UNIVERSITY OF PUNE

STRUCTURE AND SYLLABUS

OF

B. E. (PETROCHEMICAL ENGINEERING)

(COURSE – 2008)

UNIVERSITY OF PUNE

STRUCTURE OF B.E. (PETROCHEMICAL ENGINEERING)
COURSE – 2008

Sub. No.	Subject	Teaching Scheme Hrs/Week			Examination Scheme (Marks)			
		Lect	Pr	Tut/ Drg	Paper	TW	Pr	Or
		TERM - I						
412401	Reaction Engineering – II	4	-	-	100	--	-	-
412402	Process Dynamics and Control	4	2		100	25	-	50
412403	Environmental Engineering	4	2	-	100	25	50	-
412404	Elective – I	4	2	-	100	-	-	50
412405	Elective – II	4	-	-	100	-	-	-
412406	Professional Ethics	-	2	-	-	50	-	-
412407	Project	-	2	-	-	-	-	-
	Total	**20**	**10**		**500**	**100**	**50**	**100**
	Total Term – I	**30**			**750**			
		TERM – II						
412408	Refinery Process Design	4	2	-	100	50	-	
412409	Plant Design and Process Economics	4	2	-	100	-	-	50
412410	Elective – III	4	2	-	100	-	50	-
412411	Elective – IV	4	-	-	100	-	-	-
412412	Chemical Engineering Laboratory II	-	2	-	-	50	-	-
412407	Project Work	-	6	-	-	100		50
	Total	**16**	**14**	**-**	**400**	**200**	**50**	**100**
	Total Term – II	**30**			**750**			
	Total for the year	**60**			**900**	**300**	**100**	**200**
	Grand Total				**1500**			

L: Lectures / week, **Pr:** Practical / week, **T:** Tutorial, D: Drawing **TW:** Term Work, **OR:** Oral

Semester One

Elective – I, 412404

412404 A	Biochemical Engineering
412404 B	Novel Separation Processes
412404 C	Elements of Fluidization Engineering
412404 D	Green Chemistry

Elective – II, 412405

412405 A	Optimization Techniques for Process Industries
412405 B	Emerging feed stocks and Technologies for Petrochemicals
412405 C	Natural Gas Technology
412405 D	Health, Safety and Environment in Process Industry

Semester Two

Elective – III, 412410

412410 A	Process Modeling and Simulation
412410 B	Fine Chemical Industries
412410 C	Colloidal and Interface Science
412410 D	Renewable Energy Sources

Elective – IV, 412411

412411 A	Petroleum Exploration and Production Operations
412411 B	Catalyst Science and Technology
412411 C	Polymer Reaction Engineering
412411 D	Open Elective

The students can opt for any elective subject of the same semester which is not offered or taken before. The elective subject may be related to the program or may be offered by any program under faculty of engineering, university of Pune. An elective proposed by an industry may also be offered to students with the permission of Board of Studies and Faculty of Engineering. The procedure related to same has to be completed by November 30 for smooth functioning of elective.

412401 REACTION ENGINEERING-II
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme: **Examination Scheme:**
Lectures: 4 Hrs / week **Paper: 100 Marks**

Objectives:

1) To understand complications of the rate equation in case of a multiphase reaction on account of diffusional, mass transfer and heat transfer effects.
2) To get acquainted with the principles used in design of multiphase reactors.

SECTION – I

Unit I: Introduction to Heterogeneous Reactions (08)

Heterogeneous systems of various kinds, Complications of the rate equation and the contacting patterns for multiphase contact. Rate equation for surface kinetics, Langmuir-Hinshelwood kinetics

Unit II: Solid Catalyzed Reactions (08)

Pore diffusion, Pore diffusion resistance combined with surface kinetics, Model of a single cylindrical pore, Effectiveness factor, Extension of the model to arbitrary shape of particles and to arbitrary kinetics of surface reaction, Laboratory tests for predicting pore diffusion effects.

Performance equations for reactors containing porous catalyst particles, Experimental methods for finding rates, Product distribution in multiple reactions. (Case of $A \rightarrow R \rightarrow S$ only)

Unit III: Catalysis Fundamentals and Deactivating Catalysts (08)

Catalyst preparation, manufacture and characterization, Use of catalysts in refining and petrochemical industry, Mechanisms of catalyst deactivation such as fouling, poisoning etc. Rate and performance equations for deactivating catalyst, possible reactor policies for a batch of deactivating catalyst.

SECTION – II

Unit IV: Fluid –Fluid Reactions (08)

Industrial examples of absorption with reaction, liquid-liquid reactions, Rate equations for straight mass transfer and mass transfer accompanied with reaction (all important regimes). Hatta Number, Problems in tower design.

Unit V: Fluid – Particle Reactions and Non-Ideal Flow (08)

Selection of a model for fluid-particle reaction, Shrinking core model, Conversion-time relationships for various shapes and controlling regimes, Determination of rate controlling step.

Residence Time Distribution (RTD), RTD for ideal reactors, Introduction to Axial Dispersion Model, and Tanks-in-Series Model.

Unit VI: Refinery Reactions and Reactors (08)

Kinetics of conversions involving complex mixtures, Kinetic lumps, Kinetic models for catalytic cracking, Hydrocracking, reforming and thermal cracking, Principles involved in the design of multiphase reactors used in refining such as fluidized beds, trickle beds, moving beds and fixed beds.

Reference Books:

1) Levenspiel O., "Chemical Reaction Engineering", Third Edition, John Wiley and Sons, 2003.
2) Smith J. M., "Chemical Engineering Kinetics", McGraw-Hill, 1981.
3) Scott Fogler H., "Elements of Chemical Reaction Engineering", Prentice-Hall of India, 1997.
4) Sharma M. M. and L. K. Doraiswamy, "Heterogeneous Reactions – Vol. I and II", John Wiley and Sons, 1984.

412402 PROCESS DYNAMICS AND CONTROL
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:
Lectures: 4 Hrs / week
Practicals: 2 Hrs / week

Examination Scheme:
Paper: 100 Marks
Term work: 25 Marks
Oral: 50 Marks

Objectives:

1) To understand the importance of system dynamics and feedback control.
2) To be able to analyze open loop and closed-loop system properties.
3) To be able to design a control system to meet desired objectives.
4) To be able to perform model-based design and tuning of controllers.
5) To learn to understand the basic principles of digital control including Z-transforms and signal processing.

SECTION – I

Unit I: Introduction (08)

Review of Laplace transforms, Partial fraction expansions, Introduction to process control, Process control objectives and benefits, Basic principles of process control, Design aspects of process control systems, State variables and state equation for chemical processes, Input – Output model, Linearization of non-linear systems

Unit II: First and Second Order Systems (08)

First order, second order systems, Systems with time delays, Response of first order and second systems, Physical examples of first order and second order systems, Response of first order systems in series, Interacting and Noninteracting systems, and Transportation lag.

Unit III: The Control System (08)

Block diagram, Development of block diagram, Controller and final control element, comparison of response of various modes of control, Block diagram for chemical reactor control system, Reduction of block diagram, Closed loop transfer functions, overall transfer function for single and multiloop systems, Transient response of simple control systems: Proportional and proportional-integral control for load and set point changes.

SECTION – II

Unit IV: Stability of Control Systems and Frequency Response Techniques (08)

Concept of stability, Stability criterion, Routh test for stability, Concept of root locus, Plotting root locus diagrams.

Substitution rule, The Bode stability criterion. Bode diagrams for (a) First Order System, (b) First Order Systems in series, (c) Second Order System, (d) Transportation Lag (e) Proportional Controller (f) P-I Controller, (g) P-D Controller, (h) PID controller. Gain and Phase margins. Controller tuning methods, Nyquist stability criterion.

Unit V: Advanced Control Techniques (08)

Principles of digital control, Fundamentals of digital controls, Computer interface, direct digital controls, Distributed control Systems and plant wide control system, advanced control techniques like ratio control, cascade control, adaptive control, Split range control etc.

Typical schemes for the control of unit operations and processes such as inventory control, heat exchanger control, and distillation column control.

Unit VI: Digital Control Techniques and Industrial Applications of Process Control (08)

Introduction to Z-transforms, Sampling of continuous signals, design of feedback control, Programmable logic control.

Typical strategies for the control of parameters such as level, flow, pressure, temperature and composition, Control valve sizing and characteristics, Plant wide control, State-of-the-art technologies in industrial automation such as DCS, PLC, SCADA, Field bus technology etc. Recent trends in industrial process automation.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) To determine time constant of thermometer and time constant of manometer.
2) To understand control behavior of liquid level control system.
3) To determine characteristic constants of two tank interacting system and two tank non-interacting system.
4) To determine control valve characteristics.
5) To determine the response of a) Thermal system with proportional control. b) Thermal system with transportation lag and proportional control. c) Thermal system with transportation lag and PI control.
6) To determine the response of shell and tube heat exchanger with PID control.
7) To implement a control strategy for a given process using dynamic mode of a commercial process simulator such as Aspen Plus.

8) To simulate a control strategy for a given process using a commercial mathematical software such as MATLAB.
9) Study of pneumatic servo system.
10) Study of microprocessor based PID controller system.
11) Study of SCADA system.

Reference Books:

1) Donald K. Coughanowr; "Process System Analysis and Control"; McGraw Hill, Third Edition, New York, 2001
2) Seborg D. E., T. F. Edgar, D. A. Mellichamp; "Process Dynamics and Control"; Second Edition, John Wiley and Sons, New York, 2004.
3) Stephanopoulos G.; "Chemical Process Control: Introduction to Theory and Practice"; Prentice-Hall of India, 1995.
4) Thomas E. Marlin; "Process Control: Designing Processes and Control Systems for Dynamic Performance", Second Edition, McGraw-Hill, New York, 2000.
5) Ogunnaike B. A., W. H. Ray; "Process Dynamics, Modeling and Control", Oxford University Press, 1994.

