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

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.

Reading:

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.

CH304	**MASS TRANSFER-I**	**PCC**	**3 – 1 – 0**	**4 Credits**

Pre-requisites: CH253 Heat Transfer

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	2	2	-	-	-	-	-	-	-	-
CO2	2	-	1	1	-	-	-	-	-	-	--	-
CO3	3	2	3	3	-	-	-	-	-	-	-	-
CO4	3	1	3	3	-	-	-	-	-	-	-	-
CO5	3	2	2	3	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction: Types of mass transfer operations in chemical industries.

Molecular Diffusion: Stefan tube experiment to determine diffusion coefficient in gases, Fick's law of diffusion, Determination of diffusion coefficient in liquids, Diffusion of naphthalene into air – example, Two bulb method to determine diffusion coefficient in gases, Correlations for diffusion coefficient in gases and liquids, Dependence on temperature and pressure, Correlation for diffusion coefficient in multi-component gaseous mixture, Formulation of flux with a reaction occurring on surface, Diffusion in solids.

Inter-Phase Mass Transfer: Pure liquid (stationary) to gas mixture (gently mixed), Concept of mass transfer coefficient and driving force, Pure gas (stationary) to liquid mixture (gently mixed), Pure gas to liquid (laminar falling film), Concept of Sherwood number, Sherwood number correlations for various geometries and flow regimes, Theories of mass transfer coefficient for gas to turbulent liquid flow, Analogies between heat, mass and momentum transfer, Two film resistance theory.

Equipment for Gas-Liquid Operations: Components of equipment in packed towers, Bubble column, Tray towers, etc. Material balance for packed tower– Distributed parameter model, Equilibrium curve & Operating line, Concept of H_{tOG} and N_{tOG} - height of transfer unit and number of transfer units, Stage efficiency.

Humidification Operations: Psychrometric charts, Adiabatic operation, Equipment & components, Non-adiabatic operation, Design of cooling tower.

Reading:

1. Treybal R.E., Mass Transfer Operations, 3rd Ed., McGrawHill, 1981.
2. Geankoplis C.J., Transport processes and Separation Process Principles, 4th Ed., Prentice-Hall India, 2003.
3. Binay K. Dutta, Principles of Mass Transfer and Separation Processes, 2nd Ed., Prentice-Hall India, 2007.

CH305	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING LABORATORY	PCC	0 – 0 – 3	2 Credits

Pre-requisites: CH202 Fluid and Particle Mechanics, CH253 Heat Transfer, CH252 Chemical Engineering Thermodynamics-I

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

CO1	Apply numerical methods to solve problems involving material and energy balances, fluid flow operations, heat and mass transfer, evaporation, thermodynamics and mechanical operations.
CO2	Determine roots of algebraic equations, solution of simultaneous equations and ordinary differential equations.
CO3	Solve problems using regression analysis, interpolation, extrapolation and numerical differentiation and numerical integration
CO4	Solve problems using MATLAB.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	3	-	3	-	-	-	-	-	-
CO2	-	-	-	2	-	3	-	-	-	-	-	-
CO3	-	-	-	1	-	3	-	-	-	-	-	-
CO4	-	-	-	-	-	3	-	-	-	-	-	-

Detailed syllabus

Applications of Numerical Methods to Chemical Engineering Problems: Roots of algebraic equation and solution of simultaneous equations, Regression analysis, Interpolation and Extrapolation, Differentiation and Numerical Integration, Solution of ordinary differential equations.

Chemical Engineering Problems: Material and Energy balance, Fluid flow operations, Heat transfer and evaporation, Mass Transfer operations, Thermodynamics, Mechanical operations, Prediction of properties.

Reading: Lab manuals

CH306	CHEMICAL REACTION ENGINEERING LABORATORY	PCC	0 – 0 – 3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student 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	3	1	3	3	2	2	1	-	1	-	1	-
CO2	3	3	3	2	1	2	1	-	1	-	1	-
CO3	3	3	3	3	2	2	1	-	1	-	1	-
CO4	3	2	3	3	3	3	1	-	1	-	1	-
CO5	3	2	3	3	3	2	1	-	1	-	1	-
CO6	3	2	3	3	3	2	1	-	1	-	1	-

Detailed syllabus

List of experiments:

1) Saponification of ethyl acetate in batch reactor.
2) Saponification of ethyl acetate in a tubular flow reactor.
3) Kinetic studies to establish rate constant using continuous stirred tank reactor.
4) Determination of rate constant in a combined reactor (PFR followed by CSTR).
5) Kinetic studies in CSTRs in series.
6) Determination of dispersion number in a packed bed reactor.
7) Determination of rate constant and activation energy for esterification reaction.

8) Studies on gas-liquid-solid reaction using hydrodynamic cavitation- carbonization process.
9) Polymerization of acrylic acid in a batch reactor.
10) Demonstration of nitration reaction in Microreactors
11) Demonstration of Microwave Reactor
12) Demonstration of Ultrasound Probe Reactor
13) Kinetic studies using Dilatometer.

Reading:

1. Laboratory Manuals
2. Octave Levenspiel, *Chemical Reaction Engineering*, 2nd Edition, Wiley India, 2006.

CH311	NUCLEAR PROCESS ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1	1	1	-	3	-	-	-	-	-
CO2	1	2	-	-	-	-	3	-	-	-	-	-
CO3	1	2	-	-	-	-	2	-	-	-	-	-
CO4	2	3	3	3	-	-	3	-	-	-	-	-

Detailed syllabus

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.

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. 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.

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

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.

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

Reading:

1. Glasstone S and Alexender Seasonske, *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.

CH312	RENEWABLE ENERGY SOURCES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Describe the challenges and problems associated with the use of energy sources.
CO2	List renewable energy resources and technologies.
CO3	Design conversion technologies for solar, wind, biomass and hydrogen energies.
CO4	Evaluate the performance of energy conversion technologies.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	1	1	1	-	3	-	-	-	-	-
CO2	1	2	-	-	-		3	-	-	-	-	-
CO3	2	1	3	3	-	-	-	-	-	-	-	-
CO4	2	2	2	2	-	-	3	-	-	-	-	-

Detailed syllabus

Sources of energy: Energy sources and their availability, renewable energy sources.

Energy from Biomass: Introduction, Biomass as a source of energy, Biomass conversion technologies, Biogas generation, classification of biogas plants, Biomass gasification.

Solar Energy: Sun and solar energy, solar radiation and its measurement, solar energy collectors, solar energy storage, Photovoltaic systems, Application of solar energy

Wind Energy: Wind as an Energy source, Basic principles of wind energy conversion, Types of Wind machines, Components of wind energy conversion system, Performance of wind machines, application of wind energy.

Geothermal Energy: Introduction, Origin and distribution of geothermal energy, types of geothermal resources, Hybrid geothermal power plant, Application of geothermal energy

Hydrogen energy: Introduction, Hydrogen production, Hydrogen storage, Hydrogen transportation

Energy from the Oceans: Introduction, Ocean Thermal Electric Conversion (OTEC), Energy from Tides, Ocean Waves

Chemical Energy Sources: Introduction, Fuel cells, Batteries.

Reading:

1. Rai, G.D, Non-Conventional Energy Sources, Khanna Publishers, New Delhi, 2010.
2. Rajesh Kumar Prasad, T.P. Ojha, Non-Conventional Energy Sources, Jain Brothers, 2012.
3. Sukhatme S.P and J. Nayak, Solar energy – Thermal Collection and storage, 3rd Edition, Tata McGraw Hill Education Pvt Ltd., 2008.
4. MM. El – Wakil, Power Plant Technology, Tata McGraw Hill, NewYork, 1999.

CH313	FUEL CELL ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand fuel cell fundamentals.
CO2	Analyze the performance of fuel cell systems.
CO3	Understand construction and operation of fuel cell stack and fuel cell system.
CO4	Apply the modeling techniques for fuel cell systems.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	-	-	3	-	-	-	-	-
CO2	2	1	1	1	-	-	-	-	-	-	-	-
CO3	2	2	-	-	2	-	3	-	-	-	-	-
CO4	2	3	3	3	-	3	3	-	-	-	-	-

Detailed syllabus

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.

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

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

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.

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

Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal, Using renewable fuels for SOFCs

Reading:

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.

CH314	PIPING ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the key steps in a pipeline's lifecycle: design, construction, installation and maintenance.
CO2	Draw piping and instrumentation diagrams (P&ID).
CO3	Understand codes, standards and statutory regulations.
CO4	Select pipe and pipe fittings.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	1	1	1	-	-	-	-	-	-	-
CO2	1	1	1	1	-	2	-	-	-	-	-	-
CO3	2	2	-	-	2	-	-	-	-	-	-	-
CO4	1	1	3	3	1	1	-	-	-	-	-	-

Detailed syllabus

Piping: Pipeline Pigging, Pipe Laying, Pipe Lowering, Ditching, Pipeline Welding.

Pipe Design: Steel pipe design, Properties, Length and calculation of pipe in bends, American standard taper pipe threads, Floodlighting Concepts.

Hydrostatic Testing: Benefits and limitations, charts; for estimating the amount of pressure change for a change in test water temperature, chart development.

Pipeline Drying: Pipeline Dewatering, Cleaning and Drying, Brush pig run with gas, Brush pig run with liquid, Internal sand blasting. Chemical cleaning, Pipeline drying, Moisture content of air, Vacuum drying, Corrosion/Coatings, Advances in Pipeline Protection.

Gas—Hydraulics: Gas pipeline hydraulics calculations.

Liquids—Hydraulics: Marine Hose Data, CALM system, SALM system, Tandem system, Multi-point mooring system, Pressure Loss through Valves and Fittings.

Measurement: Multiphase flow meter, Pipeline flow measurement—the new influences, Liquid measurement orifice plate flange taps, Gas Measurement.

Instrumentation: Developments in Pipeline Instrumentation; Flow measurements Proving devices, Valves Acoustic line break detectors, ''Smart'' pressure sensors, Densitometers, Pipeline samplers, Pipeline monitoring systems, Computer systems, SCADA systems, Cathodic protection.

Leak Detection: Pipeline leak detection techniques.

