## National Institute of Technology, Raipur (C.G.)

### Department of Chemical Engineering

#### Course of Study

<table>
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<th>S.No.</th>
<th>Board of Studies</th>
<th>Sub. Code</th>
<th>Subject Name</th>
<th>Periods/week</th>
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**Total** 15 5 6 250 75 75 500 100 1000 24

**List of Elective**-
1. Experimental & Analytical Methods in Chemical Engineering CL41131(CL)
2. Alternative Energy Sources CL41132(CL)
3. Polymer Technology CL41133(CL)
4. Microelectronics fabrication CL41134(CL)
5. Membrane Technology CL41135(CL)
### Course of Study

#### M. Tech.: Chemical Engineering

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**List of Elective**
- 1. Advanced Process Modeling & Simulation CL41231(CL)
- 2. Advanced Environmental Engineering CL41232(CL)
- 3. Nano Technology CL41233(CL)
- 4. Operation Research CL41234(CL)
- 5. Process Intensification CL41235(CL)
### National Institute of Technology, Raipur (C.G.)

#### Department of Chemical Engineering

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<th>M. Tech.: Chemical Engineering</th>
<th>Third Semester</th>
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### National Institute of Technology, Raipur (C.G.)

#### Department of Chemical Engineering

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<th>Course of Study</th>
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Details of Course:

Prerequisite:
Concepts of binary distillation and diffusion along with basics in chemical thermodynamics

Course objectives:
To provide advanced knowledge of separation processes. Student will have knowledge of multicomponent distillation and diffusion. Also the student shall be able to discuss about industrial membrane processes.

Unit I
Multi-component Distillation column Design: Selection of two key components, number of plates, minimum number of plates, feed plate locations, minimum reflux ratio, Lewis Sorel’s method, Underwood’s equation.

Unit II
Multi-component diffusion: Maxwell’s law of diffusion, regular and random surface renewal theory, mass transfer and chemical reaction – steady state and unsteady state, film-penetration theory, interfacial turbulence.

Unit III
Diffusion-Eddy transfer Mixing length and eddy kinematics viscosity, universal velocity profile, the turbulent core, the laminar sub-layer, the buffer layer, velocity profile for all regions, velocity gradients, laminar sub-layer and buffer layer thickness.

Unit IV
Introduction to membrane separation processes: Classification of membrane processes, general membrane equation, membrane materials and membrane modules.

Unit V

Name of Text Books and References
Prerequisite:
Fluid mechanics, heat transfer, mass transfer, numerical methods, mathematics, chemical process calculations, computer languages and codes, modeling and simulation, physics, chemical reactors and chemical reaction engineering, mixers etc.

Course objectives:
The course is an advanced course to transport phenomenon where the students shall be made to solve the various physical problems of both laminar and turbulent flows to be solved by numerical methods. The equations of change shall be transformed in the light of assumptions and solved under the suitable boundary conditions to obtain the differential equation. The solution of differential equation by hand is not practical and hence come the need to discretize these equations to algebraic forms. The algebraic form of equation shall have to be solved on the space using finite difference or finite volume which shall be done through the window of CFD. CFD meshing, design and solution strategy shall be taught to the students to get the problems solved and this shall be called as numerical experiments. Thus the course aims to learn the practical behavior and solutions of problems of Chemical Engineering using solution of equation numerically.

Details of Course:

Unit I
Introduction: Basic principles and equations of change in transport of momentum, heat and mass; Equations of continuity, motion, mechanical energy, angular momentum, energy, and equation of continuity for multicomponent mixture

Unit II
Development of model equations for laminar flows: Flow of Newtonian and non Newtonian fluids, use of equation of change for developing equations for laminar flow in internal and external flows, boundary layer flows, flow in stirred tanks, flow in viscometers, flow in pipe line and over flat plates and other physical situations for both Newtonian and Non-Newtonian fluids

Unit III
CFD: Philosophy of computational fluid dynamics CFD, grid generation, structured and unstructured grids, choice of suitable grid, grid transformation of equations, some modern developments in grid generation for solving engineering problems, CFD essentials.