412403 ENVIRONMENTAL ENGINEERING
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	Examination Scheme:
Lectures: 4 Hrs / week	Paper: 100 Marks
Practical: 2 Hrs / Week	Term work: 25 Marks
	Practical: 50 Marks

Objectives:

1) To learn to appreciate interrelationship between various components of ecosystem.
2) To get acquainted with characterization of treatment methods for air and water pollution in process industry.
3) To know regulatory framework for pollution prevention.

SECTION – I

Unit I: Components of Environment and Current Environmental Issues (08)

Ecosystem - Structure and functional components of ecosystem, Impact of man on the environment, Natural and man-made impacts on water, air and land, Current environmental issues, Hazardous waste and Bio-medical waste, Global issues - Biodiversity, Climatic change, Ozone layer depletion, clean development mechanisms (CDM), Kyoto Protocol, Role of the environmental engineer

Unit II: Air Pollution and Control Methods (08)

Sources and classification of air pollutants, Major emissions from global sources, Air pollution laws and standards, Air pollution sampling and measurements, Control methods, Cleaning of gaseous effluents, Particulate and gaseous emission control, Control of specific gaseous pollutants such as sulphur dioxide emission, carbon monoxide and hydrocarbons, organic vapor from effluent gases.

Unit III Meteorological Aspects and Air pollution control (08)

Metrological aspects of air pollution dispersion, Temperature lapse rates and stability, Wind velocity and turbulence, Plume behavior, Dispersion of air pollutants.

Air pollution control from major process industries such as Petroleum refining and petrochemical plants, Thermal power plants, Cement industry, Fertilizer and Pulp and Paper industries.

SECTION – II

Unit IV: Sources and Classification of Water Pollutants (08)

Origin of wastewater, General standards for quality of water for different purposes, Water intake structures, Types of water pollutants and their effects, Water pollution laws and standards, Waste water characteristics: physical characteristics and chemical characteristics.

Unit V: Wastewater Treatment Technologies (08)

Sampling Techniques: Methods of Analysis, Characterization, oxygen demanding wastes, Basic processes of treatment, volume and strength reduction, neutralization, equalization and proportionalization.

Design of Conventional Biological Treatment: Activated sludge process, Trickling Filters, Sludge treatment and disposal, Low cost waste treatment systems, Biological waste treatment.

Tertiary Treatment Systems: Coagulation and filtration, Removal of dissolved solids, Nitrogen removal, ammonia stripping, Phosphorous removal, advanced biological systems, sludge treatment and disposal, Wastewater disposal and reuse.

Unit VI: Wastewater Treatment for Specific Industries (08)

Sources, characteristics and methodology for the treatment of industrial wastes of Dairy, sugar Beverage, Paper and pulp mills, Tannery, Textile mill, Fertilizer plant, Steel plant and Oil refinery and Petrochemical plants

Environmental Regulations:

OSHA, Regulatory framework, Regulation of hazadorous materials and substances, ISO 14000, Pollution control standards of WHO, EPA,BIS, MPCB, CPCB.

Case Studies:

Conventional water and sewage treatment plants - Industrial water treatment plants - Sludge management facilities - Wastewater reclamation plants - Field visits.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) To analyze a given hydrocarbon waste for Dissolved oxygen.
2) To analyze a given hydrocarbon waste for Chemical Oxygen Demand (COD)
3) To analyze a given hydrocarbon waste for Biological Oxygen Demand (BOD)
4) To analyze a given hydrocarbon waste for Total solids: Suspended solids, Dissolved solids, volatile solids, settleable solids and non settleable solids

5) To calculate Sludge Volume Index (SVI) of given sample.
6) To analyze a given hydrocarbon waste for Conductivity / Salt concentration.
7) To analyze a given hydrocarbon waste for Heavy metals (at least two).
8) To separate dust from gas using electrostatic precipitator.
9) To separate solids from gas using ventury scrubber.
10) To analyze a given gaseous effluent sample for SO_x, NO_x.
11) To analyze a gaseous sample for volatile organics using Gas Chromatograph.
12) To analyze a given hydrocarbon waste for Total organic carbon.

Reference Books:

1. Rao C. S.; "Environmental Pollution Control Engineering"; Wiley Eastern Ltd., 1996.
2. Peavy H. S., Rowe D. R. and Tchobanoglous George; "Environmental Engineering"; McGraw Hill, 1985.
3. Rao M. N. and H. V. N. Rao; "Air Pollution"; Tata McGraw Hill Publishing Company Limited, New Delhi, 2001.
4. George Technoglobus; Burton F. L.; "Wastewater Engineering: Treatment and Reuse"; Fourth Edition, Metcalf and Eddy, Inc.; Tata McGraw Hill, 2003.
5. De Nevers, "Air Pollution Control and Engineering", McGraw Hills, 1993
6. "Standard Methods for the Examination of Water and Wastewater", 20th Edn., American Public Health Association, Washington. D.C. 1998 of Hazardous waste treatment and disposal, 2nd Edition, McGraw-Hill, New York, 1997.

ELECTIVE-I (A)
412404 (A) BIOCHEMICAL ENGINEERING
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**
Practical: 2 Hrs / Week	**Oral: 50 Marks**

Objectives:

1. To understand use of biotechnology in chemical manufacturing.
2. To gain familiarity with fundamental principles of cell science and biochemistry.
3. To understand kinetics of enzymatic reactions and biomass production.
4. To get acquainted with transport phenomena in various types of bioreactors.
5. To know specific considerations involved in Bioseparations.

SECTION – I

Unit I: Microbiology and Biochemical Principles (08)

Cell Doctrine, Structure of cells, Important cell types, Chemicals of life, Lipids, Sugars and Poly saccharides, conversions of Nucleotides to RNA and DNA, Amino acids into proteins, Hybrid biochemicals, Hierarchy of cellular organization.

Unit II: Enzyme Technology (08)

Kinetics of enzyme catalyzed reactions, Enzyme-substrate complex and enzyme action, Michaelis-Menten kinetics, Parameter evaluation, Modulation and regulation of enzymatic activity, Enzyme deactivation, Enzyme stabilization, Industrial applications of hydrolytic and nonhydrolytic enzymes.

Introduction to enzyme immobilization.

Unit III: Kinetics of Substrate Utilization, Product Formation and Biomass Production (08)

Ideal reactors for kinetic measurements, Kinetics of balanced growth, Transient growth kinetics, structured kinetic models, Product formation kinetics, Thermal death kinetics of cells and spores.

SECTION-II

Unit IV: Transport Phenomena in Bioprocess Systems (08)

Gas-liquid mass transfer in cellular systems, Determinations of oxygen transfer rates, Mass transfer in sparged vessels, Factors affecting mass transfer coefficients, Mass and heat transfer correlations, Scale-up considerations.

Unit V: Bioreactors (08)

Fed-Batch Reactors, Enzymes-catalyzed reactions in CSTR-Various Schemes, CSTR with recycle and wall growth, Plug flow reactor, Introduction to dynamic behaviour of CSTR, Sterilization reactors, Multiphase bioreactors, Fluidized bed. Packed bed, Trickle bed, Bubble column, Aerobic and Anaerobic Fermenter, Alternate bioreactor configurations, High surface area configurations for tissue culture.

Unit VI: Bioseparations (08)

Product recovery operations, Recovery of cells and solid particles, Filtration, Centrifugation, Sedimentation, Foam separation, Extraction, Sorption, Chromatography, Membrane separations, Drying, Electrophoresis, New trends, Bioprocess economics.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) To demonstrate the use of rennet in casein coagulation in different pH conditions.
2) To hydrolyze protein-based stains in fabrics into soluble amino acids.
3) To analyze amino acid concentrations by the ninhydrin colorimetric method during the enzymatic hydrolysis of a protein.
4) To compare the enzymatic and acid hydrolysis of cellulose.
5) To study the various parameters that affect the kinetics of alpha-amylase catalyzed hydrolysis of starch.
6) To recover proteins/enzymes from a solution by salting-out.
7) To compare the effectiveness of three methods of enzyme immobilization by gel entrapment.
8) To demonstrate the use of microorganisms in food processing by using yogurt as an example.
9) Cell Differentiation by gram's stain.
10) To simulate cell fractionation based on density gradient.
11) To study the effect of sugar content on wine fermentation.
12) To measure the kinetic parameters of invertase.
13) To study separation of proteins.

Reference Books:

1) James E. Bailey and David F. Ollis, “Biochemical Engineering Fundamentals”, McGraw Hill, 1986.
2) Roger Harrison, Paud Todd, Scott Rudge, Demetri Petrides, “Bioseparations Science and Engineering”, Oxford University Press, 2003.
3) Shuler Michael L and Kargi Fikret, “Bioprocess Engineering Basic Concepts”, Prentice Hall, New Delhi, 2004.
4) Shivshanker B., “Bioseparations Principles and Techniques”, Prentice Hall, New Delhi, 2005.

ELECTIVE-I (B)
412404 (B) NOVEL SEPARATION PROCESSES
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**
Practical:2 Hrs / Week	**Oral: 50 Marks**

Objectives:

1) To identify the multiple factors influencing the choice of separation techniques.
2) To be able to qualitatively and quantitatively address the fundamental aspects of specialty separation processes.

SECTION – I

Unit I: Overview of Separation Processes and their Selection (08)

Characteristics and selection of separation process: Importance and variety of separation, economic significance, characteristics, inherent separation factor, selection, factors influencing the choice of separation process, solvent selection, selection of equipment. Recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances, Rate based versus equilibrium separation processes, Selection of separation process, Energy requirements of separation processes.

