THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

COURSE SCHEME

&

SYLLABUS

FOR

B.E.

CHEMICAL ENGINEERING

2014

Revised scheme approved by the 90th meeting of the senate (May 30, 2016)

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY, PATIALA
DEPARTMENT OF CHEMICAL ENGINEERING

Scheme of courses for B.E. (Chemical Engineering) 2014

First Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UMA001	MATHEMATICS-I	3	1	0	3.5
2	UPH001	PHYSICS	3	1	2	4.5
3	UES002	SOLID MECHANICS	3	1	2	4.5
4	UHU002	BUSINESS AND TECHNICAL COMMUNICATION	2	0	2	3.0
5	UTA001	ENGINEERING GRAPHICS	2	4	0	4.0
6	UTA003	COMPUTER PROGRAMMING	3	0	2	4.0
7	UDP001	INTRODUCTION TO CHEMICAL ENGINEERING	2	0	0	2.0
		TOTAL	18	7	8	**25.5**

SecondSemester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UMA002	MATHEMATICS-II	3	1	0	3.5
2	UCB008	APPLIED CHEMISTRY	3	1	2	4.5
3	UTA002	MANUFACTURING PROCESSES	2	0	3	3.5
4	UES001	ELECTRICAL AND ELECTRONICS SCIENCE	3	1	2	4.5
5	UES008	ENGINEERING THERMODYNAMICS	3	1	0	3.5
6		ELECTIVE I	3	1	0	3.5
		TOTAL	17	5	7	**23.0**

Elective I

1. BIOLOGICAL APPLICATIONS IN ENGINEERING
2. INTRODUCTION TO INDUSTRIAL DESIGN
3. INTERNET AND JAVA PROGRAMMING
4. BIO-COMPUTING AND GENETIC ENGINEERING
5. NUCLEAR POWER ENGINEERING
6. BIOLOGICAL CHEMISTRY
7. CHEMICAL ANALYTICAL TECHNIQUES

Third Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UMA031	OPTIMIZATION TECHNIQUES	3	1	0	3.5
2	UHU031	ORGANIZATIONAL BEHAVIOUR	3	1	0	3.5
3	UCB005	ORGANIC CHEMISTRY	3	0	3	4.5
4	UCH301	MATERIAL & ENERGY BALANCES	3	1	0	3.5
5	UCH302	PROCESS FLUID MECHANICS	3	1	2	4.5
6	UCH303	CHEMICAL ENGINEERING THERMODYNAMICS	3	1	0	3.5
7	UCH304	CHEMICAL TECHNOLOGY-I	3	0	0	3.0
		TOTAL	**21**	**5**	**5**	**26.0**

Fourth Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UMA032	NUMERICAL AND STATISTICAL METHODS	3	1	2	4.5
2	UES032	MATERIAL SCIENCE AND ENGINEERING	3	1	2	4.5
3	UHU034	HUMAN VALUES, HUMAN RIGHTS AND IPR	2	1	0	2.5
4	UCH401	FLUID AND PARTICLE MECHANICS	3	1	2	4.5
5	UCH402	HEAT TRANSFER	3	1	2	4.5
6	UCH403	CHEMICAL TECHNOLOGY-II	3	0	0	3.0
		TOTAL	**18**	**4**	**8**	**23.5**

Fifth Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH501	CHEMICAL REACTION ENGINEERING-I	3	1	2	4.5
2	UCH502	MASS TRANSFER-I	3	1	0	3.5
3	UCH503	INDUSTRIAL POLLUTION ABATEMENT	3	1	2	4.5
4	UCH 504	ENERGY TECHNOLOGY	3	1	2	4.5
5	UCH505	PROCESS EQUIPMENT DESIGN-I	3	1	0	3.5
6	UCH506	PROCESS INSTRUMENTATION AND CONTROL	3	1	2	4.5
7	UEN003	ENVIRONMENTAL STUDIES	2	0	0	2.0
8	UCH591	SUMMER TRAINING (SIX WEEKS, AFTER FOURTH SEMESTER)				4.0
		TOTAL	**20**	**6**	**8**	**31.0**

Sixth Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH601	CHEMICAL REACTION ENGINEERING-II	3	1	0	3.5
2	UCH602	MASS TRANSFER-II	3	1	3	5.0
3	UCH603	TRANSPORT PHENOMENA	3	1	0	3.5
4	UCH604	BIOCHEMICAL ENGINEERING	3	1	2	4.5
5	UCH605	PROCESS UTILITY AND INDUSTRIAL SAFETY	3	1	0	3.5
6	UCH606	PROCESS EQUIPMENT DESIGN-II	2	2	0	3.0
7	UTA012	INNOVATION & ENTREPRENEURSHIP	1	0	2	4.5
		TOTAL	**18**	**7**	**7**	**27.5**