Unit IV
Numerical fluid flow and heat transfer: Finite difference method (FDM), finite volume method (FVM) and finite element method (FEM): Discretization of ODE and PDE, approximation for first, second and mixed derivatives, approximations of volume integrals, implementation of boundary conditions, discretization errors, applications to engineering problems.
Unit V
Special Topics: Modeling two dimensional flow over a flat plate for laminar and turbulent flow, steady two dimensional incompressible laminar flow between stationary plates, laminar flow past circular cylinder, steady state heat conduction across a infinite long solid slab, flow in stirred tanks, solution of Newtonian and Non-Newtonian fluid flows, heat transfer studies in various systems.

Name of Text Books and References
Details of Course:

Unit I
**Industrial reactors:** stirred tank reactors, tubular reactors, kilns and hearth furnaces, fixed and moving bed reactors, fluidized beds, multiphase reactors, special types of reactors. Isothermal reactor design: Design structure; scale up of liquid phase batch reactor to the design of CSTR, tubular reactors, pressure drop in reactors, reversible reactions, unsteady state operation of reactors, simultaneous reaction and separation.

Unit II
**Non-isothermal reactor design:**
Energy balance, non-isothermal CSTR and PFR at steady state, equilibrium conversion, Unsteady state operation, non-adiabatic reactor operation, multiple steady state.

Unit III
**Fluid particle reactions design:** Performance equations for uniform gas composition - particles of single size + plug flow of solids, particles of different but unchanging size + plug flow of solids, particles of different but unchanging size + mixed flow of solids, particles of different size + mixed flow of solids, application to fluidized bed with entrainment of solid fines.

Unit IV
**Fluid - Fluid reactions design:** Towers for fast reactions- mass transfer with and without reaction, Towers for slow reaction, mixer settlers, semi-batch contacting patterns, reactive and extractive reactions.

Unit V
**Solid catalyzed reaction design:** Design of staged adiabatic packed bed reactors, Design of fluidized bed reactors. Scaling up test results: method of scale up and blow up, similitude.
Name of Text Books and References

Prerequisite: - Nil

Course objectives:
1. To provide a fundamental understanding of the statistical analysis of the various experimental data, planning the experiments
2. To give an in depth knowledge on interpretation of data from various analytical techniques, and understand approaches for the validation of the results.
3. To impart knowledge to the students so that they get an understanding of selection of the proper analytical method for a given system
4. Students will be able to select and apply appropriate separation methods to the analysis of real world problems.

Details of Course:

Unit I
Mathematical statistics: Introduction, random sampling, point estimation of parameters, confidence intervals, acceptance sampling, goodness of fit, $\chi^2$ test, regression, fitting straight lines, correlation.

Unit II
Atomic spectroscopy: An introduction to spectrometric methods, optical atomic spectrometry, atomic absorption and atomic fluorescence spectrometry, atomic emission spectrometry, atomic mass spectrometry, atomic X-ray spectrometry.

Unit III
Molecular spectroscopy: An introduction to ultraviolet / visible molecular absorption spectrometry, molecular luminescence spectrometry, infrared spectrometry, Raman spectroscopy, NMR spectroscopy, molecular mass spectrometry, surface characterization by spectroscopy and microscopy.

Unit IV
Separation Methods: An introduction to chromatographic separations, gas chromatography, high performance liquid chromatography, supercritical fluid chromatography and extraction, capillary electrophoresis, capillary electrophromatography.

Unit V
Electroanalytical chemistry and miscellaneous methods: Introduction to electroanalytical chemistry, potentiometry, coulometry, voltammetry, thermal methods, radiochemical methods, particle size analysis.

Name of Text Books and References
Name of Department: Chemical Engineering Department
Semester: M.Tech.- First Semester
Subject Code: CL41132 (CL)  
Course Title(Elective): Alternate Energy Sources

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Exam. Time: 3 hrs

Prerequisite:
Basic knowledge of energy, its types and basics about renewable energy. Applied Physics, Applied Chemistry.

Course objectives:
The major goal of this course is to provide fundamental knowledge that will help students understand and analyze problems with various practices of alternate energy production and use, and to evaluate the feasibility of possible solutions to these problems and also to:
1. Understand the difference between conventional and alternate energy sources and identify and distinguish between different forms of alternate energy.
2. Understand the advantages and limitations of different alternate energy sources and identify a wide variety of applications for alternate energy.
3. Understand the basic as well as advanced scientific and technical principles behind large-scale applications of alternate energy.
4. Identify selected political, social, and economic incentives that would accelerate the implementation of alternate energy.

