III year B.Tech Ist Semester (5th semester)

Sr. No.	Course Code	Course Title	L	T	P	Credits
1	CH 501	Chemical Engineering Thermodynamics - II	3	1	-	4
2	CH 502	Mass Transfer Operations - I	3	-	-	3
3	CH 503	Chemical Reaction Engineering - I	3	1	-	4
4	CH 504	Industrial Safety and Hazard Mitigation	3	-	-	3
5	CH 505	Elective – IV	3	-	-	3
6	CH 506	Elective - V	3	-	-	3
7	CH 507	Mass transfer Operations – I Lab	-	-	2	1
8	CH 508	Chemical Reaction Engineering – I Lab	-	-	2	1
9	CH 509	Soft Skills (Workshop)	-	-	2	1
		Total	18	2	6	23

II year B.Tech IInd Semester (6th semester)

Sr. No.	Course Code	Course Title	L	T	P	Credits
1	CH 601	Mass Transfer Operations - II	3	1	-	4
2	CH 602	Chemical Reaction Engineering - II	3	1	-	4
3	CH 603	Optimization Techniques	3	-	-	3
4	CH 604	Process Instrumentation	3	-	-	3
5	CH 605	Elective - VI	3	-	-	3
6	CH 606	Plant Utilities and Safety	3	-	-	3
7	CH 607	Mass Transfer Operations-II Lab	-	-	2	1
8	CH 608	Chemical Reaction Engineering - II Lab	-	-	2	1
9	CH 609	Seminar	-	-	2	1
10	CH 610	Industrial Training (to be attended by the students for 6 weeks during summer vacation and evaluation of which will be done in 7th Semester)	-	-	-	-
		Total	18	2	6	23

Elective

CH 505 Elective IV: A. Petroleum Refining & Petrochemicals
B. Fuel Cell Engineering C. Nuclear Process Engineering

CH 506 Elective V: A. Introduction to Polymer Science and Engineering
B. Fertilizer Technology **C.** Catalyst Science and Technology

CH 605 Elective VI: A. Food Technology B. Green Technology
C. Pharmaceuticals and Fine Chemicals

Semester V: Core Courses

1. CH 501 Chemical Engineering Thermodynamics - II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Calculate heat effects involved in industrial chemical processes
CO2	Determine thermodynamic properties of gaseous mixtures / solutions
CO3	Calculate Bubble-P & T, Dew-P & T for binary and multi-component systems
CO4	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems
CO5	Determine equilibrium constant and composition of product mixture at given temperature and pressure

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	✓	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

Unit I: **Vapour/Liquid Equilibrium Introduction**: The nature of equilibrium, the Phase Rule, Duhem's Theorem, VLE: Qualitative behaviour, Simple models for vapour/liquid equilibrium, VLE by modified Raoult's Law, VLE from K- value correlations.

Unit II: **Solution Thermodynamics: Theory:** Fundamental property relation, The chemical potential and phase equilibria, Partial properties, Ideal gas mixtures, Fugacity and fugacity coefficient.

Unit III: **Solution Thermodynamics: Theory:** (continued) Fugacity and fugacity coefficient: Species in the solution, Generalized correlations for the fugacity coefficient, The ideal solution, Excess properties.

Unit IV: **Solution Thermodynamics: Applications:** Liquid-phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing, Heat Effects of mixing processes.

Unit V: **Chemical Reaction Equilibria:** The reaction coordinate, Application of equilibrium criteria to chemical reactions, The standard Gibbs energy change and equilibrium constant, Effect of temperature on the equilibrium constants.

Unit VI: **Chemical Reaction Equilibria:** Relation of equilibrium constants to composition, Equilibrium conversions for single reactions, Phase rule and Duhem's theorem for reacting systems, Multi reaction equilibria, Fuel cells.

Text/Reference books:

1. J. M. Smith, H.C. Van Ness, and M.M. Abbott, Chemical Engineering Thermodynamics, 6thed, Tata McGraw Hill edition, 2003.
2. Y. V. C. Rao, "Chemical Engineering Thermodynamics", University Press 1997
3. S. I. Sandler. "Chemical Engineering Thermodynamics", Wiley, New York, 1999.

2. CH 502 Mass Transfer operations – I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand Fick's law of diffusion
CO2	Determine diffusivity coefficient in gases and liquids
CO3	Determine mass transfer coefficients
CO4	Calculate rate of mass transfer in humidification
CO5	Select equipment for gas-liquid operations

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	-	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	-	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed syllabus

Unit I: Diffusion in fluids - Fick's Law of diffusion equimolecular counter diffusion, diffusion in stationary gas. Maxwell's low of diffusion. Inter phase mass transfer - Mass transfer equilibrium, diffusion between two phases. Local mass transfer coefficient, Local and average overall mass transfer coefficients. Simultaneous heat and mass transfer.

Unit II: Material balance – steady state co current and counter current processes stage wise and differential contacts. Number of theoretical stages.Stage efficiency Height of mass transfer units.

Unit III: Gas Absorption - Equilibrium solubilities of gases.Material balance for transfer of one component. Counter current multistage operations for binary and multi component systems. Continuous contactors, absorption with chemical reaction.

Unit IV: Liquid–liquid extraction - Calculations with and without reflux for immiscible and partially miscible system.
Leaching - Leaching single and multistage operations based on solvent free co ordinates.

Unit V: ADSORPTION AND ION-EXCHANGE**:** Types of adsorption; Nature of adsorption; Freundlich equation; Types of adsorption; Nature of adsorption; Freundlich equation; Stage wise and continuous adsorption. Stage wise and continuous adsorption.Theory of ion – exchange and its application to removal of ionic impurity.