Reading:

1. McAllister E.W., Pipeline Rules of Thumb Handbook, 7th Edition, Gulf Publication, 2009.
2. Kellogg, Design of Piping System, 2nd Edition, M.W. Kellogg Co. 2009.
3. Weaver R., Process Piping Design Vol .1 and 2, Gulf Publication, 1989.

CH315	CORROSION ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the principles of corrosion
CO2	Determine corrosion rates for industrial equipment and metallic structures.
CO3	Calculate corrosion rates using electrochemical work station.
CO4	Understand corrosion resistant coatings, oxide layers.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	-	-	2	-	-	-	-	-	-	-
CO2	1	2	1	-	-	-	-	-	-	-	-	-
CO3	1	1	1	1	-	2	-	-	-	-	-	-
CO4	1	2	1	1	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction & Corrosion Principles: Definition of corrosion, impact on economy, Electrochemical reactions, Corrosion rate expressions, Polarization, Passivity, Metallurgical aspects.
Eight Forms of Corrosion: Galvanic corrosion, crevice corrosion, pitting, intergranular corrosion, erosion corrosion, stress corrosion, hydrogen damage.

Corrosion testing: Specimen preparation, exposure tests, open corrosion potential, linear polarization, Tafel slopes, corrosion current, stress corrosion, slow-strain-rate tests AC impedance.

Corrosion Prevention: Cathodic protection, sacrificial anode methods of corrosion prevention, Anti-corrosion coatings.

Modern Theory-Principles & Applications: Alloy evaluation, Nobel metal alloying, velocity effects, galvanic coupling.

Reading:

1. Fontana M, Corrosion Engineering, 3rd edition, Tata McGraw Hill Education Pvt. Ltd., 2010.
2. Pierre Roberge, Corrosion Engineering: Principles and Practice, 1st Edition, McGraw Hill, 2008.
3. Denny A. Jones, Principles and Prevention of Corrosion, 2nd Edition, Pearson-Prentice Hall, 2005.

CH316	NANOTECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the properties of nano-materials and their applications
CO2	Apply chemical engineering principles to nano-particles production and scale-up
CO3	Solve the quantum confinement equations.
CO4	Characterize nano-materials.
CO5	State the applications of nanotechnology in electronics and chemical industries.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	2	-	-	3	-	-	-	-	-	-
CO2	3	2	2	3	1	1	1	-	-	-	-	-
CO3	1	-	-	-	-	-	3	-	-	-	-	-
CO4	1	1	1	1	-	1	1	-	-	-	-	-
CO5	2	2	3	3	3	3	1	1	1	1	1	-

Detailed syllabus

Introduction to Nanotechnology: Introduction to nanotechnology and materials, Nanomaterials, Introduction to nano sizes and properties comparison with the bulk materials, different shapes and sizes and morphology.

Fabrication of Nanomaterials: Top Down Approach, Grinding, Planetary milling and Comparison of particles, Bottom Up Approach, Wet Chemical Synthesis Methods, Micro emulsion Approach, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization, Gas phase Production Methods : Chemical Vapour Depositions.

Kinetics at Nanoscale: Nucleation and growth of particles, Issues of Aggregation of Particles, Oswald Ripening, Stearic hindrance, Layers of surface Charges, Zeta Potential and pH.

Carbon Nanomaterials: Synthesis of carbon buckyballs, List of stable carbon allotropes extended fullerenes, metallofullerenes solid C60, bucky onions nanotubes, nanocones Difference between Chemical Engineering processes and nanosynthesis processes.

Quantum mechanics: Quantum mechanics Quantum dots and its Importance, Pauli exclusion principle Schrödinger's equation, Application of quantum Dots: quantum well, wire, dot, characteristics of quantum dots, Synthesis of quantum dots, Semiconductor quantum dots, Introduction - Nanoclay Synthesis method, Applications of nanoclay.

Nanomaterials characterization: Instrumentation Fractionation principles of Particle size measurements, Particle size and its distribution, XRD, Zeta potential Microscopies SEM, TEM, Atomic Forced Microscopy, Scanning and Tunneling Microscopy

Applications in Chemical Engineering: Self-assembly and molecular manufacturing : Surfactant based system Colloidal system applications, ZnO,TiO_2, Silver Nanoparticles Functional materials Applications, Production Techniques of Nanotubes, Carbon arc, bulk synthesis, commercial processes of synthesis of nanomaterials, Nanoclay, Commercial case study of nano synthesis - applications in chemical engineering, Nano inroganic materials - $CaCO_3$ synthesis, Hybrid wastewater treatment systems, Electronic Nanodevices, sensor applications,

Nanobiology: biological methods of synthesis.Applications in drug delivery, Nanocontainers and Responsive Release of active agents, Layer by Layer assembly for nanospheres, Safety and health Issues of nanomaterials, Environmental Impacts, Case Study for Environmental and Societal Impacts.

Reading:

1. Kulkarni Sulabha K., Nanotechnology: Principles and Practices, Capital Publishing Company, 2007.
2. Gabor L. Hornyak., H.F. Tibbals, Joydeep Dutta, John J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press.
3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005.
4. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009.
5. Davies, J.H. ‘The Physics of Low Dimensional Semiconductors: An Introduction’, Cambridge University Press, 1998.

SM335	ENGINEERING ECONOMICS AND ACCOUNTANCY	HSC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Prepare accounting records and summarize and interpret the accounting data for managerial decisions
CO2	Understand the macro-economic environment of the business and its impact on enterprise
CO3	Understand cost elements of the product and its effect on decision making
CO4	Understand the concepts of financial management and smart investment

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	-	-	-	3	2	2	2	-
CO2	-	-	-	-	-	-	-	3	2	2	-	-
CO3	-	-	-	-	-	-	-	3	2	2	-	-
CO4	-	-	-	-	-	-	-	3	2	3	-	-

Detailed syllabus

Engineering Economics: Introduction to Engineering Economics – Fundamental concepts – Time value of money – Cash flow and Time Diagrams – Choosing between alternative investment proposals – Methods of Economic analysis. The effect of borrowing on investment- Various concepts of National Income – Significance of National Income estimation and its limitations, Inflation –Definition – Process and Theories of Inflation and measures to control, New Economic Policy 1991 – Impact on industry.

Accountancy: Accounting Principles, Procedure – Double entry system – Journal – Ledger, Trail Balance – Cash Book – Preparation of Trading, Profit and Loss Account – Balance sheet.

Cost Accounting – Introduction – Classification of costs – Methods of costing – Techniques of costing – Cost sheet and preparation of cost sheet- Breakeven Analysis – Meaning and its application, Limitations.

Reading:

1. Henry MalcomStenar, Engineering Economic Principles, McGraw Hill, 2005.
2. K KDewett, Modern Economic Theory, Siltan Chand & Co., 2005.
3. Agrawal AN, Indian Economy, Wiley Eastern Ltd, New Delhi, 2012.
4. Jain and Narang, Accounting Part-I, Kalyani Publishers, 2012.
5. Arora, M.N., Cost Accounting, Vikas Publications, 2013.

CH351	MASS TRANSFER-II	PCC	3 – 1 – 0	4 Credits

Pre-requisites: CH302 Chemical Engineering Thermodynamics-II, CH304 Mass Transfer-I.

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 operations
CO4	Calculate drying rates and moisture content for batch and continuous drying operations

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	3	3	-	-	-	-	-	-	-	-
CO2	3	3	3	3	-	-	-	-	-	-	-	-
CO3	2	2	2	2	-	-	-	-	-	-	-	-
CO4	2	2	2	2	-	-	-	-	-	-	-	-

Detailed syllabus

Gas Absorption: Equilibrium solubility of gases in liquids, one component transferred - material balances, one component transferred counter-current multistage operation, continuous contact equipment, multicomponent systems and absorption with chemical reaction.

Distillation: Vapor-Liquid Equilibria, single stage operation - flash vaporization, differential or simple distillation, continuous rectification - binary systems, multistage tray towers-McCabe-Thiele method. Continuous contact equipment (packed towers), multicomponent systems, Extractive distillation, Azeotropic distillation, low pressure distillation (molecular distillation)

Liquid-Liquid Extraction: Liquid equilibria, equipment and flow sheets, stage-wise contact, stage type extractors and differential (continuous contact) extractors.

Drying: Equilibrium, drying operations - batch drying, the mechanism of batch drying and continuous drying, drying equipment.

Reading:

1. Treybal R.E., Mass Transfer Operations, 3rd Edition, International Student Edition, McGraw Hill International, 1981.
2. C.J. Geankoplis, Transport Processes and Separation Process Principles, 4th Edition, Prentice Hall Inc., 2009.
3. Warren L. McCabe, Jullian Smith C. and Peter Harriott - Unit operations of Chemical Engineering, 7th Edition, McGraw-Hill international edition, 2005.
4. Seader J.D. and Henley E.J., Separation Process Principles, 2nd edition, John Wiley & Sons, 2006.

CH352	CHEMICAL REACTION ENGINEERING – II	PCC	3 – 0 – 0	3 Credits

Pre-requisites: CH301 Chemical Reaction Engineering-I, CH304 Mass Transfer-I.

Course Outcomes: At the end of the course, the student 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	3	3	3	3	1	-	-	-	-	-	-	-
CO2	3	3	3	3	-	-	-	-	-	-	-	-
CO3	3	3	3	3	-	-	-	-	-	-	-	-
CO4	3	3	3	3	-	-	-	--	-	-	-	-
CO5	3	3	3	3	1	-	3	-	-	-	-	-
CO6	3	3	3	3	-	-	-	-	-	-	-	-

Detailed syllabus

RTD for Chemical Reactors: General Characteristics, Measurement of the RTD, Characteristics of the RTD, RTD in Ideal Reactors, Diagnostics and Troubleshooting, Reactor Modelling Using the RTD, Zero-Parameter Models, RTD and Multiple Reactions.

Analysis of non-ideal reactors**:** One- parameter models, two-parameter models, Tanks-in-Series (T-I-S) Model, Dispersion Model, Tanks-in-Series Model Versus Dispersion Model, Two-Parameter Models-Modelling Real Reactors with Combinations of Ideal Reactors, Other Models of Non-ideal Reactors Using CSTRs and PFRs.