Details of Course:

Unit I
Energy Scenario and Development: Overview of world and India’s energy scenario, energy and development linkage, energy sources: classification of alternate energy sources, future energy systems, clean energy technologies, renewable energy sources. Fuel cell: Principle of working, basic thermodynamic and electrochemical principles, classifications, applications of fuel cell for power generations.

Unit II
Bio-energy: Overview of biomass as energy source, biomass conversion routes: biochemical, chemical and thermo chemical, anaerobic digestion, biogas production mechanism, digesters, biogas plants, biogas utilization and storage, liquid biofuel, biodiesel, gasohol, chemical conversion of biomass for energy production, hydrolysis and hydrogenation, synthesis of biofuel, bio-refinery, thermo-chemical conversion of biomass, pyrolysis, carbonization, charcoal (biochar) production, biomass gasification, energy plantation, waste to energy.

Unit III
Nuclear and Magneto-hydro-dynamic (MHD) Energy: Nuclear fission and nuclear fusion, nuclear power plants, magneto-hydro-dynamic (MHD) energy conversion, electrochemical energy, batteries, role of carbon nanotubes in electrode, magnetic and electric storage system, super conducting magnetic energy storage (SMES) systems, capacitor and super capacitor.

Unit IV
Other Alternative Energy Sources: Advance and recent developments in other alternative energy sources. Hydrogen energy, basics of hydrogen energy, production methods, storage and transportation and applications, solar energy, wind Energy, geo-thermal energy, ocean energy, wave energy conversion, tidal energy conversion, geothermal Energy.
Unit V

Socio-economical Aspects of Energy Resources: Energy use & climate change, green house gas emission and carbon credit, impacts, mitigation, global warming, sustainability issues of energy use, rural development, poverty alleviation, employment; security of supply and use, environmental and ethical concerns, international treaties & convention on environmental mitigation, environmental laws on pollution control, energy audit.

Name of Text Books and References
Prerequisite:
Basic knowledge on polymerization reactions and structure of long chain molecules. Fundamental idea about chemical bondings and forces. General physical and chemical characteristics/properties of the materials.

Course objectives:
To get the basic concepts of polymers such as types, structure, forces, thermal transition and bonding in polymers.
To develop the deep knowledge on Polymer preparation and various methods of processing.
To give knowledge on properties and characterization techniques of polymers.
To learn about Polymer additives, blends and composite.
To address the developments in polymer processes, management and applications of polymers.

Details of Course:

Unit I
Introduction to polymers: Basic concepts and definitions, classification of polymers, polymer structure, molecular forces and chemical bonding in polymer, molecular weight and its distribution, chemical structure and thermal transition.

Unit II
Polymer preparation and processing methods: Step-reaction (condensation) polymerization, radical chain (addition) polymerization, ionic and coordination chain (addition) polymerization, copolymerization, polymerization conditions and polymer reactions. Various polymeric processing methods.

Unit III
Polymer characterization: Characterization - molecular weight and molecular size determination, thermoanalytical methods of characterization including TGA, DTA, and DSC; spectroscopy (IR, NMR, UV-visible) of polymers. Properties – solution properties, mechanical properties and polymer viscoelasticity.

Unit IV
Polymer additives, blends and composites: Additives – plasticizers, fillers and reinforcements, other important additives. Polymer blends and interpenetrating networks - polymer blends, toughened plastics and phase-separated blends, interpenetrating network. Introduction to polymer composites – Mechanical properties, composite fabrication.

Unit V
Specific topics in polymer technology: Biodegradable polymers, Scale up of polymerization processes, recent developments in polymer processes, applications of the polymers in various fields, management of polymeric products in the environment.
Name of Text Books and References
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**Examination Time**: 3 hrs

**Prerequisite**: Nil

**Course objectives**:
1. Gives a basic understanding on operating principles of electronic and optical devices, the process of semiconductor chip fabrication.
2. Give an in-depth knowledge on various steps in integrated chip manufacturing processes.
3. To encourage the students to pursue for a career in semiconductor processing facilities / research works.

**Details of Course**:

**Unit I**
**Overview and materials**: Unit processes and technologies, semiconductor substrates, phase diagrams and solid solubility, crystallography and crystal structure, crystal defects, Czochralski growth, float zone growth, Bridgman growth of GaAs, wafer preparation and specifications.