Unit VI: Gas–Liquid operations - Sparged vessels (bubble columns), mechanically agitated vessels for a single phase and gas liquid contact.liquid dispersed scrubbers, venturi scrubbers, wetted towers packed towers. Mass transfer coefficients for packed towers co-current flow of gas and liquid end effect and axial mixing.

Texts / References:

R. E. Treybal, Mass transfer operations, 3ed ed. McGraw Hill, 1980.
A. S. Foust et al. Principles of Unit Operations
J. M. Coulson and J. F. Richardson, “Chemical Engineering”, Vol. 1 ELBS, Pergaman press, 1970
J. M. Coulson and J. F. Richardson, “Chemical Engineering” Vol. 2 ELBS, Pergaman press, 1970

3. CH 503 Chemical Reaction Engineering – I

Course Outcomes: At the end of the course, students will be able to:

CO1	Compare the performance of ideal and non-ideal reactors using E- and F-curves
CO2	Determine the mean residence time and standard deviation using residence time distribution (RTD) data
CO3	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model
CO4	Understand the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer
CO5	Design fixed bed reactors involving chemical reactions with mass transfer
CO6	Determine internal and overall effectiveness factors

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO6	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Unit I: **Mole Balances** - Definition of the rate of reaction, General mole balance equation, Batch Reactors, Continuous-flow reactors, Industrial reactors

Unit II: **Conversion and Reactor Sizing** - Definition of conversion, Design equations, Applications of the design equations for continuous-flow reactors, Reactors in series

Unit III: **Rate-Law and Stoichiometry** - Basic definitions, Approach to reactor sizing and design, Stoichiometric table, expressing concentrations in terms other than conversion, Reactions with phase change

Unit IV: **Isothermal Reactor Design** - Design structure for isothermal reactors, Scale up of liquid-phase batch reactor data to the design of a CSTR, Tubular reactors, Recycle reactors

Unit V: **Collection and Analysis of Rate Data** - Batch reactor data, Method of initial rates, Method of half-life, Differential reactors, Least square analysis

Unit VI: **Catalysis and Catalytic Reactors** - Catalysts, Steps in a catalytic reaction, synthesizing a rate law, mechanism and rate-limiting step, Design of Reactors for gas-solid reactions, Heterogeneous data analysis for reactor design

Texts / References:

H. S. Fogler, “Elements of Chemical Reaction Engineering”, 3rd Ed, New Delhi-Prentice Hall, 2001

O. Levenspiel,” Chemical Reaction Engineering” Willey Eastern, 3rd Ed., 2000

J. M. Smith, “Chemical Engineering Kinetics”, 3rd Ed., McGraw- Hill, 1988

4. CH 504 Industrial Safety and Hazard Mitigation

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the effects of release of toxic substances.
CO2	Select the methods of prevention of fires and explosions.
CO3	Understand the methods of hazard identification and preventive measures.
CO4	Assess the risks using fault tree diagram.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-

Detailed syllabus

Unit I: Introduction: Safety Programs, Engineering Ethics, Accident and Loss Statistics, Acceptable Risk, Public Perceptions, Nature of the Accident Process, Inherent Safety. Industrial Hygiene: Anticipation and Identification, Hygiene Evaluation, Hygiene Control.

Unit II: Fires and Explosions: Fire Triangle, Distinction between Fires and Explosions, Flammability Characteristics of Liquids and Vapors, Limiting Oxygen Concentration and Inerting, Flammability Diagram

Unit III: Concepts to Prevent Fires and Explosions: Inerting, Controlling Static Electricity, Explosion-Proof Equipment and Instruments, Ventilation, Sprinkler Systems. Introduction to Reliefs: Relief Concepts, Location of Reliefs, Relief Types, Relief Scenarios, Data for Sizing Reliefs, Relief Systems.

Unit IV: Relief Sizing- Conventional Spring: Operated Reliefs in Liquid Service, Conventional Spring-Operated Reliefs in Vapor or Gas Service, Rupture Disc Reliefs in Liquid Service, Rupture Disc Reliefs in Vapor or Gas Service.

Unit V: Hazards Identification: Process Hazards Checklists, Hazards Surveys, Hazards and Operability Studies, Safety Reviews.

Unit VI: Safety Procedures and Designs: Process Safety Hierarchy, Managing Safety, Best Practices, Procedures—Operating, Procedures—Permits, Procedures—Safety Reviews and Accident Investigations, Designs for Process Safety.

Text / Reference:

1. D.A. Crowl and J.F. Louvar, Chemical Process Safety (Fundamentals with Applications), Prentice Hall,2011.

2. R.K. Sinnott, Coulson & Richardson's Chemical Engineering, Vol. 6, Elsevier India, 2006.

Semester V: Elective Courses

CH 505 Elective IV

A. Petroleum Refining & Petrochemicals

Course Outcomes: At the end of the course, the student will be able to:

CO1	State the composition of petroleum.
CO2	Understand the unit operations and processes in petroleum refining
CO3	Understand the technologies for conversion of petroleum refining products to chemical products
CO4	Select feed stock for conversion to products

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

DETAILED SYLLABUS:

Unit I: **ORIGIN, FORMATION AND COMPOSITION OF PETROLEUM**: Origin and formation of petroleum, Reserves and deposits of world, Indian Petroleum Industry, composition of petroleum. **PETROLEUM PROCESSING DATA**: Evaluation of petroleum, thermal properties of petroleum fractions, important products, properties and test methods.

Unit II: **FRACTIONATION OF PETROLEUM**: Dehydration and desalting of crudes, heating of crude-pipe still heaters, distillation of petroleum, blending of gasoline. **TREATMENT TECHNIQUES**: Fraction-impurities, treatment of gasoline, treatment of kerosene, treatment of lubes.