Unit II: Surfactant Based Separation Techniques (08)

Basic principles, classifications, Surfactants at inter phases and in bulk, Foam fractionation, Foam flotation, Adsorptive bubble separations, Ion flotation, Microemulsion / Macroemulsions, Hydrotopes, Solvent ablation.

Unit III: Membrane Separations (08)

Introduction, Type and choice of membranes, Plate and frame, tubular, spiral wound and hollow fibre membrane reactors and their relative merits, Membrane filtration, Microfiltration, Ultrafiltration, Reverse Osmosis, Dialysis, Models for membrane separations, Design and economics of membrane separation processes.

SECTION – II

Unit IV: Separation by Adsorption Techniques (08)

Mechanism and Isothermal Characterization, Type and choice of adsorbents, Normal adsorption techniques such as Pressure Swing Adsorption (PSA), Temperature Swing Adsorption (TSA), Types of equipment and processes, Recent advances, Process design and economics.

Unit V: Chromatographic Separations (08)

Introduction, types of chromatography, Elution chromatography: Principles and Retention theory, Band broadening and separation efficiency, Types of chromatography, Large scale elution (cyclic/batch) chromatography, Selective adsorption of biological macromolecules, Simulated countercurrent techniques, Comparison with other separation methods.

Unit VI: Ionic Separations and advanced Separation Processes (08)

Mechanism, Ion exchange resins, Capacity, Equilibrium and kinetics, Ion exchange equipment-Design and operation, Principles of Electrophoresis and Electrodialysis, Two phase partitioning, Reserve Micelle Extraction, Isoelectric Focusing.

Recent Advanced Separation Processes: Super Critical Fluid (SCF) Extraction, bio-filtration Reactive separations, Bioseparations, Parametric pumping, Cryogenic Separation, Zone melting etc.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1. Oxygen separation from air using a membrane laboratory unit.
2. Water softening using a laboratory scale reverse osmosis unit.
3. Reverse osmosis of saline solution
4. Separation of chemicals using ultra-filtration.
5. Ultrafiltration of some dilute solutions
6. Microfiltration of raw material.
7. Water softening or deionization by ion exchange.
8. Clean up of a gas stream by activated carbon adsorption.
9. Design of a gas separation experiment using pressure swing adsorption
10. Design of an experiment for separation of trace organics (or dewatering of an organic) using Pervaporation.
11. Lab. Experiment on Electrodialysis.
12. Lab. Experiment on Gas Chromatography.

Reference Books:

1. King C. J.; “Separation Processes”; Tata McGraw–Hill Publishing Co. Ltd., 1982.
2. E.J. Henley and J.D. Seader, Equilibrium Stage Separation Operations in Chemical Engineering, Wiley, 1981.
3. Richardson and Coulson; “Chemical Engineering”; Volume-II, Pergamon Press, 1993
4. Philip Schweitzer; “Handbook of Separation Techniques for Chemical Engineers”, Third Edition, Tata McGraw Hill New York, 1997.
5. Geankoplis C.J., “Transport Processes and Separation Process Principles”, Fourth Edition, Prentice-Hall of India, 2003

ELECTIVE-I (C)
412404 (C) ELEMENTS OF FLUIDIZATION ENGINEERING
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	Examination Scheme:
Lectures: 4 Hrs / week	Paper: 100 Marks
Practical: 2 Hrs / Week	Oral: 50 Marks

Objectives:

1) To get acquainted with fundamentals of fluidization engineering, different regimes, classification of particles.
2) To understand movement of bubbles mixing in bed.
3) To get qualitative appreciation of mathematical models of Fluidized Bed

SECTION – I

Unit I: Introduction to Fluidized Bed (08)

The fluidized state, Nature of hydrodynamic suspension particle-particle forces, species of fluidization, Mapping of regimes, Fluidization quality, Gas distributors, Advantage and disadvantages of fluidization.

Unit II: The Fluidization Phenomenon and Classification of Particles

Fluidization with and without carryover of particles, Estimation of minimum fluidization velocity, Terminal velocity of particles, Geldart classification of particles: Group C, Group A, Group B, Group D particles and their characteristics.

Unit III: Hydrodynamics of Fluidization Systems (08)

General bed behavior pressure drop, Flow regimes, Incipient fluidization, pressure fluctuations, phase holdups, Measurement techniques, Empirical correlations for solids holdup, liquid holdup and gas holdup, Flow models - generalized wake model, structural wake model and other important models.

SECTION – II

Unit IV: Heat and Mass Transfer Fluidization Systems (08)

Mass transfer - gas-liquid mass transfer, Liquid solid mass transfer and wall to bed mass transfer, Heat transfer - column wall - to - bed heat transfer, Immersed vertical cylinder-to-bed heat transfer, Immersed horizontal cylinder to-bed heat transfer.

Unit V: Specialized Topics of Fluidization (08)

Effect of pressure and temperature on fluidized behavior, Sintering and Agglomeration of particles, Particle residence time in bed, Particle entrainment and carryover, shapes of a single bubble, Rise velocity of bubble, Bubble breakup, Slugs, Freely bubbling beds, continuously slugging beds, Mechanism of solid mixing, Gas Backmixing, Cloud formation, Davidson model, Solids within bubble, Coalescence.

Unit VI: Industrial Applications of Fluidization / Fluidized Bed Heat Transfer (08)

Particle to gas heat transfer, Bed to surface heat transfer, Increase of available heat transfer are using immersed tubes, fluidized solids as heat transfer medium.

Fluidized Bed Drying: Advantages, Batch dryers, Continuous well mixed dryers, Continuous plug flow dryers, Vibrated dryers, Multi-stage dryers Fluid bed dryers with internal heating.

Fluidized Bed as Catalytic Reactors: Advantages, Gas motion in and around bubbles, Interphase mass transfer, Reactor model for fine particle bubbling beds, Reactor model for large particle bubbling beds, Conversion in the freeboard of reactor, Turbulent bed reactors, Axial and radial gas mixing, Two phase bubbling bed reactor models.

Term Work:

Every student should carry out minimum *six* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) Simulation of fluidized bed reactor using MATLAB
2) Determination of minimum fluidization velocity and pressure drop for fluidized bed.
3) Experiments on fluidization regimes on Fluidized bed.
4) Design of gas distributors for a fluidized bed.
5) Calculation of bubble growth inside a fluidized bed reactor.
6) Design of a fluidized bed dryer.
7) Development of mathematical models of a fluidized bed reactor.
8) Calculation of residence time in a fluidized bed system.
9) Scale up strategies and challenges for Fluidized bed reactor
10) Simulation of Fluidized Bed Reactor in commercial mathematical software such as ASPEN

Reference Books:

1) Kunii D., O. Levenspiel, “Fluidization Engineering”, Second Edition, Butterworth Heinemann, 1991.
2) D. Geldart Ed., “Gas Fluidization Technology”, John Wiley Sons, 1986.
3) Liang-Shih Fan, Gas-Liquid-Solid Fluidization Engineering, , Butterworths, 1989
4) Mosoon Kwauk, Fluidization Idealized and Bubbleless, with Applications, Science Press, 1992

ELECTIVE-I (D)
412404 (D) GREEN CHEMISTRY
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**
Practical: 2 Hrs / Week	**Oral: 50 Marks**

Objectives:

1) To acquire a fundamental understanding of basic chemistry/technology principles within the framework of Green Chemistry.
2) To get acquainted with the development of latest technologies and methodologies for environmentally benign processes currently practiced in various industrial sectors with an emphasis on the design, manufacture, and use of chemicals and processes that have little or no pollution potential or environmental risk and are both economically and technologically feasible.

SECTION-I

Unit I: Introduction (08)

Why green chemistry? Toxicity of chemicals.Accidents with chemicals.Waste and its minimisation.Sustainability (including social, political & economic factors).The green political movement.The roles and responsibilities of chemists and chemical engineers. Definition and overview of the twelve principles of green chemistry.

Unit II: Green Synthesis (08)

Establishing a full mass balance. Waste treatment/recycle. Synthetic Efficiency. Green Chemistry Metrics. Individual Reactions Analysis. Atom Economy, E-factor, & Reaction Mass Efficiency (RME).Synthesis Plans Analysis: Synthesis Tree Algorithms for Linear and Convergent Plans Raw Material Cost Estimate Material Efficiency & Synthetic Elegance Ranking. Trade off with economics. Less Hazardous Materials in Synthesis. Designing Safer Products. Renewable feedstocks.

Unit III: Green Solvents (08)

Safer Solvents and Auxiliaries. Critical review of organic solvents typically used in chemical processes.Critical review of: ionic liquids, supercritical CO2, water, fluorous phase chemistry, solvent-free / solid phase chemistry. Examples of green reagents.

SECTION-II

Unit IV: Energy Efficiency (08)

Energy Efficiency. Quantifying and minimising the use of utilities and other inputs. Overview of emerging frontiers in energy efficient synthesis such as Photochemistry, Microwave Chemistry, Sonochemistry, Electrosynthesis

Unit V: Catalysis (08)

Role of Catalysis. Heterogeneous Catalysis. Solid acids. Templated silica. Polymer-supported reagents. Homogeneous catalysis. Phase transfer catalysis. Biocatalysis. Photocatalysis

Unit VI: Hazard Minimization (08)

Design for Degradation. Rules for degradation. Process safety and thermal hazards.
Process control using real-time analysis.Process intensification

Term Work:

Every student should carry out minimum *eight* experiments/Assignments from the following list and submit the journal, which will form the term work.