External Diffusion Effects on Heterogeneous Reactions: Diffusion Fundamentals, Binary Diffusion, External Resistance to Mass Transfer, Parameter Sensitivity, the Shrinking Core Model. Rate equation for fluid solid reactions. Design of heterogeneous catalytic reactors.

Diffusion and Reaction: Diffusion and Reaction in Spherical Catalyst Pellets, Internal Effectiveness Factor, Falsified Kinetics, Overall Effectiveness Factor, Estimation of Diffusion- and Reaction-Limited Regimes, Mass Transfer and Reaction in a Packed Bed, Determination of Limiting Situations from Reaction Data, Multiphase Reactors, Fluidized Bed Reactors, Chemical Vapor Deposition (CVD).

Reading:

1. Fogler H. S., Elements of Chemical Reaction Engineering, 4thEdition, Prentice Hall of India Pvt. Ltd., 2005.
2. J. M. Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981.
3. T. J. Carberry, Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.
4. O. Levenspiel, Chemical Reaction Engineering, 3rdEdition, Wiley India, 2006.

CH353	PROCESS EQUIPMENT DESIGN & DRAWING	PCC	0 – 2 – 3	4 Credits

Pre-requisites: ME102 Engineering Graphics, CH301 Chemical Reaction Engineering-I, CH304 Mass Transfer-I, CH203 Mechanical Operations, CH251 Chemical Technology.

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

CO1	Identify equipment and instruments based on symbols
CO2	Draw process flow diagrams using symbols
CO3	Apply mechanical design aspects to process equipment.
CO4	Design heat exchangers, evaporators, absorbers, distillation columns, reactors and filters.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	2	-	-	1	-	-	-	-	-	2	3
CO2	-	2	-	-	1	-	-	-	-	-	-	-
CO3	2	-	3	3	2	2	-	-	-	-	-	-
CO4	2	-	3	3	2	3	-	-	-	-	-	-

Detailed Syllabus:

Mechanical Design of Process Equipment: Introduction to mechanical aspects of chemical equipment design, Design Preliminaries, Design of cylindrical and spherical vessels under internal pressure, Design of heads and closers, Design of tall vessels.

Drawing: Drawing of process equipment symbols for fluid handling, heat transfer, mass transfer, Drawing of process equipment symbols for vessels, conveyers and feeders etc. Drawing of process equipment symbols for, separators, mixing & comminution etc. Drawing of process equipment symbols for distillation, driers, evaporators, scrubbers etc. Drawing of process equipment symbols for crystallizer, grinding, jigging, elutriation, magnetic separation, compressor etc. Drawing of basic instrumentation symbols for flow, temperature, level, pressure and combined instruments, Drawing of miscellaneous instrumentation symbols, Detailed drawing of equipment, Drawing of flow sheet.

Process Equipment Design: Design of a heat exchanger, Design of an absorber, Design of a distillation column, Design of evaporator, Design of condenser, Design of a chemical reactor.

Reading:

1. Brownell L.E, Process Equipment Design - Vessel Design, Wiley Eastern Ltd., 1986.
2. Bhattacharya B.C., Introduction to Chemical Equipment Design - Mechanical Aspects, CBS Publishers and Distributors, 2003.
3. Towler, G. P. and R. K. Sinnott, Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design, 2nd Edition, Butterworth Heinemann, 2012.
4. Donald Kern, Process Heat Transfer, 1st Edition, Tata McGraw-Hill Education, 1950
5. Robert E. Treybal, Mass-Transfer Operations, 3rd Edition, McGraw-Hill Book Company, 1981.

CH354	MASS TRANSFER LABORATORY	PCC	0 – 0 – 3	2 Credits

Pre-requisites: CH304 Mass Transfer-I

Course Outcomes: At the end of the course, the student 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 total 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	2	2	3	2	-	-	-	-	3	-	3	-
CO2	2	-	3	-	-	3	-	-	3	-	3	-
CO3	2	-	3	-	-	-	-		3	-	3	-
CO4	2	-	3	-	-	-	-	-	3	-	3	-
CO5	2	-	3	-	-	-	-	-	3	-	3	-
CO6	2	-	3	-	-	-	-	-	3	-	3	-

Detailed Syllabus:

Steam distillation, batch distillation, packed tower distillation, sieve plate distillation, determination of diffusivity coefficient, mutual solubility data, tie-line data, distribution co-efficient, batch drying, and V.L.E data.

Reading: Lab Manuals

CH361	PHARMACEUTICALS AND FINE CHEMICALS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	-	-	-	-	-	-	-	-	-	-
CO2	1	3	-	1	-	-	-	-	-	-	-	-
CO3	-	3	-	1	-	2	-	-	-	-	-	-
CO4	2	1	1	-	-	-	3	-	-	-	-	-
CO5	1	-	-	-	-	-	2	-	-	-	-	-

Detailed Syllabus:

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

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

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

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.

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

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.

Reading:

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.

CH362	POLLUTION CONTROL IN PROCESS INDUSTRIES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze the effects of pollutants on the environment.
CO2	Understand meteorological aspects of air pollution
CO3	Understand air pollution control methods
CO4	Select treatment technologies for water/wastewater/solid waste.
CO5	Design unit operations for pollution control.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	-	-	-	-	3	-	-	-	-	-
CO2	1	3	-	-	-	-	3		-	-	-	-
CO3	1	3	-	-	-	-	3	-	-	-	-	-
CO4	1	3	-	1	-	-	3	-	-	-	-	-
CO5	1	3	3	3	-	-	3	-	-	-	-	-

Detailed Syllabus:

Introduction: Biosphere, Hydrological cycle, Nutrient cycle, Consequences of population growth, Pollution of air, Water and soil.

Air pollution sources & effects: Classification and properties of air pollutants, Emission sources, Behavior and fate of air pollutants, Effect of air pollution.

Meteorological aspects of air pollutant dispersion: Temperature lapse rates and stability, Wind velocity and turbulence, Plume behavior, Dispersion of air pollutants, Estimation of plume rise.

Air pollution sampling and measurement: Types of pollutant sampling and measurement, Ambient air sampling, Stack sampling, Analysis of air pollutants.

Air pollution control methods & equipment: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions, Design methods for control equipment.

Control of specific gaseous pollutants: Control of sulphur dioxide emissions, Control of nitrogen oxides, Carbon monoxide control, Control of hydrocarbons and mobile sources.

Water pollution: Water resources, Origin of wastewater, types of water pollutants and there effects.

Waste water sampling, analysis and treatment: Sampling, Methods of analysis, Determination of organic matter, Determination of inorganic substances, Physical characteristics, Bacteriological measurement, Basic processes of water treatment, Primary treatment, Secondary treatment, Advanced wastewater treatment, Recovery of materials from process effluents.

Solid waste management: Sources and classification, Public health aspects, Methods of collection, Disposal Methods, Potential methods of disposal.

Hazardous waste management: Definition and sources, Hazardous waste classification, Treatment methods, Disposal methods.

Reading:

1. Rao C.S., Environmental Pollution Control Engineering, Wiley Eastern Limited, India, 1993.
2. Noel de Nevers, Air Pollution and Control Engineering, McGraw Hill, 2000.
3. Glynn Henry J. and Gary W. Heinke, Environmental Science and Engineering, 2nd Edition, Prentice Hall of India, 2004.
4. Rao M.N. and Rao H.V.N - Air Pollution, Tata – McGraw Hill Publishing Ltd., 1993.
5. De A.K - Environmental Chemistry, Tata – McGraw Hill Publishing Ltd., 1999.

CH363	FERTILIZER TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	3	-	-	-	-	3	-	-	-	-	-
CO2	1	3	-	-	-	-	3		-	-	-	-
CO3	1	3	-	-	-	-	3	-	-	-	-	-
CO4	1	3	-	-	-	-	3	-	-	-	-	-

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.

Reading:

1. Sittig Mand GopalaRao 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.

CH364	FOOD TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	-	-	-	-	3	-	-	-	-	-
CO2	1	3	2	3	-	-	3		-	-	-	-
CO3	1	3	2	2	-	-	3	-	-	-	-	-
CO4	1	3	-	3	-	1	3	-	-	-	-	-

Detailed Syllabus:

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.

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.

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.

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

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

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

Reading:

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.

CH365	GREEN TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	-	-	-	-	3	-	-	-	-	-
CO2	1	3	3	-	-	-	3		-	-	-	-
CO3	1	3	3	3	2	-	3	-	-	-	-	-
CO4	1	3	-	-	-	-	3	-	-	-	-	-

Detailed Syllabus:

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.

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.

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 Chemical

Industry, 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.

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, Fluorous Biphase 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.

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.

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.

Reading:

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.

CH366	**PULP AND PAPER TECHNOLOGY**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

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

CO1	Explain process for manufacturing paper.
CO2	Understand harmful impacts of paper and pulp industries on environment.
CO3	Understand mechanical pulping, Chemi-thermo-mechanical processes, chemical pulping.
CO4	Understand methods for pulp treatment.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	-	-	-	-	3	-	-	-	-	-
CO2	1	3	-	-	2	-	3		-	-	-	-
CO3	1	3	-	-	-	-	3	-	-	-	-	-
CO4	1	3	-	-	2	-	3	-	-	-	-	-

Detailed Syllabus:

Introduction: History of Paper Making, Technological Advancements, Global and Indian Market Situation.

Paper making raw materials: Wood anatomy and chemistry, Wood chip preparation and handling at the pulp mill, Solid wood measurement, Properties of selected wood species.

Pulping processes: Introduction to pulping, Mechanical pulping, Chemical pulping, Semi-chemical pulping, Soda pulping, Kraft pulping, Sulfite pulping, Other pulping methods.

Pulp treatment: Bleaching mechanical pulps, Measurement of lignin content, Bleaching chemical pulps, Chemical recovery, Refining, Pulp characterization.

Paper making equipment and process: Fiber preparation and approach, Raw materials, Functional additives, Control additives, Wet end chemistry, Paper manufacture, Paper machine, headbox, fourdrinier wet end, Twin wire formers, cylinder machine, press section, dryer section, Post drying operations, Coating.