Unit III: **THERMAL AND CATALYTIC PROCESSES**: Cracking, catalytic cracking, catalytic reforming, Naphtha cracking, coking, Hydrogenation processes, Alkylation processes, Petrochemical Industry – Feed stocks

Unit IV: **CHEMICALS FROM METHANE**: Introduction, production of Methanol, Formaldehyde, Ethylene glycol, PTFE, Methylamines. **CHEMICALS FROM ETHANE-ETHYLENE-ACETYLENE**: Oxidation of ethane, production of Ethylene, Manufacture of Vinyl Chloride monomer, Vinyl Acetate manufacture, Ethanol from Ethylene, Acetylene manufacture, Acetaldehyde from Acetylene.

Unit V: **CHEMICALS FROM C3, C4 AND HIGHER CARBON ATOMS**: Chemical from Propylene, manufacture of Isopropanol, manufacture of Acrylonitrile, production of Acrylic acid, polymers and copolymers of propylene, production of Phenol from cumene, production of Bisphenol-A, manufacture of maleic Anhydride, production of Acetic acid and production of Butadiene from Butane.

Unit VI: **SYNTHESIS GAS AND CHEMICALS**: Steam reforming of hydrocarbons, production of synthesis gas, SNG from Naphtha, Synthesis gas via partial Oxidation.

TEXT BOOKS:

1. B.K. BhaskaraRao - Modern Petroleum Refining Processes - 3rd edition, Oxford & IBH Publishing Co. Pvt. Ltd., Jan. 1997.
2. B.K. BhaskaraRao - A Text of Petrochemicals - 2nd edition, Khanna Publications, 1998.

REFERENCE BOOK:

1. W.L. Nelson - Petroleum Refinery Engineering; McGraw Hill Book Company.

A. Fuel Cell Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	State the composition of Fuel Cell
CO2	Understand the unit operations and processes in Fuel Cell.
CO3	Understand the technologies for conversion of Fuel Cell products to chemical products
CO4	Select feed stock for conversion to products

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

DetailedSyllabus:

Unit I: Overview of Fuel Cells: What is a fuel cell, brief history, classification, how does it work, why do we need fuel cells, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency.

Unit II: Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others.

Unit III: Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.

Unit IV: Fuel cell process design: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, Fuel cell operating conditions: pressure, temperature, flow rates, humidity.

Unit V: Main components of solid-oxide fuel cells, Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modeling

Unit VI: Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal, Using renewable fuels for SOFCs

Text / Reference:

1. Hoogers G., Fuel Cell Technology Hand Book, CRC Press, 2003.
2. Karl Kordesch& Gunter Simader, Fuel Cells and Their Applications, VCH Publishers, NY, 2001.
3. F. Barbir, PEM Fuel Cells: Theory and Practice, 2nd Ed., Elsevier/Academic Press, 2013.
4. Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications, 2003.
5. O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, NY 2006.

B. Nuclear Process Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand radioactivity, nuclear fission and fusion.
CO2	Understand the interaction of alpha, beta particles and neutrons with matter
CO3	Understand neutron cycle, critical mass, reactor period and transient conditions
CO4	Understand engineering aspects of nuclear power production and environmental effects.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO3	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	-	-	-	-	-

Detailed Syllabus

Unit I: Nuclear Energy Fundamentals: Atomic structure and Radio isotopes, Nuclear fission and fusion, types and classification of nuclear reactors, nuclear fuels, other reactor materials, fuel processing flow sheet, chemical processes for nuclear power industries, separation of reactor products, nuclides.

Unit II: Nuclear Reactions and radiations: Radioactivity, interaction of alpha and beta particles with matter, decay chains, neutron reactions, fission process, growth and decay of fission products in a reactor with neutron burnout and continuous processing.

Unit III: Make up of reactor, reactor fuel process flow sheet, irradiation schemes, neutron balance, feed requirements and fuel burn up for completely mixed fuels with no recycle.

Unit IV: Nuclear Reactor theory: The neutron cycle, critical mass, neutron diffusion, the diffusion equation, slowing down of neutrons, reactor period, transient conditions and reflectors.

Unit V: Engineering Consideration of nuclear Power-Environmental effects: Introduction to nuclear power systems, Thermal-hydraulics: Thermal parameters: definitions and uses. Sources and distribution of thermal loads in nuclear power reactors. Conservation equations and their applications to nuclear power systems: power conversion cycles, containment analysis.

Unit V: Thermal analysis of nuclear fuel, Single-phase flow and heat transfer, Two-phase flow and heat transfer.

Text / Reference:

1. Glasstone S and AlexenderSeasonske, *Nuclear Reactor Engineering*, *3rd Edition*, CBS publisher, USA, 1994.
2. K. Sriram, *Basic Nuclear Engineering*, Wiley Eastern Ltd., 1990.
3. W Marshall, *Nuclear Power Technology*, Vol I, II, and III, Oxford University Press, New York 1983.

CH 506 Elective V

A. Introduction to Polymer Science and Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand thermodynamics of polymer structures
CO2	Select polymerization reactor for a polymer product.
CO3	Characterize polymers.
CO4	State polymer additives, blends and composites.
CO5	Understand polymer rheology

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO5	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-

Detailed Syllabus:

Unit I: **Introduction:** Basic concepts of Polymer Science, Various molecular forces in polymer, Various Molecular weights and their distribution.

Unit II: **Polymerization:** (i) Step growth: Mechanism, Kinetics, Polyfunctional Step growth polymerization. (ii) Radical polymerization: Mechanism, Kinetics, Effects of temperature, pressure. (iii) Ionic and Coordination Polymerization: Kinetics of Cationic and Anionic polymerization.

Unit III: **Polymerization Conditions:** Bulk, Solution, Suspension and Emulsion polymerization.

Unit IV: **Measurement of Molecular Weight:** End group analysis, Colligative property measurement, Gel Permeation Chromatography.