List of Practicals:

1. Acetylation of primary Amine.
2. Base Catalysed Aldol condensation.
3. Synthesis of BioDiesel by transesterification reaction.
4. Radical Coupling Reaction.
5. Synthesis of Adipic Acid by Green Oxidation reaction.
6. Preparation of Benzopinacol by Green Photochemical reaction.
7. Electrophilic Aromatic Substitution Reaction by Green Approach to prepare p-Bromoacetanilide.
8. Coenzyme catalyst Benzoin condensation.
9. Preparation of Benzillic Acid by rearrangement with green approach.
10. Case study of Biomass Utilization as Green Technology
11. {4+2} Cycloaddition reaction.
12. Preparation of Benzopinacolone by rearrangement.
13. Bromination of Trans stilbene by green technology.
14. To study Transesterification of dimethyl oxalate with phenol over TiO_2/SiO_2

References:

1. Anastas, P.; Warner, J. Green Chemistry: Theory and Practice; Oxford University Press: London, 1998.
2. Lancaster, M.; Green Chemistry an Introductory Text, Royal Society of Chemistry, Cambridge, UK 2002.
3. Albert S. Matlack; "Introduction to Green Chemistry" Marcel Dekker, Inc., New York, 2001.
4. Zimmerman, J.B.; Anastas, P.T. "The 12 Principles of Green Engineering as a Foundation for Sustainability" in Sustainability Science and Engineering: Principles. Ed. Martin Abraham, Elsevier Science, 2005.
5. Anastas, P.; Zimmerman, J. "Design through the Twelve Principles of Green Engineering," *Environmental Science and Technology,* 37, 94A – 101A, 2003

ELECTIVE-II (A)
412405 (A) OPTIMIZATION TECHNIQUES FOR PROCESS INDUSTRIES
(B. E. Petrochemical Engineering. 2008 Course)

Teaching Scheme: **Examination Scheme:**
Lectures: 4 Hr / week **Paper: 100 marks**

Objectives:

1. To develop understanding of the principles, techniques, standard tools of process optimization.
2. To formulate multiobjective optimization problem with and without constraints based on process requirements.
3. To gain exposure to application of optimization techniques in case of various petrochemical processes.

SECTION-I

Unit I: Principles of Optimization (08)

Introduction to optimization and its scope in chemical processes, Nature and organization of optimization problems, Design Variable, Constraints, Objective Function, Necessary and sufficient conditions.

Unit II: Single Variable Optimization Algorithms (08)

Optimality Criteria, Bracketing Methods, Region Elimination Methods: Fibonacci search and Golden section search methods, Gradient Based Methods: Newton-Raphson, Bisection, Secant methods

Unit III: Multivariable Optimization (08)

Optimality criteria, Hessian matrix, Unidirectional search, Direct Search: Simplex search, Powell's conjugate gradient methods, Gradient based methods: Steepest Descent Method, Newton's methods, Marquardt's method

SECTION-II

Unit IV: Constrained Optimization Algorithms (08)

Kuhn-Trucker Conditions, Transformation Methods: Penalty function method, Methods of multipliers, Sensitivity Analysis, Direct Search for Constrained Optimization, Feasible Direction Methods

Unit V: Specialized Search Method (08)

Integer Programming: Penalty Function method, Branch-and-Bound method, Geometric Programming, Mixed integer Programming, Dynamic Programming

Unit VI: Evolutionary Global Optimization Techniques (08)

Genetic Algorithms: Working Principles, GA Operators, Binary Coded GA, Real Coded GA, Non-dominated Sorting GA, Pareto Optimization.

Simulated Annealing, Ant Colony Optimization, Particle Swarm Optimization

Reference Books:

1. Edgar, T F, Himmelblau, D M, and Lasdon, L S, "Optimization of Chemical Processes." McGraw Hill, Boston, 2001.
2. Rao, S. S., "Optimization Theory and Applications: Theory and Practice", New Age International, 3rd Edition, 1996.
3. Deb, Kalyanmoy "Optimization for Engineering Design", Prentice-Hall of India, 1995.
4. Deb, Kalyanmoy "Multi-Objective Optimization using Evolutionary Algorithms", John Wiley & Sons Ltd. Chichester, West Sussex, England, 2001.

ELECTIVE-II (B)
412405(B) EMERGING FEED STOCKS AND TECHNOLOGIES FOR PETROCHEMICALS
(B. E. Petrochemical Engineering. 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hr / week	**Paper: 100 marks**

Objectives:

1) To know the resource constraints regarding present feed stock scenario.
2) To familiarize with emerging feedstock and appropriate technologies for processing them.

SECTION-I

Unit I: Existing Feedstock Scenario (08)

Fossil fuel feedstock, Coal, Natural Gas and Petroleum, Reserves, Present and Future Production Trends, Statics for India and World, Distribution and utilization pattern of existing fossil reserves, Demand supply scenario, Cycle of oil prices, Need for alternative feedstocks

Unit II: Non conventional Fossil Fuels (08)

Coal Bed Methane, Coal Gasification, Shale Oil, Hydrates, Reserves, Potential, and Technologies for exploitation of these resources, Cost factor

Unit III: Coal Gasification (08)

Chemistry and Technology for coal gasification and Syngas production, Fischer Tropsch Synthesis, Chemistry, Catalyst and Process Technology, Other outlets for Syngas

SECTION-II

Unit IV: Biomass (08)

Biomass potential, India, US and World, Biomass resources, Biomass Technologies, Pyrolysis, Gasification, Fermentation, Gasifier design with natural draft and forced draft. Biorefineries

Unit V: Alco Chemicals (08)

Pathways and technologies for chemicals from ethanol, isopropyl alcohol, n-butanol, isobutanol, tertiary butyl alcohol like acetaldehyde, ethyl acetate, glycol ethers, acetone, butyl acetate, ethyl acrylate, Lube oil additives, Octane boosters, other solvents, etc.

Unit VI: Chemical sequestration of carbon dioxide: (08)

Technological options for CO_2 sequestration and capture, Uses of CO_2in organic synthesis, Fertilizer, Pharmaceutical, Solvent and Synthetic Polymer Industry, Thermodynamic Barriers for CO_2 utilization, Methods of Conversion of CO_2 to fuels, Carbon credits and economics.

References

1. Alain Chauvel and Gilles Lefebvre, 'Petrochemical Processes: Technical and Economic Characteristics' Vol.2, Gulf Publishing Company, 1989
2. Christian Ngo and J.B.Natowitz, 'Our Energy Future: resources, alternatives and environment, John Wiley and Sons, 2009
3. John Rezaiyan and Nicholas P.Cheremisinoff, 'Gasification Technologies: A primer for engineers and scientists', Taylor and Francis, 2005
4. 'Robert C.Brown and Christian Stevens, 'Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power', John Wiley and Sons, 2011
5. James H.Clark and Fabien Deswarte, 'Introduction to Chemicals from Biomass' Wiley, 2008
6. Elizabeth J. Wilson and David Gerard, 'Carbon Capture and Sequestration, Integrating, Technology, Monitoring and Regulation', Blackwell Publication, 2007
7. Michele Aresta, 'Carbon dioxide as Chemical Feedstock', Wiley VCH, 2010

ELECTIVE-II (C)
412405 (C) NATURAL GAS TECHNOLOGY
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**

Objectives:

1) To understand markets, capacities, sources and technologies issues involved in natural gas production, processing and transport.
2) To get acquainted with technologies used in consumption of natural gas.

SECTION – I

Unit I: Natural Gas Resources (08)

Oil and gas reserves, Natural gas and associated gas, Outlook for world gas production, Indian Scenario. Future sources of natural gas – Coal Bed Methane and Hydrates.

Composition of natural gas, Origin of hydrocarbon & non-hydrocarbon components, Formation of natural gas reservoirs, Sweet and sour gas.

Unit II: Natural Gas Properties (08)

Phase diagram of a reservoir fluid, Cricondentherm and cricondenbar, Retrograde condensation, Dry gas, Wet gas, Condensate gas, Associated gas, Chemical components.

Sampling methods for natural gas, Measurements taken during sampling.

Volumetric properties of natural gas, Equations of state, Viscosity, thermal conductivity, surface and interfacial tension, Net and Gross Heating value – VLE calculations for natural gas.

Unit III: Hydrates (08)

Water-hydrocarbon systems, Hydrate structures, Thermodynamic conditions for hydrate formation, Kinetics of hydrate formation, Hydrate prevention.

SECTION-II

Unit IV: Natural Gas Processing (08)

Different specifications required for transport and use, Separation of condensates, Gas-Liquid separators and their design, Fractionation and purification operations, Dehydration methods, Hydrocarbon liquids recovery, Acid gas removal, Removal of nitrogen, helium and mercury, Integrated natural gas processing.

Unit V: Natural Gas Transport & Storage (08)

Different gas chains – Pipeline transport systems, Steady state flow calculations for a pipeline, Pipeline thickness calculation, Welding problems in large diameter steel pipelines, Corrosion protection, Recompression stations, Types of compressors, Multiphase flow handling. Instrumentation, Monitoring and control, Safety considerations, Expansion systems. Flow measurement.

LNG transport chain, Natural gas liquefaction, LNG carriers.

Natural gas storage-Cryogenic and Underground.

Unit VI: Natural Gas Outlets (08)

Downstream utilization technologies for natural gas in petrochemical, fertilizer and power sectors.

Lower hydrocarbons upgradation technologies**,** Methane conversion technologies.

Reference Books:

1) A. Rojey, C. Jaffret, "Natural Gas Production, Processing, Transport", Second Editions Technip, 1994.
2) Chi U. Ikoku, "Natural Gas Production Engineering", John Wiley and Sons, 1984.
3) A. Kohl and F. Riesenfeld, "Gas Purification", Gulf Publishing Company, 1985.
4) Sanjay Kumar, "Gas Production Engineering', Gulf Publishing Company, 1987.

ELECTIVE-II (D)

412405 (D) HEALTH, SAFETY AND ENVIRONMENT IN PROCESS INDUSTRY
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**

Objectives:

1) To familiarize with issues related to occupational health and industrial hygiene
2) To get acquainted with risk assessment, process safety auditing and management systems

SECTION -I

Unit I Introduction (08)

Types of hazards, analysis of hazards, precautions & preventions, grades of hazards, Safety methods, Safety measures. IS 18001:2000/ 9001:2000 ISO 14001:1996 Comparison, Importance of H.F& S, Industrial scope/Act/Compensation.