Environmental protection: Water pollution, Water quality tests, Aqueous effluent treatments, Air pollution, Air quality tests and control, Solid waste disposal.

Properties of paper: General grades of paper, Structure, Mechanical and chemical properties, Basic optical tests of paper.

Reading:

1. J.P. Casey, Pulp and Paper: Chemistry and Chemical Technology, 3rd Edition, Volumes 1 & 2., Wiley Interscience, 1980
2. G.A. Smook, Handbook for Pulp and Paper Technologists, 3rd Edition, Angus Wilde Publ, Inc, 2002.
3. Christopher J. Biermann, Handbook of Pulping and Paper Making, Academic Press, 1996.

ME435	INDUSTRIAL MANAGEMENT	ESC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the basic principles, approaches and functions of management and identify concepts to specific situations.
CO2	Understand marketing management process to discuss marketing mix in formulation of marketing strategies during the life cycle of product.
CO3	Outline various techniques for improving productivity using work study.
CO4	Understand concepts of quality management and use process control charts, concepts and tools of quality engineering in the design of products and process controls.
CO5	Use and distinguish basic methods/tools of inventory classification and control.
CO6	Identify activities with their interdependency and use scheduling techniques of project management PERT/CPM.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	-	-	-	3	3	3	-	-
CO2	-	-	-	-	-	-	-	3	3	3	-	-
CO3	-	-	-	-	-	-	-	3	3	3	-	-
CO4	-	-	-	-	-	-	-	3	3	3	-	-
CO5	-	-	-	-	-	-	-	3	3	3	-	-
CO6	-	-	-	-	-	-	-	3	3	3	-	-

Introduction: Overview of the course, Examination and Evaluation patterns; Nature, significance and role of management in organizations.

Evolution of Industry and Principles of management: Evolution of industry and professional management; Functions of management; Organization structures; Hawthorne Experiments and informal organizational structures; Motivational theories and leadership styles.

Marketing Management: Marketing management process; 4P's of marketing mix; Target marketing; Product life cycle and marketing strategies.

Work Study: Productivity and its role in the economy; Techniques for improving productivity; Method study; Principles of motion economy; Stop watch time study; Work sampling.

Quality Management: Dimensions of quality; Process control charts; Acceptance sampling; Taguchi's Quality Philosophy; Quality function deployment; Introduction to TQM.

Inventory Management: Purpose of inventories; Inventory costs; ABC classification; Economic Order Quantity (EOQ); P and Q systems of inventory control.

Project Scheduling- PERT/CPM: Project activities; Network diagrams; Critical path method (CPM); Programme Evaluation and Review Technique (PERT).

Reading

1. Koontz H and Weihrich H, Essentials of Management, 7th Ed., McGraw-Hill , New York 2007.
2. Kotler P, Marketing Management, 13th Ed., Prentice Hall of India/Pearson, New Delhi 2009.
3. Chase, Shankar, Jacobs and Aquilano, Operations and Supply Management, 12th Ed., Tata McGraw Hill, New Delhi 2010.

CH401	PROCESS DYNAMICS AND CONTROL	PCC	3 – 1 – 0	4 Credits

Pre-requisites: MA201 Mathematics-III, CH254 Process Instrumentation, CH351 Mass Transfer – II, CH352 Chemical Reaction Engineering – II.

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

CO1	Understand the dynamic behaviour of different processes
CO2	Analyze different components of a control loop
CO3	Analyze stability of feedback control system
CO4	Design controllers for first and second order processes
CO5	Analyze frequency response for controllers and processes

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	-	-	-	-	-	-	-	-
CO2	3	1	3	3	-	-	-	-	-	-	-	-
CO3	3	1	3	3	-	-	-	-	-	-	-	-
CO4	3	1	3	3	1	-	-	-	-	-	-	-
CO5	3	1	3	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Response of First order systems: Transfer Function, Transient Response, Forcing Functions and Responses. Physical examples of First and Second order systems: Examples of First order systems, Linearization, Transportation Lag.

Components of a Control System, Block Diagram, Development of Block Diagram, Controllers and Final Control Elements. Closed loop Transfer functions: Standard Block-Diagram Symbols, Transfer Functions for Single-Loop Systems and Multi-loop Systems.

Transient response of simple control systems: Servo Problem, Regulatory Problem, Controllers: Proportional, Proportional-Integral, PID Controllers. Ziegler-Nichols Controller Settings. Stability: Routh Test for Stability, Root Locus.

Introduction to frequency Response: Substitution Rule, Bode Diagrams. Control system design based on frequency response: Bode and Nyquist Stability Criterion, Gain and Phase Margins.

Advanced Control Strategies: Cascade Control, Feed-forward Control, Ratio Control, Dead-Time Compensation (Smith Predictor), Internal Model Control. Controller tuning and process identification. Control Valves: Control Valve Construction, Valve Sizing, Valve Characteristics, Valve Positioner.

Reading:

1. Coughanowr D.R., Process System analysis and Control, 2nd Edition, McGraw Hill International Edition, 2011.
2. Seborg D.E., Edgar T. E and Millichamp D.A, Process Dynamics and Control, John Wiley & Sons, 2004.
3. Stephanopolis G., Chemical Process Control, Prentice Hall India, 2008.
4. Bequette, B.W., Process Control: Modeling, Design and Simulation, 2007.

CH402	CAD AND SIMULATION LABORATORY	PCC	0 – 1 – 3	3 Credits

Pre-requisites: CH351 Mass Transfer-II, CH352 Chemical Reaction Engineering-II.

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

CO1	Simulate and design mixer, splitter, pump, flash column, heat exchanger, reactor and distillation column.
CO2	Apply Aspen software to simulate a chemical process
CO3	Apply sensitivity, design and optimization tools in Aspen software.
CO4	Estimate physical properties

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	3	-	3	-	-	-	-	-	-
CO2	3	2	2	2	-	3	-	-	-	-	-	-
CO3	3	2	2	1	-	3	-	-	-	-	-	-
CO4	2	2	-	-	-	3	-	-	-	-	-	-

Detailed Syllabus:

Design, Rating and Simulation of Chemical Engineering Equipment Using Aspen Plus / Chemcad Software: Mixer, Flow splitter; Flash column; pipe line and pipe pressure drop; Pump; Single and multistage compressors; Heat Exchangers; Distillation Columns; Reactors etc.

Simulation Exercises Using Aspen Plus /Chemcad: Physical property estimations; Simulation of a flow sheet: Mass and Energy balances; Handling user specifications on output streams.

Reading: Lab manuals

CH403	INSTRUMENTATION AND PROCESS CONTROL LABORATORY	PCC	0 – 0 – 3	2 Credits

Pre-requisites: CH254 Process Instrumentation, CH401 Process Dynamics and Control.

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

CO1	Calculate the characteristics of control valves
CO2	Determine the dynamics of level and temperature measurement process
CO3	Determine the dynamics of two capacity liquid level process without interaction and with interaction, U-tube manometer.
CO4	Determine the performance of controllers for a flow process, pressure process, level process, temperature process.
CO5	Evaluate the performance of cascade control

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	-	-	3	-	3	-	-	3	-	3	-
CO2	2	-	-	2	-	3	-	-	3	-	3	-
CO3	2	-	-	1	-	3	-	-	3	-	3	-
CO4	2	-	-	2	-	3	-	-	3	-	3	-
CO5	3	-	-	-	-	3	-	-	3	-	3	-

Detailed Syllabus:

List of experiments:

1. Control valve characteristics
2. Dynamics of Interacting process
3. Dynamics of Non-interacting process
4. Dynamics of Temperature measurement process
5. Flapper nozzle system
6. Dynamics of Cascade control system
7. Characteristics of I&P converters
8. Dynamics of Level measurement system
9. Dynamics of First and second order process
10. Design of controllers and simulation using MATLAB

Reading: Lab manuals

CH449	PROJECT WORK - PART A	PRC	0 – 0 – 3	2 Credits

Pre-requisites: CH353 Process Equipment Design & Drawing.

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

CO1	Carry out literature and market survey.
CO2	Select a process for manufacture of a chemical product
CO3	Draw flow sheet of the selected process
CO4	Perform mass balance calculations for each unit operation and process.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	2	-	2	3	2	2	3	3
CO2	3	3	3	3	2	2	1	1	2	2	3	3
CO3	3	3	3	3	1	1	1	-	-	1	3	-
CO4	3	3	3	3	2	3	1	-	-	1	3	3

Detailed Syllabus:

Feasibility study for production of any chemical product on industrial scale:

Introduction, market survey, different processes for production, selection of process, process description and material balance.

Reading: Chemical Industry Periodicals, Professional core books.

CH411	BIOCHEMICAL ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand cell and enzyme kinetics
CO2	State methods of immobilization.
CO3	Calculate volume of a bioreactor
CO4	State sterilization methods
CO5	Select downstream process to separate the products

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	3	-	-	-	-	-	-	-	-
CO2	1	1	3	3	-	-	-	-	-	-	-	-
CO3	1	1	3	3	-	-	-	-	-	-	-	-
CO4	1	1	3	3	1	-	-	-	-	-	-	-
CO5	3	2	3	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Introduction: Biotechnology, Biochemical Engineering, Biological Process, Definition of Fermentation.

Enzyme Kinetics: Introduction, Simple Enzyme Kinetics, Enzyme Reactor with Simple Kinetics, Inhibition of Enzyme Reactions, and Other Influences on Enzyme Activity.

Immobilized Enzyme: Immobilization techniques and effect of mass transfer resistance.

Industrial application of enzymes: Carbohydrates, starch conversion and cellulose conversion.

Cell Cultivation: Microbial cell cultivation, animal cell cultivation, plant cell cultivation, cell growth measurement and cell immobilization.

Cell Kinetics and Fermentor Design: Introduction, growth cycle for batch cultivation, stirred tank fermenters, multiple fermenters connected series, cell recycling, alternate fermenters and structured model.

Sterilization: Sterilization methods, thermal death kinetics, design criterion, batch sterilization, continuous sterilization and air sterilization.

Agitation and Aeration: Introduction, basic mass transfer concepts, correlation for mass transfer co-efficient, measurement of interfacial area, correlations for ‘a’ and D_{32}, gas-holdup, power consumption, determination of oxygen absorption rate, correlation for k_{La}, scale-up and shear sensitivity.