Unit V: **Polymer Processing:**Plastic technology: Molding, Extrusion, Additives and Compounding;

Unit VI: **Fiber Technology:**Textile and Fabric properties, Spinning, Elastomer technology: Vulcanization, Reinforcement.

Text/References:

1. Text book of Polymer Science: Fred W. Billmeyer, Jr., Second Edition, 1994, John Wiley and Sons, Inc., Singapore.
2. Principals of Polymerization, George Odian, Third Edition, 2002, John Wiley and Sons, Inc., Singapore.
3. Fundamentals of Polymers, Anil Kumar and Gupta, R. K., McGraw Hill, 1998.

B. Fertilizer Technology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Classify fertilizers
CO2	Explain manufacturing processes involved in production of fertilizers
CO3	Identify the effect of technologies on the health, safety and environment
CO4	State the chemical reactions and their mechanism involved

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO2	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO3	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO4	✓	✓	-	-	-	-	✓	-	-	-	-	-

Detailed Syllabus:

Introduction: Elements required for plants growth, Classification of fertilizers, Compound,

Complex and bulk blended fertilizers. N-P-K values and calculations.

Nitrogenous Fertilizers: Manufacturing Processes for Ammonia, Manufacture of ammoniumsulphate, ammonium chloride, Ammonium phosphate, Ammonium nitrate, nitric acid, Urea etc.

Economics and other strategies, Material of construction and corrosion problem.

Phosphatic fertilizers: Calculation of percentage tricalcium phosphate of lime in phosphatic rock: Manufacture of triple super phosphate and single super phosphate, Nitro phosphate, Sodium phosphate, phosphoric acid and other phosphatic fertilizers.

Potash Fertilizers: Manufacture of potash fertilizers like potassium sulphate, potassium chloride etc.

Text / Reference:

1. Sittig M and Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21st Century, 3rd Edition, WEP East West Press, 2010.

2. Austin G T., Shreve's Chemical Process Industries, McGraw Hill Book Company, New Delhi, 5th Edition, 1986.

3. Shukla S D and Pandey G N, A Text Book of Chemical Technology, Vol I & II, Vikas Publishing House Pvt. Ltd., New Delhi, 2000

C. Catalyst Science and Technology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand details of catalytic processes
CO2	Understand characterization of catalyst
CO3	Apply knowledge for catalyst selectivity
CO4	Know in newer development in the field of catalysis

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												

Detailed Syllabus:

UNIT I Heterogeneous catalytic processes, types of heterogeneous reactions. Absorption, absorption isotherms, rates of absorption, Physisorption and chemisorptions. Solid catalysis, types of catalysts, catalyst formulations and Preparation methods.

UNIT II Catalysts Characterization methods: Surface area and pore volume determinations, XRD, various Spectroscopic techniques, Temperature programmed reduction & oxidation, Electron microscopy.

UNIT III Testing of catalysts, various types of reactors, activity and selectivity studies. Effect of external transport processes on observed rate of reactions. Effect of internal transport processes: reactions and diffusion in porous catalysts.

UNIT IV Mechanism of catalytic reactions, Rates of adsorption, desorption, surface reactions, rate determining steps. Kinetic modelling and Parameter estimations, Model discriminations.

UNIT V Catalysts promoters, Inhibitors, catalyst deactivations, kinetics of catalyst deactivations. Industrial processes involving heterogeneous solid catalysts.

UNIT VI New development in solid catalysis, monolith catalysts, Nano catalysts, Fuel cell catalysts, Environmental catalysts, Insitu characterization.Design of catalysts; simulation techniques.

Semester V: Labs

1. CH 507 Mass Transfer Operations - I Lab

Course Outcomes: At the end of the course, students will be able to:

CO1	Determine efficiency of steam distillation
CO2	Plot mutual solubility curve for acetone-methyl-iso-butyl-ketone and water
CO3	Determine the overall plate efficiency of sieve plate distillation
CO4	Verify Rayleigh's equation for batch distillation
CO5	Determine HETP and HTU for given packing for distillation of benzene-acetone mixture under tota reflux
CO6	Determine the critical moisture content in drying

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	✓	-	✓	-
CO2	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO3	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO4	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO5	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO6	✓	-	✓	-	-	-	-	-	✓	-	✓	-

LIST OF PRACTICALS:

1. To determine the diffusivity of acetone in air
2. To determine the diffusivity of carbon tetra chloride in air
3. To study the absorption with chemical reaction in packed bed
4. To study multistage cross-current leaching operation for calcium carbonate, sodium hydroxide water system.
5. To draw equilibrium solubility diagram for an acetic acid, benzene, water.
6. To study counter-current single stage extraction process for water(A), acetic acid(B) and benzene(C) system
7. To study liquid-liquid extraction in packed bed (HTU/NTU)
8. To study the physical absorption in packed bed (HTU/NTU)

2. CH 508 Chemical Reaction Engineering - I Lab

Course Outcomes: At the end of the course, the student will be able to:

CO1	
CO2	
CO3	
CO4	

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4												

List of Practicals

1. Determine activation energy of acid catalyzed hydrolysis of methyl acetate.
2. To study effect of concentration of reactant and temperature on the rate of reaction.
3. To determination of specific reaction rate of acid catalyzed hydrolysis of ethyl acetate
4. Determination of specific reaction rate of acid catalyzed hydrolysis of ethyl acetate by sodium hydroxide at 298 K
5. To study the reaction between potassium persulphate and iodide
6. Kinetics of hydrolysis of methyl acetate by strong acid.
7. To study saponification of ethyl acetate.
8. Study of Isothermal continuous stirred tank reactor

CH 509 Soft Skills (Workshop)

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand corporate communication culture
CO2	Prepare business reports and proposals expected of a corporate professional
CO3	Employ appropriate speech in formal business situations
CO4	Exhibit corporate social responsibility and ethics
CO5	Acquire corporate email, mobile and telephone etiquette

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	-	-	-	-	✓	-	✓	-
CO2	-	-	-	-	-	-	-	-	✓	-	✓	-
CO3	-	-	-	-	-	-	-	-	✓	-	✓	-
CO4	-	-	-	-	-	-	-	-	✓	-	✓	-
CO5	-	-	-	-	-	-	-	-	✓	-	✓	-

Detailed Syllabus:

This course is mainly intended to improve the different soft skills of the students. The following aspects will be covered in this course.