Seventh Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH791	PROJECT SEMESTER*				16.0
		TOTAL				**16.0**

*TO BE CARRIED OUT IN INDUSTRY/RESEARCH INSTITUTION

OR

.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH792	PROJECT				6.0
2	UCH701	CATALYTIC PROCESSES	3	1	0	3.5
3		ELECTIVE-II	3	1	0	3.5
4		ELECTIVE-III	3	0	0	3.0
		TOTAL	**9**	**2**	**0**	**16.0**

Eighth Semester

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UHU081	ENGINEERING ECONOMICS	3	1	0	3.5
2	UCH801	PROCESS ENGINEERING AND PLANT DESIGN	3	1	0	3.5
3	UCH802	PROCESS MODELING AND SIMULATION	3	0	2	4.0
4		ELECTIVE-IV	3	1	0	3.5
5		ELECTIVE-V	3	0	0	3.0
6	UCH893	CAPSTONE PROJECT	0	0	2	8.0
		TOTAL	**18**	**4**	**4**	**25.5**

<u>LIST OF PROFESSIONAL ELECTIVES</u>

ELECTIVE-II

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1	UCH711	MATHEMATICAL TECHNIQUES IN CHEMICAL ENGINEERING	3	1	0	3.5
2	UCH712	DISTILLATION PROCESSES	3	1	0	3.5
3	UCH713	NON-NEWTONIAN FLUID MECHANICS	3	1	0	3.5
4	UCH714	MEMBRANE SEPARATION PROCESSES	3	1	0	3.5
5	UCH715	ALTERNATE ENERGY SOURCES	3	1	0	3.5

ELECTIVE-III

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH721	FOOD TECHNOLOGY	3	0	0	3.0
2	UCH722	FERMENTATION TECHNOLOGY	3	0	0	3.0
3	UCH723	PULP AND PAPER TECHNOLOGY	3	0	0	3.0
4	UCH724	NUCLEAR TECHNOLOGY	3	0	0	3.0

ELECTIVE-IV

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1	UCH831	NOVEL SEPARATION PROCESSES	3	1	0	3.5
2	UCH832	CFD ANALYSIS IN CHEMICAL ENGINEERING	3	1	0	3.5
3	UCH833	FLUIDIZATION ENGINEERING	3	1	0	3.5
4	UCH834	PROCESS INTEGRATION	3	1	0	3.5
5	UCH835	PROCESS OPTIMIZATION	3	1	0	3.5
6	UCH836	ENERGY MANAGEMENT IN PROCESS INDUSTRIES	3	1	0	3.5

ELECTIVE-V

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1.	UCH841	CORROSION ENGINEERING	3	0	0	3.0
2.	UCH842	NANOFLUID ENGINEERING	3	0	0	3.0
3.	UCH843	SCALE-UP AND PILOT-PLANTS METHODS IN	3	0	0	3.0
4.	UCH844	PETROLEUM TECHNOLOGY	3	0	0	3.0
5.	UCH845	POLYMER TECHNOLOGY	3	0	0	3.0

TOTAL CREDITS: 198.0

Revised scheme approved by the 90th meeting of the senate (May 30, 2016)

UDP001 INTRODUCTION TO CHEMICAL ENGINEERING

L	T	P	Cr
2	**0**	**0**	**2.0**

Course Objective:
To introduce history, importance and components of chemical engineering, concepts of unit operations and unit processes, and current scenario of chemical & allied process industries.

Introduction: Chemical engineering and technology: Origin, growth and role in process industries, Relation between chemical engineering and other engineering disciplines, Traditional versus modern chemical engineering.

Chemical Process Industry: Growth and present scenario, Process flow sheeting and symbols, Concepts of unit processes and unit operations, Problems associated with industrial expansion.

Unit Processes and Unit Operations: Description of different unit processes and unit operations, Flow-sheet representations of process plants, Physico-Chemical calculations, General material and energy balances, Momentum, heat and mass transfer operations, Chemical kinetics, Measuring devices.