Downstream Processing: introduction, solid-liquid separation, cell rupture, recovery and purification.

Reading:

1. Lee J.M., Biochemical Engineering, Ebook, version 2.32, 2009.
2. James E. Bailey & David F. Ollis, Biochemical Engineering Fundamentals, 2nd edition, McGraw Hill International, 1986.
3. Michael L. Shuler & Fikret Kargi, Bioprocess Engineering – Basic Concepts, 2nd edition, Prentice Hall of India, New Delhi, 2002.

CH412	INTERFACIAL SCIENCE	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the interfacial phenomena occurring in a larger process and quantify its effect.
CO2	Analyze ab-initio calculations for inter-colloidal forces.
CO3	Design instruments, equipment and sensors for interfacial science.
CO4	Evaluate the suitability of characterizing methods for colloids or emulsions.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	-	-	-	-	-	-	-	-
CO2	3	3	3	3	-	-	-	3	-	-	-	-
CO3	3	3	3	3	-	-	-	-	-	-	-	-
CO4	3	3	3	3		-	-	-	-	-	-	-

Detailed Syllabus:

Introduction to types of interfaces: The importance of interfaces, Surfaces and interfaces, Stable interfaces.

Capillarity and surface tension: Surface tension and work, Measurement of surface tension, The Laplace equation, The Kelvin equation, The surface tension of pure liquids.

Adsorption and thermodynamics of surfaces: Introduction, Models of the interface, Adsorption, Thermodynamic properties of interfaces, Surface excess quantities, Measurement of Adsorption, Adsorption form solution, Kinetics of Adsorption.

Surfactants & Micelles, Films and foams: Introduction, Measurement of equilibrium adsorption, Adsorption kinetics, Adsorption of non-ionized solutes, Application of surfactants, Adsorption of surfactants, Micelles, films and foams, Aerosols.

Monolayers formation: Introduction, Formation of floating monolayers, Surface pressure-area relationships, Deposition of Langmuir Blodgett (LB) films, The study of film structure, the structure and properties of floating monolayers, Interactions in monolayers, the structures of LB films, characterization and application.

The liquid-liquid interface: Emulsions, Colloids, Membranes: Introduction, Emulsions, Emulsion stability and selection of the emulsion, Micro-emulsion, Emulsion polymerization, Liquid-liquid extraction, Membranes.

The liquid-solid interface: Introduction, Colloidal dispersions, The properties of colloidal dispersions, Coagulation of lyophobic colloids by electrolytes, solvent effects in colloidal interactions, Nanoparticles.

Reading:

1. Geoffrey Barnes and Ian Gentle, Interfacial Science: An Introduction, 2nd Edition, Oxford University Press, 2011.
2. Jacob N. Israelachvili, Intermolecular and Surface Forces, 3rd Edition, Academic Press, London, 2011.
3. John B. Hudson, Surface Science: An Introduction, John Wiley & Sons, 1998.

CH413	STATISTICAL THERMODYNAMICS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the molecular level properties influencing the macroscopic properties.
CO2	Develop models for simulating real gases, liquids and solids using ensemble methods to estimate thermodynamic properties
CO3	Design molecular level architecture to enhance macroscopic properties.
CO4	Estimate macroscopic properties based on molecular level interactions.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	-	-	-	-	-	-	-	-
CO2	3	3	3	3	-	-	-	3	-	-	-	-
CO3	3	3	3	3	-	-	-	-	-	-	-	-
CO4	3	3	3	3		-	-	-	-	-	-	-

Detailed Syllabus:

Basics of Statistical Thermodynamics: The Statistical Foundation of Classical Thermodynamics, Classification Scheme for Statistical Thermodynamics, Importance of Statistical Thermodynamics.

Ensembles: Ensembles and Postulates, Canonical Ensemble, Canonical Ensemble and Thermodynamics, Grand Canonical Ensemble, Micro Canonical Ensemble, Thermodynamic Equivalence of Ensembles.

Evaluation of Probabilities: Probability- Definitions and Basic Concepts, Permutations and Combinations, Distribution Functions: Discrete and Continuous, Binomial Distribution, Poisson Distribution, Gaussian Distribution, Combinatorial Analysis for Statistical Thermodynamics.

Criteriafor Equilibrium: Equilibrium Principles, States of Equilibrium: Neutral, Metastable, and Unstable equilibrium, Maximizing Multiplicity.

Modelfor Mono-atomic Ideal Gas and Polyatomic Ideal Gases: Energy Levels and Canonical Ensemble, Partition Function, Thermodynamic Functions for Mono-atomic Ideal Gases, Grand Ensemble, Internal Degrees of Freedom, Independence of Degrees of

Freedom, Potential Energy Surface, Vibration, Rotation,Thermodynamic Functions for Poly-atomic Ideal Gases, Hindered Internal Rotation in Ethane, Hindered Translation on a Surface.

Einstein's and Debye's Model of the Solid, Simple Liquids, Phase Equilibrium, Models for Multi-Component Systems: Ideal Lattice Gas, Lattice Gas with Interactions, Solutions (Bragg-William Model and Regular Solutions, Quasi-Chemical Model), Chemical Equilibrium.

Reading:

1. Leonard K. Nash, Elements of Statistical Thermodynamics, 2nd Edition, Dover Publications, 2006.
2. Normand M. Laurendeau, Statistical Thermodynamics: Fundamentals and Applications, Cambridge University Press, 2005.
3. Stanley I. Sandler, An Introduction to Applied Statistical Thermodynamics, John Wiley &Sons, 2010.

CH414	NON-NEWTONIAN FLOW AND RHEOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the types of non-Newtonian fluids.
CO2	Understand the macroscopic behavior of the complex fluids.
CO3	Analyze the flow of non-Newtonian fluids through circular and non-circular cross sectional conduits.
CO4	Develop heat and mass transfer characteristics of non-Newtonian fluids.
CO5	Develop models of non-Newtonian fluid flow.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	2	-	-	-	-	-	-	-
CO2	2	2	2	2	2	-	-	-	-	-	-	-
CO3	2	2	2	2	2	-	-	-	-	-	-	-
CO4	2	2	2	2	2	-	-	-	-	-	-	-
CO5	1	2	2	2	2	-	-	-	-	-	-	-

Detailed Syllabus:

Non-Newtonian fluid behaviour - Introduction, Classification of fluid behaviour, Time-independent fluid behaviour, Time-dependent fluid behaviour, Visco-elastic fluid behaviour, Dimensional considerations for visco-elastic fluids.

Rheometry for non-Newtonian fluids - Introduction, Capillary viscometers, Rotational viscometers, The controlled stress Rheometer, Yield stress measurements, Normal stress measurements, Oscillatory shear measurements, High frequency techniques, The relaxation time spectrum, Extensional flow measurements.

Flow in pipes and in conduits of non-circular cross-sections - Introduction, Laminar flow in circular tubes, Criteria for transition from laminar to turbulent flow, Friction factors for transitional and turbulent conditions, Laminar flow between two infinite parallel plates, Laminar flow in a concentric annulus, Laminar flow of inelastic fluids in non-circular ducts

Flow of multi-phase mixtures in pipes - Introduction, Two-phase gas-non-Newtonian liquid flow, Two-phase liquid-solid flow (hydraulic transport).

Particulate systems - Introduction, Drag force on a sphere, Effect of particle shape on terminal falling velocity and drag force, Motion of bubbles and drops, Flow of a liquid through beds of particles, Flow through packed beds of particles (porous media), Liquid-solid fluidization.

Heat transfer characteristics of non-Newtonian fluids in pipes - Introduction, Thermo-physical properties, Laminar flow in circular tubes, Fully-developed heat transfer to power-law fluids in laminar flow, Isothermal tube wall, Constant heat flux at tube wall, Effect of temperature-dependent physical properties on heat transfer.

Momentum transfer in boundary layers - Introduction, Integral momentum equation, Laminar boundary layer flow of power-law liquids over a plate, Laminar boundary layer flow of Bingham plastic fluids over a plate, Transition criterion and turbulent boundary layer flow, Heat transfer in boundary layers, Mass transfer in laminar boundary layer flow of power-law fluids, Boundary layers for visco-elastic fluids.

Liquid mixing - Introduction, Liquid mixing, Gas-liquid mixing, Heat transfer, Mixing equipment and its selection, Mixing in continuous systems.

Reading:

1. Chhabra R.P., J.F. Richardson, Non-Newtonian Flow and Applied Rheology: Engineering Applications, 2nd Edition, Butterworth-Heinemann, 2008.
2. Christopher W. Macosko, RHEOLOGY: Principles, Measurements and Applications, WILEY-VCH, 1994.
3. Alexander Ya. Malkin, Rheology Fundamentals, ChemTech Publishing, 1994.

CH451	ELEMENTS OF TRANSPORT PHENOMENA	PCC	3 – 1 – 0	4 Credits

Pre-requisites: MA251 Mathematics-IV, CH304 Mass transfer-I.

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

CO1	Understand the analogy among momentum, heat and mass transport.
CO2	Formulate a mathematical representation of a flow/heat/mass transfer phenomena.
CO3	Solve flow/heat/mass transfer problems either individually or coupled for simple geometries analytically.
CO4	Identify the similarities among the correlations for flow, heat and mass transfer at interfaces.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	2	-	2	1	-	-	-	-	-
CO2	3	1	3	3	-	3	-	-	-	-	-	-
CO3	3	-	3	3	-	3	-	-	-	-	-	-
CO4	2	-	3	3	-	3	-	-	-	-	-	-

Detailed Syllabus:

Introduction

Momentum Transfer: Newton's law of viscosity & mechanism of momentum transport, Continuity equation, Equation of motion, Navier-Stokes Equation, Laminar velocity profiles in simple geometries such as flow between parallel plates, flow in a circular pipe, flow down an inclined plane, Time dependent velocity profile, Turbulent flow correlations, Flow in packed beds, Flow past objects,

Heat Transfer: Fourier's law of heat conduction & mechanism of heat transport, Heat conduction-convection equation, Temperature profile for simple geometries with/without heat generation, Temperature profile in laminar flowing fluids with/without heat generation, Time dependent Temperature profile, Natural convection, Inter-phase heat transport.