1. Report writing skills
2. Preparing report as per the given format using computer (MS word)
3. Preparing documents in MS Word & EXCEL formats.
4. Preparing slides for power point presentation
5. Reading & listening skills
6. Public speaking skills

Semester VI: Core Courses

1. CH 601 Mass Transfer Operations – II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Select solvent for absorption and extraction operations
CO2	Determine number of stages in distillation, absorption and extraction operations
CO3	Determine the height of packed column in absorption, distillation and extraction
CO4	Calculate drying rates and moisture content for batch and continuous drying

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: **Distillation** - Vapour liquid equilibria, flash vapourisation, batch distillation, differential distillation.

UNIT II: **Continuous fractionation -** Binary systems, Mc-Cabe.Thiele and PonchonSavarit method calculations with multiple feeds and withdrawal

UNIT III: **Humidification** - Vapour liquid equilibrium, enthalpy for pure substances, vapour gas contact operation. Psychrometric charts and measurement of humidity
Dehumidification and Cooling Tower Design - Adiabatic and non adiabatic operations evaporative cooling, cooling tower design and dehumidification methods.

UNIT IV: **Drying** - Drying equilibrium and rate of drying, drying operation batch and continuous number of transfer units.

UNIT V: **Crystallisation** - Theories of crystallisation nucleation and crystal growth. principles of supe saturation. different types of crystallisers.

UNIT-VI: **Special topics in separation:** Types of membranes for osmosis and dialysis; Mechanism of solute/solvent rejection in the process; Design of R.O. and dialysis units; applications.

Texts / References:

R. E. Treybal, Mass transfer operations, 3ed ed. McGraw Hill, 1980.
J. M. Coulson and J. F. Richardson, “Chemical Engineering”, Vol. 1 ELBS, Pergamon press, 1970
J. M. Coulson and J. F. Richardson, “Chemical Engineering” Vol. 2 ELBS, Pergamon press, 1970

2. CH 602 Chemical Reaction Engineering – II

Course Outcomes: At the end of the course, students will be able to:

CO1	Compare the performance of ideal and non-ideal reactors using E- and F-curves.
CO2	Determine the mean residence time and standard deviation using residence time distribution (RTD)
CO3	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model
CO4	Understand the effect of velocity, particle size and fluid properties on rate of reactions cntrolled by mass transfer
CO5	Design fixed bed reactors involving chemical reactions with mass transfer
CO6	Determine internal and overall effectiveness factors

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO6	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: **Multiple Reactions -** Maximizing desired product in parallel reactions, Maximizing desired product in series reactions, Stoichiometric table using fractional conversion

UNIT II: **Multiple reactions in PFR and CSTR –** An alternative approach to using fractional conversion

UNIT III: **Nonelementary Reaction Kinetics -** Fundamentals, Searching for a mechanism, polymerization, enzyme reaction fundamentals, Bioreactors

UNIT IV: **External Diffusion Effects on Heterogeneous Reactions -** Mass transfer fundamentals, Binary diffusion, External resistance to mass transfer, The shrinking core model

UNIT V: **Distribution of Residence times for Chemical Reactors -** General characteristics, Measurement of RTD, Characteristics of RTD, RTD in ideal reactors, Reactor modeling with RTD, Zero-parameter models

UNIT VI: **Models for non-ideal reactors -** One-parameter models; tank-in-series model, dispersion model

Texts / References:

H. S. Fogler, "Elements of Chemical Reaction Engineering", 3^{rd} Ed, New Delhi-Prentice Hall, 2001
O. Levenspiel," Chemical Reaction Engineering" Willey Eastern, 3^{rd} Ed., 2000
J. M. Smith, "Chemical Engineering Kinetics", 3^{rd} Ed., McGraw- Hill, 1988

3. CH 603 Optimization Techniques

Course Outcomes: At the end of the course, the student will be able to:

CO1	Formulate and solve linear Programming Problems
CO2	Determine the optimum solution to constrained and unconstrained problems
CO3	Apply dynamic programming principle to Linear programming problems
CO4	Determine the integer solutions to Linear Programming Problems

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	✓	✓	-	-	✓	-	-	-
CO2	-	-	-	-	✓	✓	-	-	✓	-	-	-
CO3	-	-	-	-	✓	✓	-	-	✓	-	-	-
CO4	-	-	-	-	✓	✓	-	-	✓	-	-	-

Detailed Syllabus:

UNIT I: Single-variable optimization algorithms: Optimal problem formulation, Optimization algorithms, Optimality criteria, Bracketing methods, Region-elimination methods, Point-estimation method, Gradient based methods, Root finding using optimization techniques.

UNIT II: Multi-variable optimization algorithms: Unidirectional search, Direct search methods, Gradient based methods.

UNIT III: Constrained optimization algorithms: Kuhn-Tucker conditions, Transformation methods,

UNIT IV: Sensitivity analysis, Direct search for constrained minimization, Linearized search techniques, Feasible direction method, Generalized reduced gradient method, Gradient projection method

UNIT V: Specialized algorithms: Integer programming, Geometric programming.

UNIT VI: Nontraditional optimization algorithms: Genetic algorithms, Simulated annealing, Global optimization.