Traditional and Current Chemical Engineering Areas: Natural resources and their utilization, Pollution and its abatement, Conventional and alternate energy resources, New materials, Bioengineering and biotechnology, Food technology, Safety and health aspects, Professional ethics, Future challenges, Nanotechnology, Bioinformatics.

Computers in Chemical Engineering: Role of computers in chemical engineering, Process modeling and simulation, Software applications, Concepts of scale-up and dimensional analysis.

Course Learning Outcomes (CLO)

The students will be able to:

1. know what is chemical engineering and its relation to other disciplines
2. list chemical processes and unit operations
3. list different chemical and engineering areas
4. make use of computer and software in process industries

Text Book:

1. *Ghosal, S.K., Sanyal, S.K. and Datta, S., Introduction to Chemical Engineering, Tata McGraw-Hill Publishing Company Ltd. (1997).*

2. *Badger, W.A., and Banchero, J.T., Introduction to Chemical Engineering, McGraw-Hill Book Company (1997).*

Reference Books:

1. *McCabe, W.I., and Smith, J.C., Unit Operations in Chemical Engineering, McGraw- Hill Book Company (2004).*
2. *Perry, R.H., and Green, D.W., Perry's Chemical Engineers' Handbook, McGraw-Hill Book Company (2007).*
3. *Rao, M.G., and Sittig, M., Dryden's Outlines of Chemical Technology for the 21st* Century, *East-West Press (1997).*
4. *Pushpavanam, S., Introduction to Chemical Engineering, PHI Learning Private Ltd. (2012).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	40
2	EST	60

UCH301 MATERIAL AND ENERGY BALANCES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:

To understand and apply the basics of calculations related to material and energy flow in the processes.

Introduction: Units and dimensions, Stoichiometry of chemical equations, Mole and weight fractions, Unit operations and unit processes with reference to material and energy balance calculations.

Behaviour of Gas and Liquid Mixtures: Gas laws, Raoult's law, Henry's law, Duhring's plot, Saturation, Partial saturation, Relative saturation, Real gases, Bubble point and dew point temperatures.

Material Balance Calculations: Law of conservation of mass, General material balance equation, Material balance calculations without chemical reactions, Material balance calculations with chemical reactions, Recycling, Bypass, Purge, Analysis of degrees of freedom.

Energy Balance Calculations: General energy balance equation, Internal energy, Enthalpy, Heat capacity of gases, liquids, and solids, Latent heats, Heats of formation, combustion, reaction and dissolution, Enthalpy-concentration chart, Fuel heating value, Theoretical flame temperature, Energy balance calculations in unit operations and systems with and without chemical reactions, Humidity and psychrometric chart, Energy balance calculations in humidification and adiabatic cooling.

Course Learning Outcomes (CLO)

The students will be able to:

1. perform material balance for problems without chemical reactions.
2. perform material balance for problems involving chemical reactions.
3. performPerform energy balance for problems without chemical reactions.
4. perform energy balance for problems involving chemical reactions.

Text Books:

1. *Himmelblau, D.M. and Riggs, J.B., Basic Principles and Calculations in Chemical Engineering, Prentice Hall of India (2003).*
2. *Bhatt, B.I. and Vora, S.M., Stoichiometry, Tata McGraw Hill (2004).*

Reference Books:

1. *Hougen, O.A., Watson, K.M. and Ragatz, R.A., Chemical Process Principles, Volume-I, C.B.S. Publications (2004).*
2. *Felder, R.M, and Rousseau, R.W., Elementary Principles of Chemical Processes, C.B.S. Publications (2000).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional	25

Revised scheme approved by the 90th meeting of the senate (May 30, 2016)

UCH302 PROCESS FLUID MECHANICS

L	T	P	Cr
3	**1**	**2**	**4.5**

Course Objective:
To understand basic concept of fluid flow and its application to chemical process industries including pipe flow, fluid machinery and agitation & mixing.

Introduction: Basic fluid concepts, Velocity and stress fields, Classification of fluids.

Fluid Statics: Basic equations for pressure field, Manometers.

Fluid Kinematics: Methods of describing fluid motion, Velocity and acceleration of a fluid particle, Type of fluid flows, Circulation and vorticity, Potential and stream functions.

Fluid Dynamics: Euler's equation of motion, Bernoulli's equation, Momentum equation, Kinetic energy and momentum correction factors.

Dimensional Analysis: Methods of dimensional analysis, Rayleigh method and Buckingham π-theorem.

Flow through Pipes: Laminar and turbulent flows, Friction factor, Moody's chart, K-factors, Valves, Pipe networks.