Mass Transfer: Fick's law of diffusion & mechanism of mass transport, Species balance equation with convection-diffusion and reaction, Diffusion in solids, Dispersion model for laminar flow in tubes, Stefan tube experiment – determination of diffusion constant, Interphase mass transport - Mass transfer for flow past spheres.

Analogies: Analogies between momentum, heat & mass transfer correlations for friction factor/Nusselt Number/Sherwood Number.

Reading:

1. Bird R.B., Stewart W.E. and Light Foot E.N. Transport Phenomena, 2nd Edition, John Wiley &Sons., 2007.
2. Geankoplis C.J., Transport Processes and Separation Process Principles, 4th Edition, Prentice Hall Inc., 2009.

CH452	PLANT DESIGN AND PROCESS ECONOMICS	PCC	3 – 1 – 0	4 Credits

Pre-requisites: CH351 Mass Transfer-II, CH352 Chemical Reaction Engineering-II, SM335 Engineering Economics and Accountancy.

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

CO1	Analyze alternative processes and equipment for manufacturing a product.
CO2	Design plant layout and engineering flow diagrams.
CO3	Perform economic analysis related to process design.
CO4	Evaluate project profitability.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	-	-	-	-	-	-	-	-	-	
CO2	2	2	3	3	3	-	2	-	1	-	2	-
CO3	-	-	2	2	2	-	-	3	1	-	-	-
CO4	-	-	1	1	1	-	-	3	-	-	-	-

Detailed Syllabus:

Introduction: Chemical Engineering plant design, Overall design consideration, Practical considerations in design, engineering ethics in design.

General Design Considerations: Health and Safety hazards, Loss prevention, Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control.

Process Design Development: Development of design database, Process creation, Process design criteria, Process flow diagram (PFD), Piping and instrumentation diagram (P&ID), Vessel and piping layout isometrics, Equipment design and specifications.

Flow sheet synthesis and development: General procedure, Process information, Functions diagram, Process flow sheet, Software use in process design.

Cost and asset accounting: General accounting procedure, Balance sheet and Income statements.

Analysis of Cost Estimation: Cash flow for industrial operations, Factors affecting investment and production costs, Capital investments, Fixed capital and working capital, Estimation of capital investment, Cost indices, Estimation of total cost, Gross profit, Net profit and cash flow, Cost scaling factors, Net present value analysis.

Interest and Insurance: Interest, Simple interest, Compound interest, Nominal and effective interest rates, Continuous interest, Costs of capital, Time value of money, Annuity, Cash flow patterns, Income taxes, Present worth, Future worth, Taxes and Insurance.

Depreciation: Depreciable investments, Methods for calculating Depreciation.

Profitability Analysis: Profitability standards, Costs of capital, Minimum acceptable rate of return, Methods of calculating profitability, Rate of return on investment, Payback period, Net return, Discounted cash flow rate of return, Net present worth, Payout period, Alternative investments, Replacements.

Optimum design and design strategy: Defining the optimization problem, Selecting an objective function, Structural optimization, Parametric optimization, Variable screening and selection, Optimization Applications.

Reading:

1. Peters M.S., K.D. Timmerhaus and R.E. West. “Plant Design and Economics for Chemical Engineers”, McGraw Hill, 5th Edition, 2011.
2. Turton R., R.C. Baile, W.B. Whiting, J. A. Shaeiwitz. “Analysis, Synthesis and Design of Chemical Processes”, PHI, New Delhi, 3rd Edition, 2011.
3. Seider W.D., J.D. Seader, D.R. Lewin, “Product and Process Design Principles: Synthesis, Analysis, and Evaluation, Wiley, 2nd Edition, 2004.

CH491	SEMINAR	PCC	0 – 0 – 3	1 Credits

Pre-requisites: None

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 topics.
CO3	Collect and consolidate required information on a topic.
CO4	Prepare a seminar report.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2	1	1	-	-	-	-	-	3
CO2	1	1	-	-	1	1	-	-	3	2	3	3
CO3	-	1	-	-	1	-	1	-	-	-	3	3
CO4	-	-	-	-	-	-	-	-	1	-	3	1

Detailed Syllabus: Any topic of relevance to Engineering / Science.

Reading: Journals, Magazines, etc.

CH499	PROJECT WORK- PART B	PRC	0 – 0 – 6	4 Credits

Pre-requisites: CH204 Energy Technology & Conservation, CH303 Industrial Safety and Hazard Mitigation, CH351 Mass Transfer-II, CH352 Chemical Reaction Engineering-II, ME435 Industrial Management, CH449 Project Work A.

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

CO1	Perform energy balance
CO2	Design critical equipment involved in the process
CO3	Perform cost estimation and profitability study
CO4	Select location for plant based on societal, economical, environmental, availability of raw materials, human resources, power.
CO5	Design pollution control and safety systems to meet environmental standards.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	3	2	3	2	-	3	-	3	3
CO2	3	1	3	3	1	3	-	-	3	-	3	3
CO3	3	-	2	2	3	1	2	3	3	2	3	-
CO4	-	3	-	-	3	-	3	3	3	3	3	2
CO5	2	2	3	3	1	-	3	1	3	-	3	2

Detailed Syllabus:

Feasibility study for production of any product on industrial scale, Energy balance, design of equipment, cost estimation, profitability analysis, plant layout, site selection, environmental considerations and safety.

Reading: Chemical Industry Periodicals, Professional core books

CH461	MICROSCALE UNIT OPERATIONS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the micro-scale processes.
CO2	Solve fluid flow phenomena for single and immiscible liquids in micro-channels.
CO3	Design architectures of micro-fluidic devices for chemical & medical applications
CO4	Integrate theoretically components for assembly of Lab-on-a-chip devices.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	-	-	-	-	-	-	-	-	-	-
CO2	3	-	-	2	3	-	-	-	-	-	-	--
CO3	-	-	-	3	-	2		-	-		-	-
CO4	-	-	-	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Physics and Chemistry at microscale: Introduction, Ranges of forces of microscopic origin, Microscopic length scales intervening in liquids and gases, Micromanipulation of molecules and cells in Microsystems, The physics of miniaturization, miniaturization of electrostatic systems, miniaturization of electromagnetic systems, miniaturization of mechanical systems, miniaturization of thermal systems, miniaturization of systems for chemical analysis.

Fluid dynamics in micro channels: Introduction, hypotheses of hydrodynamics, Hydrodynamics of gases in Microchannels, Flow of liquids with slip at the surface, Microhydrodynamics, Microfluidics involving inertial effects.

Interfacial phenomena: a few ideas about capillarity, Microfluidics of drops and bubbles, two-phase flows, emulsion in Microsystems.

Reaction, Mixing and separation in micro chambers: Introduction, The microscopic origin of diffusion process, Advection-diffusion equation and its properties, Analysis of dispersion phenomena, chaotic mixing, mixing in Microsystems, Adsorption phenomena, Dispersion with chemical kinetics, Chromatography.

Instruments for micro devices: Introduction, Examples of microfluidic structures, connectors, Examples of micro-fabricated valves and pumps.

Fabrication of micro devices, Applications of micro devices: Introduction, Current situation of micro-technologies, The environment of micro-fabrication, Photolithography, Micro-fabrication methods for silicon and glass MEMS, Methods of Fabrication for plastic MEMS.

Reading:

1. Tabeling P, Introduction to Microfluidics, Oxford University Press, 2010.
2. N.T. Nguyen, Steven Wereley, Fundamentals and Applications of Microfluidics, 2nd Edition, Artech Housenc., 2002.
3. Ronald F. Probstein, Physicochemical Hydrodynamics: An Introduction, 2nd Edition, Wiley-Interscience,2003.

CH462	PROCESS DESIGN PRINCIPLES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify steps in product and process design
CO2	Understand principles of steady-state flow sheet simulation
CO3	Understand heuristics for process synthesis
CO4	Design reactors for complex configurations.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	-	3	3	-	3	-	-	-	-	-	-
CO2	2	1	3	3	-	3	-	-	-	-	-	-
CO3	2	1	3	3	-	3	-	-	-	-	-	-
CO4	2	-	3	3	-	3	-	-	-	-	-	-

Detailed Syllabus:

Design Process: Design opportunities, steps in product and Process design, Environmental protection, Safety considerations, Engineering ethics, Role of computers.

Molecular Structure Design: Introduction, Property estimation methods, Optimization to Locate molecular structure.

Process Creation: Introduction, preliminary Database Creation, Experiments, preliminary Process Synthesis, Development of Base-Case Design.

Process Synthesis: Introduction, Principles of Steady-state Flowsheet simulation, Synthesis of the Toluene Hydrodealkylation process, Steady state Simulation of the Monochlorobenzene Separation Process, Principles of Batch flowsheet Simulation.

Heuristics for Process Synthesis: Introduction, Raw materials and Chemical Reactions, Distribution of Chemicals, Separations, Heat removal from and Addition to Reactors, Heat Exchangers and Furnaces, Pumping, Compression, Pressure Reduction, Vacuum, and Conveying of Solids, Changing the Particle Size of Solids and Size Separation of particles, Removal of Particles from Gases and Liquids.

Reactor Design and Reactor Network Synthesis: Reactor models, Reactor Design for Complex Configurations, Reactor Network Design Using the Attainable region.

Reading:

1. Sieder, W.D.,Seader J.D. and Lewin D.R., Process Design Principles: Synthesis Analysis and Evaluation, John Wiley & Sons, 3rd Edition, 2008.
2. J.M., Douglas, Conceptual Design of Chemical Processes, McGraw Hill International Editions, 1988.
3. Loren T Biegler, Grossman E.I., Westerberg, Systematic Methods of Chemical Process Design, A.W. Prentice Hall Intl ed,1997.