Texts / References:

Deb K., Optimization for Engineering Design, Algorithms and Examples, Prentice Hall of India, New Delhi 1996

4. CH 604 Process Instrumentation

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the measurement techniques for Pressure and Temperature
CO2	Understand the measurement techniques for Flow and Level
CO3	Understand recording, indicating and signaling instruments
CO4	Analyze repeatability, precision and accuracy of instruments

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	-	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	-	-	✓	✓	-	-	-	-	-	-	-
CO3	✓	-	-	✓	✓	-	-	-	-	-	-	-
CO4	✓	-	-	✓	✓	-	-	-	-	-	-	-

Detailed syllabus

Unit I: Characteristics of Measurement System -Elements of instruments, static and dynamic characteristics, basic concepts of response of first order type instruments, mercury in glass thermometer, bimetallic thermometer, pressure spring thermometer, static accuracy and response of thermometers.

Unit II: Pressure Measurement- Pressure, vacuum and head manometers, measuring elements for gage pressure and vacuum, measuring pressure in corrosive liquids, measuring of absolute pressure, static accuracy and response of pressure gages.

Unit III: Temperature Measurement–Industrial thermocouples, thermocouple wires, thermo couple wells and response of thermocouples.

Unit IV: Flow Measurement- head flow meters, open channel meters, area flow meters, flow of dry materials, viscosity measurement.

Unit V: Level Measurement- direct measurement of liquid level, level measurement in pressure vessels, measurement of interface level, level of dry materials.

Unit VI: Instruments for Analysis - recording instruments, indicating and signaling instruments, instrumentation diagram.

Text / Reference:

1. Patranabis D, Principles of Industrial Instrumentation, 2nd Edition, Tata McGraw Hill Publishing Company, New Delhi, 1999.

2. EckmanDonald P., Industrial Instrumentation, Wiley Eastern Ltd., 2004.

3. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, 1st Edition, Tata McGraw-Hill Education Private Limited, 2009.

5. CH 606 Plant Utilities and Safety

Course Outcomes: At the end of the course, the student will be able to:

CO1	List utilities in a plant.
CO2	Understand properties of steam and operation of boilers for steam generation
CO3	Understand refrigeration methods used in industry
CO4	Compare power generation methods
CO5	Classify and describe the types of water, water treatment methods, storage and distributior techniques

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO4	✓	-	✓	✓	-	✓	-	-	-	-	-	-
CO5	✓	-	✓	✓	-	✓	✓	-	-	-	-	-

Detailed Syllabus:

UNIT I: Identification of common plant utilities: water, compressed air, steam, vacuum, refrigeration, venting, flaring and pollution abating. Water and its quality, storage and distribution for cooling and fire fighting.

UNIT II: Steam generation by boilers: Types of boilers and their operation, Steam generation by utilizing process waste heat using thermic fluids, Distribution of steam in a plant.

UNIT III: Principles of refrigeration: Creation of low temperature using various refrigerants.Creation of low pressure/vacuum by pumps and ejectors.

Unit IV: Safety in Chemical Processes: Introduction, Chemical Process classification, Process design and safety parameters. Safety parameters in the process design of phenol from cumene, safety in polyvinyl chloride plant.
Chemicals and their Hazards: Introduction, Acetonitrile, acetyl chloride, butyl amine, acrylamide, acrylonitrile, allyl alcohol, benzene, bromine, isopropyl alcohol, acetaldehyde, ethylene oxide, butane, n-hexane, anhydrous ammonia, acetone, toluene, p-xylene, acetic acid, monochloro benzene, oleum, carbon mon

Unit V: Hazards in Chemical Process plants: Introduction, Hazards, Hazard code and explosive limit, electrical safety in chemical process plants, static electricity hazards, pressure vessel hazards, LEL and UEL of various compounds, explosive hazard, flammable liquid hazards, protection to storage tanks, fire zone location, fireball, fireball hazard. Safety in handling gases, liquids and solids: Introduction, safety in handling of gases, chlorine hazards, chlorine leakage management, safety in handling of fluorine, important safety considerations in ammonia storage, flammable solids storage, flammable liquid storage, handling of LNG, requirements to be fulfilled for storing hydrocarbons or chemicals, fail safe concept, transportation of hazardous chemicals, Hazardous in plastics processing.

Unit VI: Combating Chemical Fires: Classification of fires, control of high vaour pressure fire, fire fighting foams, foam for fire protection, Foam characteristics, gaseous agent extinguishing system, automatic sprinkler system, chemical extinguishing powders, natural gas fire control. Portable fire extinguishers: Soda-acid extinguishers, carbon dioxide extinguisher, dry chemical fire extinguisher, general safety precautions for maintenance of fire extinguishers.

Safety Checklist: safety studies for chemical plants, safety checklist during startup, safety checklist during shutdown mode, safety checklist for installation, safety needs during construction. Protective devices.

Text / Reference:

1. D. A. Wangham, Theory and practice of Heat engines, ELBS cambridge University press, 1970.
2. J. L. Threlkeld, Thermal Environmental Engineering, Prentic Hall 1970.
3. S.D.Dawande, Chemical Hazards and safety, Dennet& Co publishers, 2007

Semester VI: Elective Courses

CH 605 Elective VI

A. Food technology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Explain techniques in food processing
CO2	Design process equipment to achieve the desired quality of food
CO3	Develop novel food processes that have a minimal effect on food quality
CO4	Design efficient controllers to maintain food quality

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	-	-

Detailed Syllabus

Unit 1: Introduction: General aspects of food industry, World food demand and Indian scenario, Constituents of food, Quality and nutritive aspects, Product and Process development, engineering challenges in the Food Processing Industry.