Flow Measuring Devices: Impinging jet, Pitot tube, Orifice and venturi meter, Rotameter, V-notch and weirs, Water current meter.

Pumps and Compressors: Types, Working principles, NPSH, Cavitation, Priming, Basic equations.

Flow of Compressible Fluids: Basic equations: Adiabatic, isothermal and isentropic flows.

Laboratory Work:
Verification of Bernoulli's theorem, Calibration of venturimeter, Centrifugal pumps characteristic curves, Calibration of orifice meter, Determination of friction factor for pipes of different materials, Determination of hydraulic coefficients of an orifice, Verification of momentum equation, Determination of loss coefficients for various types of pipe fittings, Calibration of a triangular notch, Calibration of rotameter, Visualization of laminar and turbulent flow.

Course Learning Outcomes (CLO)

The students will be able to:

1. calculate shear force, pressure, and various kinematic quantities
2. analyze fluid flow problems involving the application of the momentum and energy equations
3. analyze fluid flow problems with dimensional analysis
4. solve the problems related to pipe flows and fluid machinery

Text Book:

1. *Cengel, Y. A., Fluid Mechanics Fundamentals and Applications (in SI units),Tata McGraw-Hill (2010).*

Reference Books:

1. *McCabe, W., Smith, J. and Harriot, P., Unit Operations of Chemical Engineering, McGraw-Hill (2005).*
2. *Levenspiel, O., Engineering Flow and Heat Exchanger, Springer (1998).*
3. *Foust, A.S., Wenzel, L.A., and Clump C.W., Principles of Unit Operations, John Wiley (2008).*
4. *Fox, R.W., McDonald, A.T, and Pritchard, P.J., Introduction to Fluid Mechanics, John Wiley (2008).*
5. *Wilkes, J.O., Fluid Mechanics for Chemical Engineers with Microfluidics and CFD, Prentice Hall of India (2005).*
6. *Denn, M., Process Fluid Mechanics, Prentice Hall (1979).*
7. *Kumar, D.S., Fluid Mechanics and Fluid Power Engineering, Kataria& Sons (2009).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (may include lab/tutorials/ assignments/ quizzes)	40

UCH 303 CHEMICAL ENGINEERING THERMODYNAMICS

L	T	P	Cr
3	1	0	3.5

Course Objective:
To understand the theory and applications of classical thermodynamics, thermodynamic properties, equations of state, methods used to describe and predict phase equilibria.

Introduction: Laws of thermodynamics and their applications to real processes, Heat capacities, Heat effects during: Phase change, formation, combustion and mixing, Enthalpy-concentration diagram, Thermodynamic analysis of flowing fluids.

Thermodynamic Properties of Fluids and Equations of State: Relationships among thermodynamic properties, Behavior of gases in multi-component systems, Thermodynamic properties of gases and their mixtures, Thermodynamic diagrams, Equations of state and generalized property correlations for gases.

Vapour-Liquid Equilibria and Solution Thermodynamics: Criteria for equilibrium, Fugacity of gases and liquids, Composition of phases in equilibrium, Generalized correlations for the fugacity coefficients, Models for the excess Gibbs energy, Effect of pressure and temperature on phase behavior, Chemical reaction equilibria.

Refrigeration and Liquefaction: Refrigeration cycle, Vapor compression cycle, Eco-friendly refrigerants, Absorption and adsorption refrigeration, Liquefaction processes.

Course Learning Outcomes (CLO)

The students will be able to:

1. apply fundamental concepts of thermodynamics to engineering applications.
2. estimate thermodynamic properties of substances in gas and liquid states.
3. determine thermodynamic efficiency of various energy related processes.

Text Books:

1. *Smith J. M. and Van Ness H. C., Chemical Engineering Thermodynamics, Tata McGraw-Hill (2007).*
2. *Rao, Y. V. C., Chemical Engineering Thermodynamics, University Press (1997).*

Reference Books:

1. *Weber, H. C. and Meissner, H. P., Thermodynamics for Chemical Engineers, John Wiley, (1970).*
2. *Hougen, O.A., Watson, K.M. and Ragatz, R.A., Chemical Processes Principles (Thermodynamics), Part 2, C.B.S. Publications (2006).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional	25

Revised scheme approved by the 90th meeting of the senate (May 30, 2016)

CH304 CHEMICAL TECHNOLOGY-I

L	T	P	Cr
3	0	0	3.0

Introduction to Chemical Engineering: Unit operations and unit processes, functions of a chemical engineer in chemical and bio-chemical process industries. Study of the following chemical industries/processes involving process details, production trends, material and energy balances, flow sheets, engineering problems pertaining to materials of construction, waste regeneration/recycling, environmental and energy conservation measures.