**Unit II**
**Hot processing and ion implantation**: Diffusion, atomistic models of diffusion, analytic solutions of Fick’s law, corrections to simple theory, analysis of diffused profiles, thermal oxidation, the deal-grove model of oxidation, the linear and parabolic rate coefficients, oxide characterization, the effects of dopants during oxidation and polysilicon oxidation, ion implantation, coulomb scattering, shallow junction formation, rapid thermal processing, rapid thermal activation of impurities, rapid thermal processing of dielectrics.

**Unit III**
**Pattern transfer**: Optical lithography, lithography overview, diffractions, advanced mask concepts, photoresists, photoresist types, organic materials and polymers, non-optical lithographic techniques, vacuum science and plasmas, etching, wet etching, chemical mechanical polishing, reactive ion etching.

**Unit IV**
**Thin films**: Physical deposition – evaporation and drying, sputtering high density plasma sputtering, chemical vapor deposition, metal chemical vapor deposition, epitaxial growth, metal organic chemical vapor deposition.

**Unit V**
**Process integration**: Device isolation, contacts, metallization, CMOS technologies, GaAs technologies, silicon bipolar technologies, MEMS, integrated circuit manufacturing, introduction to devices and integrated circuit formation, introduction to integrated circuits, packaging.

**Name of Text Books and References**
Prerequisite:
Fundamental principles of mass transfer operations, understanding of various driving forces of mass transfer. Basic knowledge on modelling equations, determination of rate equations, design of batch and continuous reactors.

Course objectives:
To provide a compact, intensive, hands-on introduction with engaging assignments and activities to membrane technology.
To learn the principles of membrane technology and engineering aspects of membrane separation processes, including gas permeation, pervaporation, reverse osmosis, ultrafiltration, microfiltration, and dialysis.
To provide the knowledge on mechanisms of transport in membranes, and design and modelings of membrane processes.
To teach the current trends and future directions of membrane technology.

Details of Course:
Unit I
Fundamentals of the membrane separation: Basic principles, classifications of membranes and its processes, membrane materials and properties, preparation and characterization of membranes.

Unit II

Unit III
Membrane reactor function and use: Membrane modules, flow patterns, concentration polarization, fouling and its control, industrial/commercial and environmental applications of membrane separation.

Unit IV
Important membrane separation processes and their modeling for Liquid and Gas streams: Reverse osmosis, nanofiltration, ultrafiltration, microfiltration, dialysis and electro dialysis. pervaporation and gas permeation.

Unit V
Specific Topics: Advancements in polymeric, nano-composite, ceramic, metal and liquid membrane process. future challenges and directions in membrane science and technology.

Name of Text Books and References
Details of Course:

**Prerequisite:**
Fluid mechanics, heat transfer, mass transfer, numerical methods, mathematics, chemical process calculations, computer languages and codes, modeling and simulation, physics, chemical reactors and chemical reaction engineering, mixers etc.

**Course objectives:**
The lab involved the numerical solution of some common problems of chemical engineering and aim to visualize the effect of various factors on the flow of heat and mass transfer.

**List of experiments**

2. Study of flow maldistribution in different shapes of headers.
3. Velocity boundary layer analysis of flow of fluid over a flat plate in laminar flow.
4. Study of laminar and turbulent flow in pipe line.
5. Modeling of forced convection in pipe line flows.
6. Study of flow of fluid over air foil and effect of angle of attack.
7. Modeling steady flow past cylinder and other geometries.
9. Study the effect of roughness in turbulent flow through pipe line.
10. Study of flow of fluid through a nozzle.
12. Modeling motion of sphere in cylinder falling under gravity.

**Software**
Ansys Fluent
Details of Course:

Prerequisite:
A basic course in chemical reaction engineering which is part of a bachelor program in chemical engineering. Principles of chemical reactor analysis and design. Experimental determination of rate equations, design of batch and continuous reactors.