Unit II Occupational Safety, Health and Environment Management (08)

Bureau of Indian standards on safety and health 14489 - 1998 and 15001 – 2000 OSHA, Process Safety Management (PSM) as per OSHA, PSM principles, OHSAS – 18001, EPA Standards, Performance measurements to determine effectiveness of PSM, Importance of Industrial safety, role of safety department, Safety committee and Function

Unit III Fire and other Hazards (08)

General cause and **c**lassification of fire, Grades of fire hazard, Classification of buildings / structures / materials. / chemicals according to fire load. Fire hazard analysis, Detection of fire, extinguishing methods, fire fighting installations with and without water, Machine guards and its types, automation. High-pressure hazards, safety, emptying, inspecting, repairing, hydraulic and nondestructive testing, hazards and control in refinery.

SECTION –II

Unit IV Fire Fighting Systems (08)

Different types of fire alarms / detectors and extinguishers, fire fighting requirements as per NBC 1983 / Municipality water supply requirements for fire, required fire flow, storage. Wet risers, sprinkler, fire fighting services etc.

Unit V Radiation and Industrial Hazards (08)

Types and effects of radiation on human body, Measurement and detection of radiation intensity. Effects of radiation on human body, Measurement – disposal of radioactive waste, Control of radiation, Industrial noise -Sources, and its control, Effects of noise on the auditory System and health, Measurement of noise, Classification of hazardous chemicals / conditions, Classes of Explosive, Different air pollutants in industries, Effect of different gases and particulate matter, acid fumes, smoke, fog on human health, Vibration - effects, measurement and control measures, Industrial Hygiene.

Unit VI Protection and Prevention measures of Accidents and Hazards (08)

Protection and prevention measures of accidents and hazards, Transportation and storage of chemicals, leakage and accident prevention. Industrial risk and Disaster management, Survey of two industries for disaster / safety control systems, Electrical Safety Programme, pollution control Practices in petrochemical sector.

Reference books:

1. R.K. Jain and Sunil S.Rao, Industrial Safety, Health and Environment Management Systems, Khanna publishers, New Delhi, 2006
2. Goetsch D.L., "Occupational Safety and Health for Technologists", Engineers and Managers", Prentice Hall, 1999
3. Slote. L, Handbook of Occupational Safety and Health, John Willey and Sons, New York
4. National Safety Council and Associate (Data) Publishers Pvt. Ltd., "Industrial Safety and Pollution Control Handbook, 1991
5. Frank P Lees - Loss prevention in Process Industries, Vol. 1 and 2, Butterworth-Heinemann, 1991

412406 PROFESSIONAL ETHICS
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Practical: 2Hrs/week	**Term Work: 50 Marks**

Objectives:

1) To familiarize students with contemporary ethical and professional conduct issues
2) To provide students with guidelines for evaluating and resolving ethical dilemmas and decision-making in Professional career

Term work:

Term work and theory are considered to be integral part of the course. Term work shall consist of a journal consisting of regular assignments and presentations completed in the practical class and at home. As far as possible, submission should be word processed on a computer using a standard package by the student himself. Oral presentations exercises and group discussions should be conducted batch wise so that there is a closer interaction.

Every student should carry out minimum *Six Assignments* from the following list and submit the journal, which will form the term work.

Scenario management case studies in following areas:

1. AIChE Code of Professional Ethics
2. Professional ethics
3. Social consequences of an engineering policy decision
4. Safety analysis of a process plant
5. Environmental impact analysis of a process
6. IPR infringement
7. Global warming issues
8. Problems of globalization
9. Business Ethics Case Studies

Reference books:

1) Mike Martin and Roland Schinzinger, "Ethics in Engineering", McGraw Hill, New York 1996.
2) M. Govindarajan, S.Natarajan, V.S. Senthilkumar, “Engineering Ethics” Prentice – Hall of India Pvt. Ltd. New Delhi, 2004
3) R.S. Naagarazan, Professional ethics and human values, New Age international Publishers.
4) Charles D.Fleddermann, "Engineering Ethics", Prentice Hall, New Mexico, 1999.

412408 REFINERY PROCESS DESIGN
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**
Practicals: 2 Hrs / week	**Term Work: 50 Marks**

Objectives:

1) To get acquainted with process design of distillation columns involving multicomponent and complex mixtures.
2) To learn methodologies practiced in rating and designing heat transfer equipment used in refining and process industry.
3) To learn process design aspects related to pumps and compressors

SECTION – I

Unit I: Multicomponent Distillation (08)

Dew point and bubble point for multicomponent mixtures.Design of multicomponent distillation column, Number of variables, Selection of key components, Selection of column pressure, Feed condition, Plate-to-plate calculations, Empirical short cut methods, Introduction to rigorous solution procedures.

Unit II: Petroleum Refinery Distillation (08)

TBP, EFV, ASTM distillation curves and their relevance, Material balance and flash zone calculations for petroleum refinery distillation columns, Pump around and pump back calculations, Overall energy requirements, Estimation of number of equilibrium stages, Design using Packie charts and Watkins method, Introduction to rigorous solution procedure based on pseudo components.

Unit III: Column Design (08)

Process design of distillation towers. Flooding charts. Trays and packings. Vacuum devices.Pressure drops. Height,diameter,supports.Piping requirements. Aspects of mechanical design. A typical P&ID for a distillation column.
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SECTION –II

Unit IV: Heat Exchangers (08)

Types of heat exchangers used in refinery, Heat exchanger analysis, Effectiveness-NTU method. Kern's method, Bell's method, Heat transfer coefficients in condensation and boiling, Considerations involved in design of reboilers and condensers, air-cooled exchangers. Introduction to TEMA codes, Introduction to heat exchanger-networking problems encountered in crude refining, Basic terminology used in Pinch Technology

Unit V: Fired Heaters (08)

Heat load calculations for furnace heaters used in crude refining, Basic constructional features, Different furnace types, Review of factors to be considered in the design of fired heaters, Introduction to manual calculations methods.

Unit VI: Pumps and Compressors (08)

Types of pumps and compressors.Selection criteria.Power rating calculations based on process duty.Use of operating curves of centrifugal pump.NPSHR and NPSHA.Pump Cavitation. Surge problem in compressors.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) Calculations for bubble point and dew point of a multicomponent hydrocarbon mixture.
2) Multicomponent distillation design using short cut methods
3) Flash calculations for multicomponent and complex mixtures
4) Design of atmospheric distillation column using Watkins method
5) Rating and design calculations for shell and tube heat exchanger
6) Optimum heat exchanger design using a professional design software
7) Detailed process design of a distillation column
8) Preparation of specification sheet for a centrifugal pump based on process duty
9) Preparation of specification sheet for a multistage compressor based on process duty
10) Simulation of multicomponent distillation column using a commercial process simulator such as Aspen Plus.
11) Simulation of multicomponent absorption column using a commercial process simulator such as Aspen Plus.
12) Simulation of Petroleum Refinery Distillation using a commercial process simulator such as Aspen Plus.
13) Detailed process design of a shell and tube heat exchanger for a given duty using TEMA codes.
14) Design calculations for a refinery furnace heater using an empirical method.
15) Heat exchanger network synthesis for a refining unit using a commercial simulator such as Aspen Plus.

Reference Books:

1) Van Winkle M., “Distillation”, McGraw Hill, 1967.
2) Watkins, “Petroleum Refinery Distillation”, McGraw Hill, 1993
3) Sinnott R. K., “Coulson and Richardson’s Chemical engineering”, Vol. 6, Third Edition, Butter Worth-Heinemann, 1999.
4) Kern D. Q., “Process Heat Transfer”, McGraw Hill, 1965.
5) Cao Eduardo,”Heat Transfer in Process Engineering”,McGraw Hill,2010
6) Kayode Coker, “Ludwig’s Applied Process Design for Chemical and Petrochemical Plants”, 4th Ed, Elsevier, 2007

412409 PLANT DESIGN AND PROCESS ECONOMICS
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:
Lectures: 4 Hrs / week
Practical: 2 Hrs / week

Examination Scheme:
Paper: 100 Marks
Oral: 50 Marks

Objectives:

1. To understand economic considerations involved in process plant design.
2. To enable students to understand the concept of process design, practical difficulties in design, various stages of process design, understanding of theory that is needed for process engineer
3. Master the basic techniques of economic evaluation, including accounting techniques, taxes, investment, interest and insurance.
4. To get introduced to various aspects and stages of process plant design such as process design, pilot plants, plant design and project engineering.

SECTION-I

Unit I: Process Engineering and Plant Design (08)

General overall design considerations, Anatomy of chemical engineering projects, Process design: codes, Standard sources of information, Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control.

Process Development: Feasibility study, Development of design database, Process development and commercialization, Importance of laboratory development to pilot plant, scale up methods, Process Creation, Process, process licensing, selection of contractor, scope and contract types, Plant, Erection and commissioning.

Unit II: Engineering Flow Diagrams and Safety Aspects (08)

Process Design Diagrams / Documents: Introduction to block, process flow, Logic, Information flow diagrams. Preparation of PID, trip and interlock systems, MOC and valve selection, color code of pipeline, Equipment datasheets, Layout engineering (Plot Plan)

Safety In Process and Plant Design: Intrinsic / extrinsic safety, Safety of personnel, equipment and plant classification of plant areas, Fire protection systems, Flare systems, Safety relief valves, Flame arrestors, rupture disc and explosion venting etc., Health , Safety and Environmental hazards, Loss Prevention: Hazard Assessment Techniques: HAZOP, HAZAN, Fault Tree Analysis, etc

Unit III: Project Engineering (08)

Project Management and Statutory Regulations: Site Layout, Plant Layout, Battery Limits and Off Site Facilities, Stages of project, Use of Milestone chart / GANT chart/BAR chart, PERT and CPM techniques for project monitoring and control, Preparation of project reports (Feasibility Reports), Annual report of a company.