Unit 2: Basic principles: Properties of foods and processing theory, Heat transfer, Effect of heat on micro-organisms, Basic Food Biochemistry and Microbiology: Food Constituents; Food fortification, Water activity, Effects of processing on sensory characteristics of foods, Effects of processing on nutritional properties, Food safety, good manufacturing practice and quality Process Control in Food Processing.

Unit 3: Ambient Temperature Processing: Raw material preparation, Size reduction, Mixing and forming, Separation and concentration of food components, Centrifugation, Membrane concentration, Fermentation and enzyme technology, Irradiation, Effect on micro-organisms, Processing using electric fields, high hydrostatic pressure, light or ultrasound.

Unit 4: Heat processing using steam, water and air: Blanching, Pasteurisation, Heat sterilization, Evaporation and distillation, Extrusion, Dehydration, Baking and roasting.

Unit 5: Heat processing by direct and radiated energy: Dielectric heating, Ohmic heating, Infrared heating.

Unit 6: Post Processing Applications Packaging: Coating or enrobing, Theory and Types of packaging materials, Printing, Interactions between packaging and foods, Environmental considerations.

Text / Reference:

1. Fellows P., Food Processing Technology: Principles and Practice, 2nd Edition, Woodhead Publishing, 2000.

2. Toledo R, Fundamentals of Food Process Engineering, 3rd Edition, Springer, 2010.

3. Singh, R.P. &Heldman, D.R., Introduction to Food Engineering, 3rd Edition, Academic Press, UK, 2001.

4. Smith J.M., Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981

B. Green technology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand principles and concepts of green chemistry
CO2	Develop manufacturing processes to reduce wastage and energy consumption
CO3	Design the technologies to reduce the level of emissions from buildings and core infrastructure
CO4	Analyze the effects of pollutants on the environment

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO2	✓	✓	✓	-	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	-	-

Detailed Syllabus

Unit 1: Principles and concepts of Green Chemistry: Introduction, Sustainable Development and Green Chemistry, Atom Economy, Atom Economic Reactions, Rearrangement Reactions, Addition Reactions, Atom Un-economic Reactions, Substitution Reactions, Elimination Reactions, Wittig Reactions, Reducing Toxicity, Measuring Toxicity.

Unit 2: Waste- Production, Problems and Prevention: Introduction, Some Problems Caused by Waste, Sources of Waste from the Chemical Industry, The Cost of Waste, Waste Minimization Techniques, The Team Approach to Waste Minimization, Process Design for Waste Minimization, Minimizing Waste from Existing Processes, On-site Waste Treatment, Physical Treatment, Chemical Treatment, Biotreatment Plants, Design for Degradation, Degradation and Surfactants, DDT, Polymers, Some Rules for Degradation, Polymer Recycling, Separation and Sorting, Incineration, Mechanical Recycling, Chemical Recycling to Monomers.

Unit 3: Measuring and controlling environmental performance: The Importance of Measurement, Lactic Acid Production, Safer Gasoline, Introduction to Life Cycle Assessment, Green Process Metrics, Environmental Management Systems, The European Eco-management and Audit Scheme, Eco-labels, Legislation, Integrated Pollution Prevention and Control. Catalysis and green chemistry: Introduction to Catalysis, Comparison of Catalyst Types, Heterogeneous Catalysts, Basics of Heterogeneous Catalysis, Zeolites and the Bulk ChemicalIndustry, Heterogeneous Catalysis in the Fine Chemical and Pharmaceutical Industries, Catalytic Converters, Homogeneous Catalysis, Transition Metal Catalysts with Phosphine Ligands, Greener Lewis Acids, Asymmetric Catalysis, Phase Transfer Catalysis, Hazard Reduction, C–C Bond Formation, Oxidation Using Hydrogen Peroxide, Biocatalysis, Photocatalysis.

Unit 4: Organic solvents, Environmentally benign solutions: Organic Solvents and Volatile Organic Compounds, Solvent-free Systems, Supercritical Fluids, Supercritical Carbon Dioxide, Supercritical Water, Water as a Reaction Solvent, Water-based Coatings, Ionic Liquids, Ionic Liquids as Catalysts, Ionic Liquids as Solvents, FluorousBiphase Solvents. Renewable resources: Biomass as a Renewable Resource, Energy, Fossil Fuels, Energy from Biomass, Solar Power, Other Forms of Renewable Energy, Fuel Cells, Chemicals from Renewable Feedstocks, Chemicals from Fatty Acids, Polymers from Renewable Resources, Some Other Chemicals from Natural Resources, Alternative Economies, The Syngas Economy, The Biorefinery, Chemicals from renewable feed stocks.

Unit 5: Emerging Greener technologies and Alternative energy solutions: Design for Energy Efficiency, Photochemical Reactions, Advantages of and Challenges Faced by Photochemical, Processes, Examples of Photochemical Reactions, Chemistry Using Microwaves, Microwave Heating, Microwave-assisted Reactions, Sonochemistry, Sonochemistry and Green Chemistry, Electrochemical Synthesis, Examples of Electrochemical Synthesis. Designing greener processes: Conventional Reactors, Batch Reactors, Continuous Reactors, Inherently Safer Design, Minimization, Simplification, Substitution, Moderation, Limitation, Process Intensification, Some PI Equipment, Examples of Intensified Processes, In-process Monitoring, Near-infrared Spectroscopy.

Unit 6: Industrial case studies: A Brighter Shade of Green, Greening of Acetic Acid Manufacture, EPDM Rubbers, Vitamin C, Leather Manufacture, Tanning, Fatliquoring, Dyeing to be Green, Some Manufacturing and Products Improvements, Dye Application, Polyethene, Radical Process, Ziegler–Natta Catalysis, Metallocene Catalysis, Eco-friendly Pesticides, Insecticides. An integrated approach to a greener chemical industry: Society and Sustainability, Barriers and Drivers, The Role of Legislation, EU White Paper on Chemicals Policy, Green Chemical Supply Strategies.