CH463	PLANT UTILITIES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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 distribution techniques.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	-	3	-	-	-	-	-	-
CO2	2	2	3	3	-	3	-	-	-	-	-	-
CO3	2	2	3	3	-	3	-	-	-	-	-	-
CO4	2	-	3	3	-	3	-	-	-	-	-	-
CO5	2	-	3	3	-	3	3	-	-	-	-	-

Detailed Syllabus:

Importance of Process utilities in Chemical Plant: Different utilities - water, steam, compressed air, vacuum, refrigerants, their properties and requirements, selection and application of different utilities.

Compressed air and Vacuum: Use of Compressed air, process air and instrument air, Process of getting instrument air, Vacuum.

Steam: Properties of steam, types of steam generator / Boiler, steam handling and distribution, steam traps, steam nozzles, Scaling, trouble shooting, preparing boiler for inspection, Boiler Act.

Refrigeration: Refrigeration cycles, Different methods of refrigeration used in industry, different refrigerants, Simple calculation of C.O.P. Refrigerating effects.

Liquefaction processes: Liquefaction process, liquefaction of air, liquefaction of natural gas.

Power Generation: Internal Combustion engines, Gas turbines, steam power plants.

Water: Hard and soft water, water treatment, Water Resources, storage and distribution of water resources and conservation of water.

Reading:

1. Jorgenson R., Fan Engineering, Buffalo Rorge Co., 8th Edition, 1983.
2. Lyle, O., Efficient Use of Steam, HMSO, London, 1974.
3. Stoecker, W.F., Refrigeration and Air Conditioning, Mc-Graw Hill, 2nd Edition, 1983.
4. Chattopadhyay, P., Boiler operations engineering, Tata McGraw Hill, 1998.
5. Perry R.H., Green D.W., Perry's chemical Engineer's Handbook, McGraw Hill, NewYork, 8th Edition, 2007.

CH464	POLYMER TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	-	2	1	-	-	-	-	-
CO2	3	3	3	3	3	3	2	-	-	-	-	-
CO3	3	2	1	1	-	-	-	-	-	-	-	-
CO4	3	3	3	3	3	-	1	-	-	-	-	-
CO5	3	3	3	3	2	-	2	-	-	-	-	-

Detailed Syllabus:

Introduction and Classification of Polymers. Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, synthesis procedure for monomers Styrene, ethylene, Vinyl monomers etc., Thermoplastics, Linear Branch, Cross Linked Polymers, Ewart Kinetics for emulsion polymerization.

Addition polymers – kinetics, synthesis and reactions, Condensation polymers, Kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits

Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Smith Ewart Kinetics for emulsion polymerization, Kinetics of free radical polymerization, Chain transfer agents, Kinetics of Step growth polymerization, Ziegler Natta polymerization Processes, Differentiation based on kinetics of Anionic and cationic polymers.

Polymerization reactors types and mode of operation, Polymerization reactor design, control of polymerization, Post polymerization unit operations and unit processes

High Performance and Specialty Polymers, Polymer additives, compounding. Fillers plastisizers lubricants colourants UV stabilizers, fire retardants, antioxidants, Different moulding methods of polymers.

Impact flexural tensile testing methods of polymers, Mechanical Properties of Polymers, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers.

Manufacturing of typical polymers with flow-sheet diagrams properties &application: PE, PP, PS, Polyesters, Nylons, ABS, PC.

Reading:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000.
2. Premamoy Ghosh, Polymer Science and Technology, 3rd Edition, Tata Mc. Graw-Hill Publishing Company, New Delhi, 2010.
3. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.

CH465	BIOTECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand microbial, plant and animal cells.
CO2	Select methods of cell culture and tissue culture.
CO3	Design fermentation technology for industrial microbiology.
CO4	Apply biotechnology in food, agriculture, environment and energy sectors.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	3	1	-	-	-	-	-	-	-	-	-
CO2	2	1	-	-	-	2	-	-	-	-	-	-
CO3	2	3	1	3	-	-	1	2	-	-	-	-
CO4	3	2	1	1	-	-	-	-	-	-	-	-

Detailed Syllabus:

Introduction: Basics, applications of biotechnology.

Plant cell and Tissue Culture: Introduction to gene structure, expression and regulation; Implication for plant transformation; Protein targeting; Heterologous promoters; Genome size and organization; Plant tissue culture – plasticity and tot potency; culture environment; Growth regulators, media regulators; Culture types.

Biotechnology of Animals: Animal breeds; Embryo transfer and transgenic animals; Animal cell culture; Recombinant vaccines for animal health; Biotechnology in animal production.

Fermentation Technology and Industrial Microbiology: The range of fermentation processes; microbial biomass; microbial enzymes; microbial metabolites; recombinant products; transformation processes; Media for industrial fermentations – Typical medium formulation, energy sources, carbon sources, nitrogen sources, minerals, growth factors, nutrient recycle; Sterilization – Medium sterilization, sterilization of the fermentor and feeds.

Food and Agriculture Biotechnology: Food Biotechnology – Preservation technology; Food production Technology; Food quality and control Agriculture Biotechnology – Plant breeding, Crop science and production, Pest management.

Environmental and Energy Biotechnology: Waste water treatment – Physical, chemical, biological methods, aerobic and anaerobic methods; Bioremediation – types of bioremediation, bioremediation of hydrocarbons; Bio energy – Energy and Biomass Production from wastes, biofuels, bio hydrogen and biomass.

Reading:

1. H.D. Kumar, A Text Book on Biotechnology, Affiliated East West Press Private Ltd., 2000.
2. James E. Bailey and David F. Ollis, Biochemical Engineering Fundamentals, 2nd Edition, Tata McGraw Hill Education Pvt. Ltd., 2010.

CH466	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Formulate lumped and distributed parameter mathematical models for chemical processes
CO2	Calculate degrees of freedom for the developed mathematical models
CO3	Solve the model equations describing chemical processes and equipment
CO4	Analyze the results of the solution methods.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	3	3	-	3	-	-	-	-	-	-
CO2	3	2	3	3	-	-	-	-	-	-	-	-
CO3	3	3	3	3	-	-	-	-	-	-	-	-
CO4	3	3	3	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Mathematical Formulation of the Physical Problems- Introduction, Representation of the problem, blending process, continuous stirred tank reactor, Unsteady state operation, heat exchangers, distillation columns, biochemical reactors.

Analytical (explicit) Solution of Ordinary Differential Equations encountered in Chemical Engineering Problems-Introduction, Order and degree, first order differential equations, second order differential equations, Linear differential equations, Simultaneous differential equations, .

Formulation of partial differential equations- Introduction, Interpretation of partial derivatives, Formulation partial differential equations, particular solutions of partial differential equations, Orthogonal functions, Method of separation of variables, The Laplace Transform method, Other transforms.

Unsteady state heat conduction in one dimension - Mass transfer with axial symmetry - Continuity equations; Boundary conditions - Iterative solution of algebraic equations- The difference operator - Properties of the difference operator- Linear finite difference equations-

Non-linear finite difference equations- Simultaneous linear differential equations - analytical solutions - Application of Statistical Methods.

Reading:

1. Rice R. G. and D. Do Duong, ‘Applied mathematics and modeling for chemical engineers’ John Wiley & Sons, 1995.
2. Jenson J F and G. V. Jeffereys, 'Mathematical Methods in Chemical Engineering', Academic Press, 1977.
3. B. A. Finlayson, 'Introduction to Chemical Engineering Computing', Wiley India Edition, 2010
4. Singaresu S. Rao, 'Applied Numerical Methods for Engineers and Scientists', Prentice Hall, 2002.
5. Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall India, 2^{nd} Edition, 2011.

CH467	MEMBRANE TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the technologies of membrane synthesis
CO2	Classify the membranes
CO3	Select membrane according to the application.
CO4	Understand the mathematical models of membrane processes.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	2	-	2	-	-	-	-	-
CO2	-	1	1	2	-	-	-	-	-	-	-	-
CO3	-	2	1	2	2	-	2	-	-	-	-	-
CO4	2	2	2	2	2	2	-	-	-	-	-	-

Detailed Syllabus:

Introduction: Membrane separation process, Definition of Membrane, Membrane types, Advantages and limitations of membrane technology compared to other separation processes, Membrane materials.

Preparation of synthetic membranes: Phase inversion membranes, Preparation techniques for immersion precipitation, Synthesis of asymmetric and composite membranes, and Synthesis of inorganic membranes.

Transport in membranes: Introduction, Driving forces, Transport through porous membranes, transport through non-porous membranes, Transport through ion-exchange membranes.

Membrane processes: Pressure driven membrane processes, Concentration as driving force, Electrically driven membrane processes

Polarisation phenomena and fouling: Concentration polarization, Membrane fouling

Modules: Introduction, membrane modules, Comparison of the module configuration

Reading:

1. Mulder M, Basic Principles of Membrane Technology, Kluwer Academic Publishers, London, 1996.
2. Richard W. Baker, Membrane Technology and Research, Inc. (MTR), Newark, California, USA, 2004.
3. Kaushik Nath, Membrane Separation Processes, Prentice-Hall Publications, New Delhi, 2008.

CH468	CHEMICAL PROCESS OPTIMIZATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Translate a verbal description of the chemical engineering problem into mathematical description.
CO2	Formulate unconstrained or constrained objective functions of chemical engineering problems
CO3	Understand how the problem formulation influences its solvability
CO4	Solve the optimization problem.
CO5	Interpret the results of optimization and present the insights.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	3	-	3	-	-	-	-	-	-
CO2	2	2	3	3	-	3	-	-	-	-	-	-
CO3	1	3	3	3	-	-	-	-	-	-	-	-
CO4	2	1	3	3	-	-	-	-	-	-	-	-
CO5	2	2	3	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Thenature and organization of optimization problems: Scope and Hierarchy, General procedure for solving optimization problems, Formulation of the objective function, Basic concepts of optimization - Continuity, Convexity and applications, Necessary and sufficient conditions for an extremum.

Optimization of unconstrained functions: Functions of single variable, scanning and bracketing procedures, Newton and Quasi-Newton methods, Evaluation of one-dimensional search methods.

Unconstrained multivariable optimization: Methods using function values only, Methods using first derivatives, Newton's method and Quasi-Newton's method.

Linear programming and applications: Graphical methods, Simplex algorithm, Barrier methods, Linear mixed integer programs. Non-linear programming with constraints - Direct substitution, Quadratic programming, Penalty, Barrier and Augmented Lagrangian methods.