SECTION – II

Unit IV: Overview of Process Economics (08)

Economic decision making in the CPI, Process plant components, elements of costing and principles of accounting, Total cost components, Types and methods of cost estimation, Cost estimation for equipment and plant, Direct / indirect manufacturing costs.

Unit V: Manufacturing Cost Estimation (08)

Various cost indices, William's sixth tenth rule, methods of estimation of fixed capital, product cost estimation, Financing, Interest and investment cost, present worth and discount annuities, Source of capital, Depreciation, Taxes and Insurances, Balance Sheets, Perpetuity, Inflation.

Unit VI: Profitability: Alternative investments and replacements (08)

Profitability: Alternative investments and replacements, profitability standards, discounted cash flow, rate of return, capitalized cost, payment period, alternative investments, analysis with small investments, increments and replacements, Break Even Analysis.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) Standard symbols (IS code) for PFDS / PIDS etc.
2) Development of Block diagrams/ Process flow diagrams
3) Development of Piping and Instrumentation (PID) diagrams.
4) Development Trip and interlock systems / Logic diagrams.
5) Development of Layout drawings
6) Process flow sheet development using commercial process simulator such as Aspen Plus.
7) Development of GANT/BAR Charts etc. for a given Project
8) Project Engineering problems via PERT/CPM network
9) To study the use of commercial software such as Aspen Plus/Hysys/UNISIM used in plant design
10) Heat Exchanger Network (HEN) synthesis using a commercial process simulator such as Aspen Plus.
11) To carry out cost estimation exercise for a given process.
12) To read and analyze Balance Sheet published by a petrochemical company.

Reference Books:

1) M.S. Peters and K. D. Timmerhaus, "Plant Design and Economics for Chemical Engineers", Fourth Edition, McGraw Hill International Book Co., 1991
2) James R. Cooper, "Process Engineering Economics", Marcel Delkker Inc, New York, 2003
3) Coulson, J.M., Richardson J.E. and Sinnott R.K., "Chemical Engineering", Vol. VI, Pergamon Press, 1991.
4) R. Turton, R. C. Bailie, W. B. Whiting, and J. A. Shaeiwitz, " Analysis, Synthesis, and Design of Chemical Processes", Prentice Hall, Upper Saddle River, New Jersey, 1998.
5) L. S. Srinath, "PERT and CPM, Principles and Applications", Third Edition, East-West Press, 2002.

ELECTIVE-III (A)

412410(A) PROCESS MODELING AND SIMULATION

(B. E. Petrochemical Engineering. 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lecture: 4 Hr / week	**Paper: 100 marks**
Practical: 2 Hr / week	**Practical: 50 marks**

Objectives:

1) To get introduced to modeling and simulation of steady state and dynamic behavior of chemical processes.
2) To understand physical and empirical modeling techniques.
3) To gain hands-on experience with commercial simulators.

SECTION-I

Unit I: Principles of Process Modeling (08)

Introduction, Uses of Mathematical Model, Scope of Coverage, Principles of Formulation, Fundamental Laws, Mathematical models, their classification (deterministic vs stochastic, linear vs nonlinear, lumped parameter vs distributed parameter, dynamic vs steady state with examples) Model building, Change in Models based on addition or relaxation of assumptions. Incorporation of fluid thermodynamics, chemical equilibrium, reaction kinetics, feed / product property estimation in mathematical models.

Unit II: Mathematical Model of Chemical Engineering Systems (08)

Input-output models, Degrees of freedom analysis, Dynamic models of representative chemical engineering processes like binary distillation column, Heat Exchanger, CSTR, Gas Absorber, Flash vaporizer etc.

Unit III: Numerical Solution Strategy (08)

Linear Algebric Equations; Crammers Rule, Gauss Elimination Methods, LU Decomposition, Gauss Seidal Iterative Method, Computation of Eigen values and Eigen vectors

Nonlinear Algebric Equations: Bisection Method, Newton Raphson Method, Secant Method.

Solution of Ordinary Differential Equation Initial Value Problem: Eulers Method, Runge Kutta Methods, Milne predictor corrector method, Stiff Differential Equation, Solution of Partial Differential Equation: Finite Difference Method.

SECTION-II

Unit IV: Process Simulation (08)

Process simulation, Scope of process simulation, Steady state and dynamic simulation, Formation of problem, Process simulation approaches for steady state and dynamic simulation, Process simulator, Structure of process simulator, Integral process simulation, Simulation tools, Modular approaches, Equation solving approach, Decomposition of networks.

Unit V: State – Space Representations of Chemical Engineering Systems (08)

State variables and state equations for chemical process, State-space representations. Selection of state variables, and typical examples from petrochemical engineering, Lumped parameter and distributed parameter models.

Unit VI: Empirical Process Models (08)

Development of empirical models from process data, Linear and nonlinear regression, Advantages and Disadvantages of Empirical Models

Artificial Neural Networks: Supervised Learning, Multilayer Perceptron, Error Back Propagation, Generalization.

Fuzzy Logic: Membership Functions, Fuzzy Logic, Rule based Modeling

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) Modeling and simulation of batch reactor carrying out a set of series and parallel reactions using commercial mathematical software such as MATLAB
2) Simulation with Recycle: Sequential and Simultaneous Solution Methods
3) Calculation of bubble point / dew point for multicomponent hydrocarbon mixture with help of commercial process simulator such as Aspen Plus
4) Flash calculations for a multicomponent hydrocarbon mixture with help of commercial process simulator such as Aspen Plus
5) Mathematical modeling and simulation of a reactor with help of commercial process simulator such as Aspen Plus
6) Mathematical modeling and simulation of multicomponent distillation column
7) Mathematical modeling and simulation of lumped parameter model of tray column
8) Continuous stirred tank reactor simulation
9) Simulation of Ammonia Process
10) Simulation of Catalytic Reformer

Reference Books:

1) Luyben W. L., “Process Modeling, Simulation and Control for Chemical Engineering”, McGraw Hill Book Company, 1990.
2) Seborg D. E., T. F. Edger, D. A. Mellichamp, “Process Dynamics and Control”, John Wiley, 1989.
3) Smith C. L., R. L. Pike and P. W. Murill, “Formulation Optimization of Mathematical Models”, International Text, Pennsylvania, 1970.
4) Roger G. E. Franks, “Modeling and Simulation in Chemical Engineering”, Wiley Inter Science, New York, 1972.
5) Finlayson, B. A., “Introduction to Chemical Engineering Computing”, John Wiley & Sons, New Jersey, 2006.

ELECTIVE-III (B)
412410 (B) FINE CHEMICAL INDUSTIRES
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lecture: 4 Hr / week	**Paper: 100 marks**
Practical: 2 Hr / week	**Practical: 50 marks**

Objectives:

1) To get introduced to Fine Chemicals and Fine Chemical Industry.
2) To understand synthesis of Fine Chemicals and Catalysis.
3) To know about Process Development for Fine Chemicals.
4) To learn about Separation Processes and Production Plants for Fine Chemicals.

SECTION-I

Unit I: Introduction (08)

Fine chemicals and fine chemical industry. Market size and structure, general trends, growth drivers and globalization. Outlets for fine chemicals as pharmaceuticals, agrochemicals, animal health industry, dyes and pigments, fragrances and flavours, food and other additives, sepciality chemicals, intermediates and bio molecules. Characteristic features of fine chemicals manufactures.

Unit II: Synthesis of Fine Chemicals (08)

Historical development and complexity of molecules. Typical examples in the area of pharmaceuticals, agrochemicals, animal health industry, dyes and pigments, flavours and fragrances, additives, intermediates, speciality chemicals and biomolecules. Comparison between alternative routes. Importance of environmentally benign routes and green chemistry.

Unit III: Catalysis in Fine Chemicals (08)

Homogenous and Heterogeneous Catalysts. Catalytic transformations based upon the type of catalyst and type of conversion. Examples of catalytic reduction, catalytic oxidation and catalytic C - C bond formation. Catalysis by solid acids and zeolites, catalysis by solid bases. Role of solvent and catalytic conversions in water. Biocatalysis and enantioselective catalysis. Selection of catalyst and catalyst performance.

SECTION-II

Unit IV: Process Development (08)

Difference in process development for fine chemicals and commodities. Steps in process development. Conceptual design and development of individual steps. Pilot plants. Environmental and safety aspects. Economic evaluation and study report. Scale up procedures and effects. Modeling techniques. Scale up of separation and purification techniques. Chemical reactor scale up, design and operation. Basic thermodynamics and kinetics. Reactor choice and selection. Safety in design.

Unit V: Separation Methods (08)

Separation methods with specific reference to fine chemicals. Distillation, Extraction, Crystallization, Adsorption and Membrane Separation.

Unit VI: Production Plants (08)

Dedicated plants. Multiproduct and Multipurpose Plants. Mixed Plants. Production Cost. Design and Scheduling of Batch Plants. Production Planning and Scheduling. Principles of good manufacturing practice.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) Synthesis of sodium dodecyl benzene sulfonate.
2) 12 Alkyl dimethyl benzyl ammonium chloride
3) Determination of Acid value, iodine value, saponification value
4) Preparation of detergent
5) Preparation of vanishing cream flavor
6) Synthesis of benzyl alcohol
7) Synthesis of Cinnamaldehyde
8) Synthesis of Methoxynaphthalene
9) Synthesis of coumarin VI Pesticides
10) Preparation of water-soluble phenolic resin adhesive
11) Synthesis of urea-formaldehyde resin adhesive and modulation
12) Polyvinyl acetate latex paint preparation
13) Preparation of polyacrylate latex paint
14) Gel Preparation of Barium Titanate Nano-Powder

Reference Books:

1) Peter Pollak, “Fine Chemicals The Industry and Business”, Willey Interscience, 2007
2) Cybulski A., Sharma M.M., Moulign J.A., Sheldon R.A., “Fine Chemicals Manufacture Technology and Engineering”, Elsevier Science & Technology Books, 2001.
3) Rao C.S., “The Chemistry of Process Development in Fine Chemical and Pharmaceutical Industry”, Second Edition, John Wiley & sons, 2006
4) Stanley M., “Catalysis for Fine Chemical Synthesis”, John Wiley & Sons, 2006.