Industrial and Fuel Gases: Oxygen, nitrogen, hydrogen, carbon dioxide, natural gas, LPG, producer gas, water gas, carbureted water gas, coke oven gas, synthesis gas.

Nitrogen Industries: Ammonia, nitric acid, ammonium sulphate, ammonium nitrate, urea, calcium ammonium nitrate.

Phosphorus Industries: Phosphorus, phosphoric acid, phosphatic fertilizers.

Mixed Fertilizer: N.P.K. fertilizers, diammonium hydrogen phosphate.

Chlor-Alkali Industries: Brine electrolysis, manufacture of caustic soda and chlorine in mercury cells, diaphragm cells, membrane cells, hydrochloric acid. Soda ash.

Sulphur Industries: Sulphur dioxide, sulphuric acid, oleum.

Ceremic Industries: Portland cement, Other Cement, Lime, Gypsum.

Glass Industries: Methods of manufacture of glass and special glasses.

Explosives, Propellants, and Toxic Chemical Agents: Types and characteristics of explosives, industrial explosives, propellants, rockets and Missiles, propellants for rockets.

Metallurgical Industries: Iron and steel.

Cryogenics in chemical industries

Course Learning Outcomes (CLO)

The students will be able to:

1. understand the processes involved in the manufacturing of various inorganic chemicals.
2. prepare the process flow diagrams.
3. analyze important process parameters and engineering problems during production.

Text Books

1. *Rao, M.G. and Sittig, M., Dryden's Outlines of Chemical Technology-for the 21st century, Affiliated East West Press (1998) 3rd ed.*
2. *Austin, G.T., Shreve's Chemical Process Industries, McGraw Hill (1998) 5th ed.*

Reference Book

1. *Faith, W.L., Keyes, D.B. and Clark, R.L, Industrial Chemicals, John Wiley (1980) 4th ed.*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may include assignments/ quizzes)	20

UCH401 FLUID AND PARTICLE MECHANICS

L	T	P	Cr
3	1	2	4.5

Course Objective:
To understand basic principles of various mechanical operations, construction and working of the equipments.

Characterization of Solid Particles: Determination of mean particle size, Particle shape and size distribution.

Screening: Types of screens, Screen effectiveness, Particle size analysis using screens.

Size Reduction: Principles of crushing and grinding, Laws of size reduction, Industrial size reduction equipment, Closed and open circuit grinding.

Fluid-Solid Separations: Stoke's law, Free and hindered settling, Clarification and thickening, Elutriation, Zigs, Froth flotation, Centrifugal separation.

Flow Past Immersed Bodies: Friction in flow through packed beds, Motion of particles through fluids.

Fluidization: Mechanism of fluidization, Determination of minimum fluidization velocity, Determination of velocity range for the operation of a fluidized bed, Types and applications of fluidization.

Filtration: Theory of filtration and filtration equipment.

Handling of Solids: Storage of solids, Sizing of hoppers and bins, Conveying systems: Mechanical, pneumatic and hydraulic, Mixing of solids and liquids.

Laboratory Work:
Screen analysis, Power requirement in mixing, Plate and frame filter press, Leaf filter, Elutriation, Pressure drop in fluidized bed and packed bed, Sedimentation, Centrifugal pump characteristics, Size reduction, Cyclone separator.

Course Learning Outcomes (CLO)

The students will be able to:

1. solve and analyze problems of size reduction and solid-solid separation methods.
2. analyze and design of equipment handling fluid-particle systems.
3. analyze mixing process, and sizing of hoppers and bins and selection of suitable solid conveying systems.
4. analyze and solve problems related to flow through beds of solids.

Text Books:

1. *McCabe, W.L., Smith, J.C., and Harriot, P., Unit Operations of Chemical Engineering, McGraw-Hill (2005).*
2. *Richardson, J.F., Harker, J.H. and Backhurst, J.R., Coulson and Richardsons Chemical Engineering, Vol. 2, Butterworth-Heinemann (2007).*

Reference Books:

1. *Foust, A.S, Wenzel, L.A, Clump, C.W., Maus, L. and Anderson, L.B., Principles of Unit Operations, John Wiley (2008).*
2. *Perry, R.H, and Green, D.W., Perry's Chemical Engineers' Handbook, McGraw Hill (2007).*
3. *Narayanan, C.M. and Bhattacharya, B.C., Mechanical Operations for Chemical Engineers Incorporating Computer Aided Analysis, Khanna Publishers (2005).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (may include lab/tutorials/ assignments/ quizzes)	40

UCH402 HEAT TRANSFER

L	T	P	Cr
3	1	2	4.5

Course Objective:
To understand the fundamentals of heat transfer mechanisms in fluids and solids and their applications in various heat transfer equipment in process industries.

