transportation and storage of cement, precautions during transportation and storage of cement.

Unit 8:BLENDING AND HOMOGENIZATION

Pre-blending of limestone, various types of stackers and reclaimers. Homogenization of raw meal in silo: batch blending and continuous homogenization.

Unit 9: CEMENT CLINKER

Clinker minerals, absorption of various constituents in phases. Bouge's calculation, phase diagrams. Polymorphs of alite and belite.

Unit 10: FORMATION OF CLINKER MINERALS

Chemical reactions during clinkerization, role of minor constituents in clinkerization, thermochemistry of clinker formation. Microscopic examination of cement minerals.

Unit 11: TYPES OF CEMENTS

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

Unit 12: QUALITY CONTROL IN CEMENT

Sample collection, Quality control procedure, requirements of scheme of testing and inspection. Sample collection techniques: auto samplers and robotic control in cement plants, sample preparation. Quality control points and quality norms at various stages. Quality control norms mentioned in scheme of testing and inspection defined by Bureau of Indian Standards.

Unit 13: ENERGY TRENDS AND WASTE UTILIZATION IN CEMENT

Basic concerns, energy economy, energy audit, conservation of natural resources, usage of industrial wastes for cement manufacture. Usage of alternative fuels and technological advancements.

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-1to Unit-4
Test-2	25 Marks	Based on Unit-5 to Unit-8 and around 30% from coverage of Test-1
Test-3	35 Marks	Based on Unit-9 to Unit-13 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

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