ELECTIVE-III (C)
412410 (C) COLLOIDIAL AND INTERFACE SCIENCE
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lecture: 4 Hr / week	**Paper: 100 marks**
Practical: 2 Hr / week	**Practical: 50marks**

Objectives:

1) To understand the basic terminology used in interface and colloid science.
2) To get acquainted with formation and stability considerations in case of a colloidal system.
3) To get familiarized with basic governing equations for interfacial phenomena.

SECTION – I

Unit I: Introduction to Interface and Colloidal Science (08)

Examples of surface and colloidal phenomena in industry and nature, Historical perspective. Areas where future research is needed, nature of interfaces, Surface free energy, Work of cohesion and adhesion, Surface activity and surfactant structures, Physical and chemical interactions between atoms and molecules interactions between surfaces and particles, Surface tension.

Unit II: Adsorption (08)

Gibbs Surface Excess, Gibbs Adsorption Isotherm, Adsorption at solid-vapour interface, Energetic considerations, Physical adsorption versus chemisorption, Chemisorption and catalysis, Solid-Vapour adsorption isotherms: Langmuir, Freundlich, BET, Adsorption at solid-liquid interfaces. Adsorption at liquid-liquid interfaces, Gibbs monolayers.

Unit III: Capillarity (08)

Capillary flow, Driving forces, Interfacial tension, Contact angle, Laplace expression for pressure difference across a curved interface, Capillary flow and spreading processes, Contact angle effects, Some practical capillary systems such as wetting in woven fibers and papers, repellency control, detergency, enhanced oil recovery.

SECTION-II

Unit IV: Electrostatic Forces and Electrical Double Layer (08)

Sources of interfacial charge, Electrostatic theory, Coulomb's law, Boltzmann's distribution and the Electrical double layer., Double layer thickness, Specific ion adsorption and the stern layer, Overview of electrokinetic phenomena (Electro-osmosis and Electrophoresis).

Unit V: Colloids and Colloidal Stability (08)

Working definition of colloids, Practical applications of colloids and colloids phenomena. Mechanisms of colloid formation, Sources of colloidal stability, Steric or entropic stabilization, Coagulation kinetics, DLVO theory and its applications.

Unit VI: Emulsions (08)

Emulsion formation, Classification of emulsifiers and stabilizers, Flocculation and coalescence. Adsorption at liquid-liquid interfaces, General considerations of emulsion formation and stability. Mechanistic details of stabilization, Solubility parameters, Hydrophilic-Lipophile balance. Phase inversion temperature, Association colloids such as micelles, Ionic and nonionic surfactants. Kraft temperature, Critical micelle concentration, Microemulsions.

Term Work:

Every student should carry out minimum *eight* experiments from the following list and submit the journal, which will form the term work.

List of Practicals:

1) To determine surface tension properties of different liquids.
2) To determine critical micelle concentration and mean aggregation number of a micellar system
3) To determine effect of salt concentration and temperature on CMC and aggregation number.
4) To verify the equation governing capillary flow.
5) To determine wetting / spreading behaviour of a liquid on given surface.
6) To examine electro-flocculation as a tool for colloidal precipitation.
7) To determine electro-phoretic behaviour of a colloid system.
8) To determine electro-osmotic behaviour of a colloid system.
9) To prepare a colloidal solution (such as Indian Ink) using colloid mill.
10) To determine surface area of a catalyst pellet using BET isotherm.
11) To verify Freundlich isotherm for acetic acid adsorption using charcoal.
12) To observe demonstrations of the following:
    a) Tyndall effect,
    b) Marangoni effect,
    c) Clarification of sugar cane juice,
    d) Spontaneous formation of microemulsion,
    e) Foam column stability,
    f) Froth floatation,
    g) Aerosol formation using atomizer.

Reference Books:

1) Drew Myers, “Surfaces, Interfaces and Colloids: Principles and Applications”, Second Edition, Wiley-VCH, 1999.
2) Adamson Arthur M.and Gast A.P., “Physical Chemistry of Surfaces”, Sixth Ed, John Wiley & Sons, 1997
3) Hiemenz P. C., Rajagopalan R., “Principles of Colloid and Surface Science”, Third Edition, Marcel Dekker, 1997.

ELECTIVE-III (D)
412410 (D) RENEWABLE ENERGY SOURCES
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lecture: 4 Hr / week	**Paper: 100 marks**
Practical: 2 Hr / week	**Practical: 50marks**

Objectives:

1) Provide an overview of the promising areas of new and renewable sources of energy.
2) Give an understanding of environmental consequences of energy conversion and how renewable energy can reduce air pollution and positively affect the global climate change.
3) Provide analysis of energy conversion, utilization and storage for renewable technologies and for more conventional fossil fuel-based technologies.

SECTION-I

Unit 1: Introduction (08)

Energy scene of supply and demand in India and the world, energy consumption in various sectors, potential of non-conventional energy resources, Solar distillation, Solar drying, Wind energy, Review of Tidal, Wave and ocean thermal energy, Geothermal energy.

Unit 2: Solar Energy (08)

Solar radiation and its measurement, limitations in the applications of Solar Energy, Solar collectors – types, and constructional details. Solar water heating, applications of Solar Energy for heating, drying, space cooling, water desalination, solar concentrators, photovoltaic power generation using silicon cells.

Unit 3: Bio-Fuels (08)

Importance, combustion, pyrolysis and other thermo chemical processes for biomass utilization. Alcoholic fermentation, anaerobic digestion for biogas production.

SECTION-II

Unit 4: Wind Power and Tidal Power (08)

Wind Power: Principle of energy from wind, windmill construction and operational details and electricity generation and mechanical power production.

Tidal Power: Its meaning, causes of tides and their energy potential, enhancement of tides, power generation from tides and problems, Principles of ocean thermal energy conversion (OTEC) analysis and sizing of heat exchangers for OTEC.

Unit 5: Geothermal Energy (08)

Geo technical wells and other resources dry rock and hot aquifer analysis, harnessing geothermal energy resources

Unit 6: Energy Storage and Distribution (08)

Importance, biochemical, chemical, thermal, electric storage, Fuel cells, Types of fuel cells: phosphoric acid, molten salt, solid oxide and other types of fuel cells, Anodes and cathodes. Fuel cells as alternative energy source, distribution of energy.

List of Practicals:

1. To study thermal performance of solar flat plate collector
2. To measure solar insolation
3. To find efficiency of a solar photovoltaic cell
4. To carry out performance analysis of a solar concentrator
5. To study wind energy conversion into electrical energy
6. To study novel uses of solar energy (such as solar pond, solar photocatalysis etc)
7. To study lead acid or any other battery as an energy storage device
8. To study mechanism of electrical energy distribution
9. To study products of biomass pyrolysis
10. To study design and operation of biomass gasifier

Reference Books:

1. Rai, G.D. 'Non-conventional Energy Sources', Khanna Publishers, Delhi.
2. Twiddle, J. Weir, T. 'Renewable Energy Resources,' Cambridge University Press, 1986.
3. Veziroglu, N., 'Alternative Energy Sources', Volume 5 & 6, McGraw-Hill, 1978.
4. Diwakar Rao P. L., 'Energy Conservation Handbook', Utility Publication Ltd., 1988.
5. Douglas C, 'Energy Technology Handbook', McGraw-Hill.

ELECTIVE-IV (A)
412411(A) PETROLEUM EXPLORATION AND PRODUCTION OPERATIONS
(B. E. Petrochemical Engineering. 2008 Course)

Teaching Scheme: **Examination Scheme:**
Lecture: 4 Hr / week **Paper: 100 marks**

Objectives:

1. To understand a petroleum reservoir system.
2. To understand the basic principles and operations in upstream petroleum industry

SECTION – I

Unit I: Distribution of Reserves (08)

Worldwide distribution of oil and gas reserves, Subsurface data sampling and data interpretation, Measurement scaling.

Unit II: Origin of Hydrocarbons (08)

Origin of hydrocarbons, accumulation and migration of hydrocarbons, Reservoir traps.

Unit III: Properties of Reservoir Rocks and Fluids (08)

Properties of reservoir rocks and fluids, Rock – fluid interface, Reservoir description by direct and indirect methods, Oil and Gas in place.

SECTION-II

Unit IV: Drilling Operations (08)

Drilling of oil and gas wells, Classification of wells, Drilling operating systems, Drilling fluids. New trends in drilling engineering.

Unit V: Well Stimulation (08)

Well completions and stimulations, Gun perforating, Hydrocarbon production techniques, Hydrocarbon recovery mechanisms, Artificial lift techniques, Secondary recovery.

Unit VI: Recent Development (08)

Non-conventional hydrocarbon energy sources, International trading in oil and gas, Recent developments.

Reference Books:

1. Bradley, "Petroleum Engineering Handbook", SPE
2. Mian, M. A., "Petroleum Engineering Handbook for Practicing Engineer", Vol. I and II, Pennwell Publication, 1992.
3. Deshpande, B.G., "World of Petroleum", Wiley, 1990.
4. John, F., Cook, M., and Graham, M., "Hydrocarbon Exploration and Production", Elsevier, 1998.