Optimization of stage and discrete processes, Applications of optimization: Heat transfer and energy conservation, separation processes, chemical reactor design and operation.

Reading:

1. Edgar T.F. and D. M. Himmelblau, 'Optimization of Chemical Processes', 2nd Edition, McGraw Hill, 2001
2. Singiresu S Rao, 'Engineering Optimization: Theory and Practice', 4th Edition, John Wiley & Sons Ltd., 2009
3. Mohan C. Joshi and Kannan M. Moudgalya, 'Optimization: Theory and Practice', Alpha Science International Limited, 2004
4. K. Urbanier and C. McDermott, 'Optimal Design of Process Equipment', John Wiley & Sons, 1986.

CH469	SCALE-UP METHODS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand scale up in chemical engineering plants.
CO2	Apply dimensional analysis technique for scale up problems.
CO3	Scale up of chemical reactors.
CO4	Scale up mixers and heat exchangers, distillation columns and packed towers.

Mapping of course outcomes with program outcomes

Course outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	-	-	-	-	-	-	-	-
CO2	1	2	1	2	-	-	-	-	-	-	-	-
CO3	3	3	3	3	-	-	-	-	-	-	-	-
CO4	3	3	3	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Principals of Similarity, Pilot Plants & Models: Introduction to scale-up methods, pilot plants, models and principles of similarity, Industrial applications.

Dimensional Analysis and Scale-Up Criterion: Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering, experimental techniques for scale-up.

Scale-Up of Mixing and Heat Transfer Equipment: Typical problems in scale up of mixing equipment and heat transfer equipment.

Scale-Up of Chemical Reactors: Kinetics, reactor development & scale-up techniques for chemical reactors.

Scale-Up of Distillation Column & Packed Towers: Scale-up of distillation columns and packed towers for continuous and batch processes.

Reading:

1. Johnstone and Thring, Pilot Plants Models and Scale-up methods in Chemical Engg., McGraw Hill, New York, 1962.
2. W. Hoyle, Pilot Plants and Scale-Up, Royal Society of Chemistry, 1st Edition, 1999.
3. Marko Zlokarnik, Dimensional Analysis and Scale-up in Chemical Engineering, Springer Verlag, Berlin, Germany,1991.
4. E. Bruce Nauman, Chemical Reactor Design, Optimization and Scale-up, McGraw Hill, New York, 2002.

OPEN ELECTIVES

CE390	ENVIRONMENTAL IMPACT ANALYSIS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the environmental attributes to be considered for the EIA study.
CO2	Formulate objectives of the EIA studies.
CO3	Identify the suitable methodology and prepare Rapid EIA.
CO4	Prepare EIA reports and environmental management plans.
CO5	Plan the methodology to monitor and review the relief and rehabilitation works.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	3	-	3	-	3	-	-	3
CO2	-	-	-	-	3	-	3	-	3	-	-	3
CO3	-	-	-	-	3	-	3	-	3	-	-	3
CO4	-	-	-	-	3	-	3	-	3	-	-	3
CO5	-	-	-	-	3	-	3	-	3	-	-	3

Detailed Syllabus:

Introduction: The Need for EIA, Indian Policies Requiring EIA , The EIA Cycle and Procedures, Screening, Scoping, Baseline Data, Impact Prediction, Assessment of Alternatives, Delineation of Mitigation Measure and EIA Report, Public Hearing, Decision Making, Monitoring the Clearance Conditions, Components of EIA, Roles in the EIA Process. Government of India Ministry of Environment and Forest Notification (2000), List of projects requiring Environmental clearance, Application form, Composition of Expert Committee, Ecological sensitive places, International agreements.

Identifying the Key Issues: Key Elements of an Initial Project Description and Scoping, Project Location(s), Land Use Impacts, Consideration of Alternatives, Process selection: Construction Phase, Input Requirements, Wastes and Emissions, Air Emissions, Liquid Effluents, Solid Wastes, Risks to Environment and Human, Health, Socio-Economic Impacts, Ecological Impacts, Global Environmental Issues.

EIA Methodologies**:** Criteria for the selection of EIA methodology, impact identification, impact measurement, impact interpretation & Evaluation, impact communication, Methods-Adhoc methods, Checklists methods, Matrices methods, Networks methods, Overlays methods, Environmental index using factor analysis, Cost/benefit analysis, Predictive or Simulation methods. Rapid assessment of Pollution sources method, predictive models for impact assessment, Applications for RS and GIS.

Reviewing the EIA Report: Scope, Baseline Conditions, Site and Process alternatives, Public hearing. Construction Stage Impacts, Project Resource Requirements and Related Impacts, Prediction of Environmental Media Quality, Socio-economic Impacts, Ecological Impacts, Occupational Health Impact, Major Hazard/ Risk Assessment, Impact on Transport System,Integrated Impact Assessment.

Review of EMP and Monitoring: Environmental Management Plan, Identification of Significant or Unacceptable Impacts Requiring Mitigation, Mitigation Plans and Relief & Rehabilitation, Stipulating the Conditions, What should be monitored? Monitoring Methods, Who should monitor? Pre-Appraisal and Appraisal.

Case Studies: Preparation of EIA for developmental projects- Factors to be considered in making assessment decisions, Water Resources Project, Pharmaceutical industry, thermal plant, Nuclear fuel complex, Highway project, Sewage treatment plant, Municipal Solid waste processing plant, Tannery industry.

Reading:

1. Jain, R.K., Urban, L.V., Stracy, G.S., *Environmental Impact Analysis*, Van Nostrand Reinhold Co., New York, 1991.
2. Barthwal, R. R., *Environmental Impact Assessment*, New Age International Publishers, 2002
3. Rau, J.G. and Wooten, D.C., *Environmental Impact Assessment,* McGraw Hill Pub. Co., New York, 1996.
4. Anjaneyulu.Y., and Manickam. V., Environmental Imapact Assessment Methodologies, B.S. Publications, Hyderabad, 2007.
5. Wathern.P., Environmental Impact Assessment- Theory and Practice, Routledge Publishers, London, 2004.

EE390	LINEAR CONTROL SYSTEMS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze electromechanical systems using mathematical modelling
CO2	Determine Transient and Steady State behavior of systems using standard test signals
CO3	Analyze linear and non-linear systems for steady state errors, absolute stability and relative stability
CO4	Design a stable control system satisfying requirements of stability and reduced steady state error

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	3	-	3	-	-	3	-	-	-
CO2	-	-	-	3	-	3	-	-	3	-	-	-
CO3	-	-	-	3	-	3	-	-	3	-	-	-
CO4	-	-	-	3	-	3	-	-	3	-	-	-

Detailed syllabus:

Introduction - control system, types, feedback and its effects-linearization

Mathematical Modelling of Physical Systems. Block diagram Concept and use of Transfer function. Signal Flow Graphs- signal flow graph, Mason's gain formula.

Time Domain Analysis of Control Systems - BIBO stability, absolute stability, Routh-Hurwitz Criterion.

P, PI and PID controllers. Root Locus Techniques - Root loci theory, Application to system stability studies.

Frequency Domain Analysis of Control Systems - polar plots, Nyquist stability criterion, Bode plots, application of Bode plots.

Reading:

1. B.C. Kuo, Automatic Control Systems, 7th Edition, Prentice Hall of India, 2009.
2. I.J. Nagarath and M. Gopal: Control Systems Engineering, 2nd Edition, New Age Pub. Co. 2008.

ME390	AUTOMOTIVE MECHANICS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze operation and performance indicators of transmission systems, internal combustion engines and after treatment devices.
CO2	Understand operation of engine cooling system, lubrication system, electrical system and ignition system.
CO3	Understand fuel supply systems in an diesel and petrol vehicles
CO4	Analyze current and projected future environmental legislation and its impact on design, operation and performance of automotive power train systems.
CO5	Understand operation and performance of suspension, steering and braking system.
CO6	Understand layout of automotive electrical and electronics systems.

Mapping of course outcomes with program outcomes

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	-	-	-	-	3	-	-	-
CO2	-	-	-	-	-	-	-	-	3	-	-	-
CO3	-	-	-	-	-	-	-	-	3	-	-	-
CO4	-	-	-	-	-	-	-	-	3	-	-	-
CO5	-	-	-	-	-	-	-	-	3	-	-	-
CO6	-	-	-	-	-	-	-	-	3	-	-	-

Detailed syllabus

Introduction: Layout of an automotive chassis, engine classification.

Cooling Systems: Air cooling, air cleaners, Water cooling: Thermosyphon and pump circulation systems, Components of water cooling systems- Radiator, thermostat etc.

Engine Lubrication: Petroils system, Splash system, Pressure lubrication and dry sump system

Ignition System: Battery, Magneto and Electronic, Engine Starting drives

Fuel supply system: Components in fuel supply system, types of feed pumps, air cleaners, fuel and oil filters, pressure and dry sump systems.

Engine testing and Performance: Performance parameters, constant and variable speed test, heat balance test, performance characteristics. Engine Emissions: SI and CI engine emissions, emission control methods

Automotive electrical and electronics: Electrical layout of an automobile, ECU, sensors, windscreen wiper, Electric horn.

Transmission: Clutch- Single and multiplate clutch, semi & centrifugal clutch and fluid flywheel, Gear box: Sliding mesh, constant mesh and synchromesh gear box, selector mechanism, over drive, Propeller shaft and Differential.

Suspension System: Front and rear suspension, shock absorbers, Rear Axles mountings, Front Axle. Steering Mechanism: Manual and power steering systems, Braking System: Mechanical, Hydraulic and Air braking systems.

Engine service: Engine service procedure.

Reading:

1. S. Srinivasan, Automotive Mechanics, Tata McGraw-Hill, 2004.
2. K.M.Gupta, Automobile Engineering, Vol.1 and Vol.2, Umesh Publications, 2002
3. Kirpal Singh, Automobile Engineering, Vol.1 and Vol.2, Standard Publishers, 2003.
4. William H.Crouse and Donald L. Anglin, Automotive Mechanics, Tata McGraw-Hill, 2004
5. Joseph Heitner, Automotive Mechanics, East-West Press, 2000.