Text / Reference:

1. Mike Lancaster, Green Chemistry, Royal Society of Chemistry, 2010.
2. Paul T. Anastas John C. Warner, Green Chemistry: Theory and Practice, Oxford University Press, 2000.
3. Jay Warmke, Annie Warmke, Green Technology, Educational Technologies Group, 2009.

C. Pharmaceuticals and Fine Chemicals

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the grades of chemicals
CO2	State properties, uses and testing of pharmaceuticals and fine chemicals
CO3	Draw flow sheets for manufacture of pharmaceuticals and fine chemicals
CO4	Understand tablet making and coating, preparation of capsules and extraction of crude drugs
CO5	Understand sterilization

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	-	-	-	-	-	-	-	-	-	-
CO2	✓	✓	-	-	-	-	-	-	-	-	-	-
CO3	✓	✓	-	-	-	-	-	-	-	-	-	-
CO4	✓	-	-	✓	-	-	-	-	-	-	-	-
CO5	✓	-	-	✓	-	✓	-	-	-	-	-	-

Unit 1: A brief outline of different grades of chemicals – Reagent grade and Laboratory grade.

Unit 2: Outlines of preparation – Different methods of preparation of Reagent grade and Laboratory grade Chemicals.

Unit 3: Uses and testing of the pharmaceuticals and fine chemicals – Applications of medicinal value Chemicals and their quality testing procedures.

Unit 4: Properties, assays and manufacture of Pharmaceuticals and fine chemicals with flow sheets-Physical and Chemical properties, methods of assessing the quality and industrial methods of formulating the drugs and fine chemicals that have no medicinal value but are used as the intermediates.

Unit 5: Compressed Tablet making and coating – Types of tablets and Methods of compressed tablet making and coating.

Unit 6: Preparation of capsules and extraction of crude drugs – Industrial procedures of capsule formulation and methods of recovering the drugs formulated from the reaction mixture. Sterilization – Need for sterilization, Sterilization methods, batch and continuous sterilization.

Text / Reference:

1. Remington, Pharmaceutical Sciences, Mak. Publishing Co., 16th Edition, 1980.
2. William Lawrence Faith, Donald B. Keyes and Ronald L. Clark, Industrial Chemicals, 4th Edition, John Wiley & Sons, 1975.
3. Gurdeep R. Chatwal, Synthetic Drugs, Himalaya Publishing House, 2002.

Semester VI: Labs

2. CH 607 Mass Transfer Operations – II Lab

LIST OF PRACTICALS

1. T-x-y diagram for water-acetone system
2. To prove Rayleigh equation by carrying out simple distillation of methanol-water system
3. To carry out crystallization of given salt
4. To determine rate of drying of given sample and to plot (kg moisture content/ kg of dry solid) V/S time and rate of drying V/S time
5. To study Swenson Walker crystallizer
6. Determination of HETP (Height equivalent to theoretical plate)
7. Study of fluidized bed dying
8. Study of steam distillation

3. CH 608 Chemical Reaction Engineering – II Lab

Course Outcomes: At the end of the course, students will be able to:

CO1	Determine the kinetics of chemical reaction in Batch reactor, CSTR, PFR
CO2	Determine the kinetics using Dilatometer
CO3	Determine the temperature dependency of reaction rate constant
CO4	Analyze the performance of reactors through RTD studies
CO5	Compare the performance of CSTR-PFR with PFR-CSTR reactor systems
CO6	Compare the performance of single CSTR with series of CSTRs

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO2	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO3	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO4	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO5	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO6	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-

List of experiments

1. Studies on gas-liquid-solid reaction using hydrodynamic cavitation-carbonization process.

2. Polymerization of acrylic acid in a batch reactor.
3. Demonstration of nitration reaction in Microreactors
4. Demonstration of Microwave Reactor
5. Demonstration of Ultrasound Probe Reactor
6. Kinetic studies using Dilatometer.

CH 609 Seminar

Course Outcomes: At the end of the course, the student will be able to:

CO1	Acquire knowledge on topics outside the scope of curriculum.
CO2	Communicate with group of people on different topic
CO3	Collect and consolidate required information on a topic
CO4	Prepare a seminar report

Mapping of course outcomes with program outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	✓
CO2	✓	✓	-	-	✓	✓	-	-	✓	✓	✓	✓
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	✓	✓
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	✓	✓

Each student is expected to collect information on recent advances in Chemical Engineering by regularly referring to national and international journals and reference books. At the end of the semester he/she is required prepare a report as per the guide lines prescribed by the Department. Each student will be assigned a guide for this seminar course.

Every student shall give a power point presentation on his Seminar topic before a panel of examiners.

CH 610 Industrial Training

Course Outcomes: At the end of the course, the student will be able to:

CO1	Acquire knowledge on topics outside the scope of curriculum on summer training.
CO2	Communicate with group of people on different topics of summer training.
CO3	Collect and consolidate required information on a topic of summer training.
CO4	Prepare a seminar report on summer training

Mapping of course outcomes with program outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	✓
CO2	✓	✓	-	-	✓	✓	-	-	✓	✓	✓	✓
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	✓	✓
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	✓	✓

Each student is expected to spend FOUR weeks in any one factory/project/workshop at the end of sixth semester (during summer vacation). Here he/she shall observe layout, working and use of various machinery, plants, design, instruments, process etc. under the general supervision of the foreman/artisan/engineer of the factory etc.

The student shall submit the report in a systematic technical format about the major field of the factory, particularly about the section/department where he/she has received the training giving details of equipment, machinery, materials, process etc. with their detailed specifications, use etc. The report shall be checked and evaluated by the concerned teacher and appropriate grade shall be awarded.