ELECTIVE-IV (B)
412411 (B) CATALYSIS SCIENCE AND TECHNOLOGY
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**

Objectives:

1. To understand the concepts of functionality of catalyst and kinetics of catalytic processes.
2. To develop idea of important properties of industrial catalysts, methods of manufacturing catalyst and its characterization.
3. To get acquainted with industrial catalytic reactors, their design and operations.

SECTION – I

Unit I: Catalytic Reaction Pathways (08)

Heterogeneous Catalysis, Selectivity, activity, functionality, active site, Turnover number, Inhibitor, Reaction Pathways, Adsorption, Adsorption Isotherm, Important Characteristics of Industrial Catalysts. Homogeneous catalysis.

Unit II: Kinetics of Catalytic Reaction (08)

Rate and Kinetics Models of Catalytic Reactions: Langmuir-Hinshelwood Model, Rideal Model, Identifying limiting step of reaction, Poisoning and Deactivation of Catalysts, Regenerability of Spent Catalyst.

Unit III: Manufacture of Catalysts and their Characterization (08)

Catalyst preparation and manufacturing: Precipitation Method, Impregnation, Special preparative Methods, Catalyst Supports, Promoters, Catalyst Characterization, Surface area, Pore Volume, Pore size Distribution, Mechanical Properties.

SECTION – II

Unit IV: Different Type of Catalysts (08)

Supported Metal Catalysts: Metal activity, Metal dispersion, Alloy catalysts, Sintering, Mobility, Redispersion, Carbon formation and Poisoning

Acid Catalysts: Source of acidity, Determination of acid strength, correlations between acidity and catalytic activity, mechanism of catalytic cracking, Acid-Base catalysts
Zelolites: Pore structure, Synthesis, Diffusion, Shape selective catalysis, Activity, Catalytic Cracking with zeolites.

Unit V: Processing of Petroleum and Hydrocarbons (08)

Catalytic cracking, Catalytic reforming: Catalyst dual functionality, Reactor configurations, Cyclizxation, Isomerization, Hydrodesulfurization: Kinetics, Trickle bed reactor, Hydrocraking

Unit VI: Industrial Applications in Petrochemical Industry (8)

Manufacture of phthalic anhydride: Reactor configuration, hot spot formation, Ethylene to ethylene oxide, Steam reforming: Catalysts, Reforming process, Fischer-Tropsch synthesis: Mechanism, Catalysts, Process, Water gas shift reaction: High temperature shift catalyst, Low temperature shift catalyst, Methanol synthesis: High temperature process, Low temperature process, Kinetics, Ammonia synthesis: Reactor configuration.

Reference Books:

1) Satterfield C. N., “Heterogeneous Catalysis in Industrial Practice”, Second Edition, McGraw Hill, 1993.
2) Smith J. M., “Chemical Engineering Kinetics”, Third Edition, McGraw Hill, 1984.
3) Froment G. F. and Bischoff, K. B. “Chemical Reactor Analysis and Design”, John Wiley & Sons, 1995.

ELECTIVE-IV (C)
412411(C) POLYMER REACTION ENGINEERING
(B. E. Petrochemical Engineering. 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hr / week	**Paper: 100 marks**

Objective

1) To understand the mechanism of polymerization and their effect on the engineering design of polymerization reactors.
2) To understand the distinguishing features of and challenges involved in polymer manufacturing processes as compared to monomer manufacturing processes.
3) To get acquainted with technologies used for manufacturing polymers at commercial scale

SECTION-I

Unit I: Introduction (08)

Conventional and Commercial approaches, Addition polymerization Kinetics, Condensation polymer kinetics, Ionic polymerization kinetics, Relationship between kinetic chain length and average degree of polymerization.

Unit II: Polyaddition reactions (08)

Kinetics and rates of polymerization of styrene, Methyl methacrylate, Ethylene, Polycondensation reactions –Characteristics, Homogeneous and heterogeneous polycondensation reaction kinetics, Maximum degree of polycondensation, Industrial polycondensation

Unit III: Kinetics of chain chemical reactions (08)

Characteristics of chain reactions, Stationary and non stationary chain reactions, Kinetics of branched chain reactions, Auto acceleration and inhibition of chain kinetics, Kinetics of inhibition

SECTION-II

Unit IV: Copolymerization (08)

Introduction, Classification of copolymers, Basic principles of copolymers, Kinetics of copolymerization, Mayo's copolymer equation, Determination of feed and polymer, Determination of monomer Reactivity ratios, Copolymerization for limiting cases, Types of copolymesr behavior, Overall rate of copolymerization, Alfrey Price Q–e scheme, Statistical derivation of copolymerization equation, Range and applicability, of copolymerization, variation of copolymer composition with conversion and applications of copolymerization, Rates of copolymerization for chemical and diffusion controlled termination, Examples.

Unit V: Emulsion and Suspension Polymerization (08)

Introduction to Smith- Ewart's emulsion polymerization kinetics, Experimental techniques in emulsion polymerization, Rates of polymerization for case I and case II, Estimation of total number of particles, Empirical correlations for emulsion polymerization, Vinyl Chloride suspension polymerization.

UNIT VI: Reactors for polymerization (08)

Batch, PFR, CSTR with residence time, average molecular weight and control strategies, Programmed operation of Polyaddition reactors, Low and high conversion reactors, Industrial Polymerization reactors.

Reference Books:

1. G.N. Burnett, “Mechanism of polymerization reaction”, Interscience, 1954.
2. Anil Kumar, S.K. Gupta, “Fundamentals of Polymer Science and Engineering”, Wiley, 1978.
3. G.S. Misra, “Introductory Polymer Chemistry”, Wiley Eastern Ltd., New Delhi, 1993.
4. F. Wilkinson, “Chemical Kinetics and Reaction Mechanism”, Van Norstrand Reinhold Company Ltd, England, 1980.
5. F. Rodrigues, “Principles of Polymers systems”, McGraw Hill, New York 1970
6. George Odian, “Principles of Polymerization”, 2nd Edition John Wiley and Sons, New York 1981.

ELECTIVE-IV (D)
412411 (D) OPEN ELECTIVE
(B. E. Petrochemical Engineering 2008 Course)

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 Hrs / week	**Paper: 100 Marks**

The students can opt for any elective subject of the same semester which is not offered or taken before. The elective subject may be related to the program or may be offered by any program under faculty or engineering, university of Pune.

412412 CHEMICAL ENGINEERING LABORATORY-II
(B. E. Petrochemical Engineering, 2008 Course)

Teaching Scheme: **Examination Scheme:**
Practical: 2 Hrs / week **Term Work: 50 Marks**

Objectives:

1) Develop operating procedures, design and conduct experiments, interpret experimental results and uncertainties, and draw valid conclusions
2) Prepare and evaluate written and oral reports based on chemical process project work
3) Use of Software Packages: Word, Excel, MATLAB, Aspen Plus, HYSYS

Term work:

Every student should carry out minimum *twelve* exercises from the following list and submit the journal, which will form the term work.

List of Experiments:

1. Continuous Reactive Distillation
2. Kinetics of a (Solid-Liquid) Esterification Reaction
3. Hydrodynamics of Air lift reactor
4. Reaction kinetics - batch, CSTR and PFR
5. Ion exchange ($CuSO_4$ removal from water and HCl regeneration)
6. Gas scrubber (CO_2 removal from air with NaOH or DEA)
7. Enzyme kinetics (glucose trinder reaction)
8. Residence Time distribution
9. Ion Exchange column
10. Agitation and Mixing
11. Multiphase Flow
12. Bioreactor
13. Froth Flotation
14. Ultrafiltration, Nanofiltration, Microfiltration
15. Pressure, Temperature, Liquid Level and flow Control by Microprocessor based PID Controller
16. Process Modeling and Simulation case studies using commercial software such as Aspen Plus, Hysys, and Unisim.

412407: PROJECT WORK

Teaching Scheme:
Practical: I term 2 hrs / week
Practical: II term 6 hrs / week.

Examination Scheme:
Term work: 100 Marks
Oral: 50 Marks

Objectives:

Project work aims at developing skills in the students whereby they apply the totality of knowledge and skills gained through the course in the solution of particular problem or undertaking a project. Students should work in a team in a planned manner on a chosen engineering topic based on the knowledge gained throughout the program. The project assignment can be individual assignment or a group assignment. There should not be more than three students if the project work is given for a group.

Contents:

Every student will be required to submit a project report in a typed form in standard format. Three identical copies should be bound and embossed according to University regulations. This project should be related to the curriculum, and should be either selected by the student or approved by the faculty member, who will guide the student, or assigned by the department.

The project work will consist of an investigation work, computer simulation, design problem or experimentation or set up of prototype equipment related to curriculum. Every student will be orally examined in the topic incorporated in the project and in the related area of specialization.

Students will be allotted project in a group. The project is to be completed in two parts: Project I in Semester I and Project II in Semester II. Each project will have one guide from the faculty. Students may be encouraged to choose a co guide from the industry, wherever possible.

Students are expected to carry out an in-depth literature survey based on chemical/engineering abstracts, national/international journals using online/print media.

A proper planning of the project work is expected. The project group should prepare activity chart and submit the same along with the reports for part I and part II. The group should also submit and present the work completed in semester I in an appropriate format. The actual contents of the project report may be decided in consultation with the project guide.

Stage I: This stage will include a report consisting of synopsis, the plan for experimental/theoretical work and the summary of the literature survey carried out till this stage. This stage will include comprehensive report on literature survey, design and fabrication of experimental set up and/or development of model, relevant computer programs and the plan for stage II.

Stage II: This is the final stage in the Project work. This stage will include comprehensive report on the work carried out at this stage and relevant portions from stage I, including experimental studies, analysis and/or verification of theoretical model, conclusions.