Course objectives:
To provide a core foundation for the analysis and design of chemical reactors
To learn about reaction kinetics for single, multiple, isothermal, non-isothermal reactions and reactor design procedures
To analyse the experimental results on the basis of theory taught in the introductory course in chemical reaction engineering

List of experiments

1. Kinetic study of dissolution of benzoic acid in batch reactor
2. Study of a non-catalytic homogeneous reaction in an isothermal batch reactor
3. To study a non-catalytic homogeneous reaction in a straight type plug flow reactor under ambient conditions
4. To study residence time distribution (RTD) in a CSTR
5. To study a non catalytic homogeneous second order liquid phase reaction in a CSTR
6. To study a non catalytic homogeneous reaction in a packed bed
7. Study a second order saponification reaction in a semi-batch reactor and to determine the reaction rate constant
8. Study of the hydrolysis of acetic anhydride or propylene oxide with water in presence of an acid catalyst (H₂SO₄) and to predict the degree of conversion from time-temperature data
9. To study a photo-catalytic reaction and the mineralization of industrial or synthetic effluents
## Details of Course:

### Prerequisite:

UG level chemical engineering thermodynamics, ordinary differential equations, UG level applied chemistry.

### Course objectives:

The objectives of this course are;

1. To provide students with tools in applying thermodynamics principles.
2. To predict physical phenomena and to solve engineering problems.
3. To teach the students how to use state equations for property calculation.
4. To define the basic activity coefficient models and to apply them and solve phase equilibria problems for vapor-liquid equilibrium (VLE), liquid-liquid equilibrium (LLE), solid liquid equilibrium (SLE), and solid-vapor equilibrium (SVE), as well as chemical reaction equilibrium.
5. To show how to use thermodynamics principles and concepts for the analysis of chemical processes.

### Unit I

**An Introduction to Vapour-Liquid Equilibria:** Qualitative behaviour of the vapour-liquid equilibria (VLE), Simple models for vapour - liquid equilibria: Raoult’s and Henry’s laws, Dew point and bubble point calculations, VLE by modified Raoult’s law and K-value correlations. Flash calculations.

### Unit II


### Unit III

Unit IV
**Chemical Reaction Equilibria:** The reaction coordinate, Multireaction stoichiometry, Application of equilibrium criteria to chemical reactions, The standard Gibbs energy change and equilibrium constant, Effect of temperature on the equilibrium constant, Evaluation of equilibrium constants, Relation of equilibrium constants to composition, Gas-phase and liquid-phase reactions, Equilibrium conversions for single reactions, Single phase reactions, Reactions in heterogeneous systems, Multireaction equilibria.

Unit V
**Topics in Phase Equilibria:** The gamma/phi formulation of VLE, VLE from cubic equations of state, Equilibrium and stability, Liquid-liquid equilibrium, Vapour-liquid equilibrium, Solid-liquid equilibrium, Osmotic equilibrium and osmotic pressure.

**Name of Text Books and References**
2. M. Modell and R.C Reid: Chemical Engineering Thermodynamics, Prentice-Hall.
3. S. I. Sandler: Chemical and Engineering Thermodynamics, Wiley and Sons.
Prerequisite:
A basic knowledge on the control system.

Course objectives:
1. To provide the students an in-depth knowledge on advanced control strategies.
2. To impart knowledge on theoretical analysis of complex processes, controller tuning and process identification.
3. Ability to analyze the sampled data control system and application of the same to some of the physical systems.
4. Details of Course: To give an understanding on multivariable control systems.

Unit I
Advanced control strategies, controller tuning and process identification: Cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control, controller tuning, tuning rules, process identification.

Unit II
Control valves and theoretical analysis of complex processes: Control valve construction, valve sizing, valve characteristics, valve positioned, control of a steam-jacketed kettle, dynamic response of a gas absorber, distributed-parameter systems.

Unit III

Unit IV
State-space methods: State-space representation of physical systems, state variables, transfer function matrix, transition matrix, multivariable control, control of interacting systems, stability of multivariable systems, decoupling, relative gain array.

Unit V
Model predictive control: Predictions for SISO models, predictions for MIMO models, model predictive control calculations, set-point calculations, selection of design and tuning parameters, implementation of MPC.

Name of Text Books and References
Prerequisite:
A basic knowledge on the three modes of heat transfer.

Course objectives:
1. To give an in-depth understanding of basic heat transfer principles to the students.
2. Ability to model multidimensional heat conduction processes, leading to a governing equation.
3. To provide an understanding of forced convection system principles and equations.
4. To give the students a feel of heat transfer applications in chemical engineering processes.

Details of Course:

Unit I
Conduction: General three dimensional differential equation of heat conduction, steady state systems without and with internal heat generation, systems with variable thermal conductivities, mathematical and graphical analysis of 2-D systems, electrical analog of 2-D systems, numerical relaxation methods for 2-D and 3-D systems.

Unit II
Transient heat conduction: Lumped systems, systems with finite surface and internal resistance, systems with negligible surface resistance; use of charts, numerical procedures and graphical solution of transient heat conduction.

Unit III
Forced convection heat transfer: Analytical and semi-analytical solution, equations for velocity and temperature distribution in vertical and horizontal planes for cylinders and spheres, physical significance of dimensionless groups with respect to momentum and energy equations.

Unit IV
Radiation: Radiation heat transfer concepts; angle factor calculations; network method of analysis of radiation exchange; radiation calculation through gas and vapors.

Unit V
Specific applications: Design of compact heat exchangers, heat transfer due to boiling, liquid metal heat transfer, pinch technology.

Name of Text Books and References

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<th>Name of Department</th>
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<td>Course Title(Elective):</td>
<td>Advanced Process Modeling &amp; Simulation</td>
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<td>(Min. Pass Marks: 40)</td>
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Details of Course:

Prerequisite:
Mathematics, chemical reaction engineering, mass transfer, heat transfer, fluid flow, control.

Course objectives:
Apply the knowledge of mathematics in solving engineering problems

Details of Course:

Unit I

Unit II

Unit III
Modeling and simulation of unsteady and steady state heat transfer processes: Shell and tube heat exchanger, multiple effect evaporators, condenser.

Unit IV
Modeling and simulation of mass transfer operations I: Modeling and simulation of unsteady and steady state distillation, flashing processes.

Unit V
Modeling and simulation of mass transfer operations II: Modeling and simulation of unsteady and steady state drying, extraction and absorption processes.

Name of Text Books and References
Prerequisite:
Basic knowledge of environmental engineering, chemical engineering unit operations, unit process and chemical kinetics, mathematical knowledge of solving matrices and differential equations.

Course objectives:
To impart in-depth knowledge of environmental engineering calculations and design.
To impart step by step, practical calculation procedures in different areas of environmental engineering.
To integrate regulatory requirements into environmental designs.

Details of Course:
Unit I

Unit II
Physico-chemical waste water treatment: Waste Water Treatment Systems, Screening Devices, Comminutors, Grit Chamber, Flow Equalization, Sedimentation, Primary Sedimentation Tanks, Coagulation, Electrocoagulation

Unit III

Unit IV


Unit V
Name of Text Books and References

NATIONAL INSTITUTE OF TECHNOLOGY, RAIPUR

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<tr>
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**Prerequisite:**
Knowledge of basic sciences, application of mass transfer and heat transfer

**Course objectives:**
To prepare, characterize various nano metarials and its application in various fields.

**Unit I**
**Introduction to nanotechnology:** background, definition, basic ideas about atoms and molecules, physics of solid state, review of properties of matter and quantum mechanics.

**Unit II**
**Preparation of nano materials:** Preparation of Nanostructured Materials, Lithography, nanoscale lithography, E-beam lithography, dip pen lithography, nanosphere lithography. Sol gel technique Molecular synthesis, Selfassembly, Polymerization,

**Unit III**
**Characterization of nano materials:** Characterization of Nano-structured materials. Cross-cutting, nano materials in heat and mass transfer applications, Molecular electronics, Nanophotonics

**Unit IV**

**Unit V**
**Emerging trends in applications of nanotechnology:** Industrial applications of Nanotechnology: Development of carbon nanotube based composites. Nanocrystalline silver Antistatic conductive coatings, nanometric powders, sintered ceramics, nanoparticle ZnO and TiO₂ for sun barrier products, quantum dots, sensors, molecular electronics, other significant implications

**Name of Text Books and References**
Details of Course:

Prerequisite:
Mathematics, basic chemical engineering, basic management

Course objectives:
Application of various optimization techniques in chemical engineering problems.

Unit I

Unit II

Unit III
Transportation problem: North – West corner rule and Vogel's approximation method to find optimal basic feasible solution, Modi method.

Unit IV
Assignment problem: Characteristics of M/M/1/∞, M/M/1/K and M/M/c/∞ queuing models in the steady-state. Introduction to the inventory problem: Deterministic and probabilistic models.

Unit V
Introduction to network construction: CPM/PERT techniques, critical path method(CPM), determination of critical path (Labeling Method), the project evaluation and review Technique(PERT), probability considerations in PERT, distinction between PERT and CPM, project cost, time-cost optimization algorithm.

Name of Text Books and References
Prerequisite:
Fluid mechanics, heat transfer, mass transfer, chemical reactors and chemical reaction engineering.

Course objectives:
The course is an advanced course to chemical engineering and do consider as the advancement of the chemical engineering field in the last many decades. Here the history of the chemical systems such as reactors, columns, chambers etc is focused to see what is prevalent in the industry till date and how could once look for the intensification of the existing either through modification or change. The reluctance of change is the major reason of emergence of change in any system and so is in chemical engineering, however there is scope in latest technologies which needs to be highlighted. So learn the birth of process intensification where the advances system of momentum, heat and mass transfer are discussed in the five units of this course. The student shall learn about how could once provided a technology which is cheap, safe and clean compared to the conventional.

Details of Course:
Unit I
History, philosophy and principles of process intensification (PI): Introduction, philosophy and opportunities of PI, Types of PI equipments - Equipments and methods.

Unit II
High gravity in chemical processing: Historical development, fundamentals, mechanical design, applications, scale-up and commercial use, future, rotation packed bed, spinning disc reactor.

Unit III
Multifunctional heat exchanger: Introduction, compact heat exchanger technology, single phase flow, heat transfer and mass transfer, applications.
Micro-reaction technology: Microtechnology, effect of miniaturization, microfabrication, implementation.

Unit IV
Structured catalysis and reactors: Introduction, overview of structured reactors, gas phase reactions, multiphase reactions.
Inline and high intensity mixers: Importance of mixing, motionless mixers, mixing concepts, mixing performance in inline mixers, design guidelines and correlations.

Unit V
Reactive and hybrid separations: Reactive distillation, membrane based reactive separations, reactive extraction, reactive crystallization, reactive absorption, extractive distillation, adsorptive distillation, membrane distillation, membrane chromatography, membrane extraction.
Process intensification industrial practice: Positive results on PI on various aspects, PI methodology, Case studies.
Name of Text Books and References
Prerequisite:
Basic knowledge on water, soil, air and noise pollution. International and national standards and acts for water and air quality. Fundamentals of water and wastewater treatment and, water pollutants.

Course objectives:
- To analyse the experimental results on the basis of theory taught in the introductory course of environmental engineering.
- To learn the various wastewater treatment techniques.
- To get knowledge on water, wastewater, soil and air quality standards.
- To know the various analytical methods available for wastewater treatment.
- To learn fundamentals of water chemistry.

List of experiments

1. Determination of the turbidity, electrical conductivity and pH of the given water sample.
2. Determination of optimum coagulant dosage for given water sample using Jar Test Apparatus.
3. Determination of acidity, alkalinity and types of hardness in given water sample.
4. Determination of various types of solids in the given water sample.
5. Determination of sulphate and sulphide in the given water sample.
7. Determination of C.O.D. in the given water sample.
8. Determination of oil and grease in the given water sample.
9. Determination of residual chlorine in the given water sample.
10. Determination of coliforms using MPN Test in the given water sample.
11. Determination of toxic heavy metals concentration in the given water sample using AAS.
12. Determination of alkali and alkaline earth metals in the given water sample using Flame Photo meter
13. Determination of NOx, SOx and COxin the given air sample
14. Determination of noise/Sound level at different places.
15. Determination of particulate matter in air sample.

Reference Books:
<table>
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<tr>
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**Prerequisite:**
Mathematics, chemical reaction engineering, mass transfer, heat transfer, fluid flow, control.

**Course objectives:**
Apply the knowledge of mathematics in solving engineering problems

**List of experiments**

1. Simulation of CSTR in series
2. Simulation of batch reactor
3. Simulation of non-isothermal reactor
4. Simulation of fluidized bed reactor
5. Simulation of shell and tube heat exchanger
6. Simulation of multiple effect evaporator
7. Simulation of flash drum
8. Simulation of absorber
9. Simulation of distillation tower
10. Simulation of extractor