Heat Transfer: Introduction, Applications, Relation between heat transfer and thermodynamics, Transport properties, Heat transfer coefficients.

Conduction: Fourier's law, Thermal conductivity, Heat conduction equations: Rectangular, cylindrical and spherical coordinates, Composite wall structure, Insulation and its optimum thickness, Extended surfaces, Unsteady state conduction.

Convection: Newton's law of cooling, Boundary layer theory, Heat transfer in laminar and turbulent flows inside tubes, Colburn analogy, Heat transfer by external flows across: Cylinders, tube bank and spheres, Natural convection, Convection with phase change: Boiling and condensation.

Radiation: Basic equations, Emissivity, Absorption, Black and gray body, Thermal radiation between two surfaces.

Heat Exchangers: Classification of heat exchangers, LMTD and ε-NTU methods, Heat exchangers: Double pipe, shell and tube, air-cooled, plate type, Fouling.

Evaporators: Classification, Single and multiple effect evaporators, Enthalpy balance, Performance of evaporators: Capacity and economy, Methods of feeding.

Reactor Heating and Cooling Systems: Time required for heating and cooling of agitated batch reactors, Helical cooling coils, Jacketed vessels.

Laboratory Work:
Thermal conductivity of a metal rod, Thermal conductivity of insulating power, Emissivity measurement, Parallel flow/counter flow heat exchanger, Heat transfer through composite wall, Drop wise & film wise condensation, Heat transfer through a pin-fin, Heat transfer in natural convection, Heat transfer in forced convection, Critical heat flux, Stefen-Boltzman's law of radiation, Heat flow through lagged pipe, Shell and tube heat exchanger.

Course Learning Outcomes (CLO)

The students will be able to:

1. solve conduction, convection and radiation problems
2. design and analyse the performance of heat exchanger and evaporators
3. calculate heating and cooling requirements for reactors.

***Text Books*:**

1. *McCabe, W.L., Smith J.C., and Harriott, P., Unit Operations of Chemical Engineering, McGraw-Hill (2005).*
2. *Holman, J.P., Heat Transfer, Tata McGraw-Hill Education (2008).*

***Reference Books*:**

1. *Kern, D.Q., Process Heat Transfer, Tata McGraw-Hill (2008).*
2. *Frank, P.I. and David, P.D., Fundamentals of Heat and Mass Transfer, John Wiley & Sons (2007).*
3. *Cengel, Y.A., Heat and Mass Transfer, Tata McGraw-Hill Publishing Company Limited (2007).*
4. *Alan, S.F., Leonard, A.W. and Curtis, W.C., Principles of Unit Operations, Wiley India (P) Ltd., (2008).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (may include lab/tutorials/ assignments/ quizzes)	40

UCH403 CHEMICAL TECHNOLOGY-II

L	T	P	Cr
3	0	0	3.0

Study of the following chemical industries/processes involving process details, production trends, material and energy balances, flow sheets, engineering problems pertaining to materials of construction, regeneration/recycling, environmental and energy conservation measures.

Petroleum and Petrochemical Industries: Origin and composition of petroleum, classification of petroleum, Manufacture of petroleum products and their uses and properties. Petroleum refining, physical and chemical conversion products, lubricating oils, petrochemical precursors, methane, olefines, acetylenes and aromatics.

Coal and Coal Chemicals: Types of coal, destructive distillation of coal, distillation of coal tar, chemicals from coal.

Pulp and Paper Industries: Cellulose derivatives, pulp, paper and boards. Types of raw material for pulping, various pulping methods, recovery of chemicals from black liquor. Manufacture of paper, quality improvement of paper.

Sugar and Starch Industries: Raw and refined sugar, byproducts of sugar industries, Starch and starch derivatives.

Oils and Fats: Types of oil, different fatty acids, extraction of oil from seeds, oil purification, hydrogenation of oil.

Soaps and Detergents: Types of soaps, soap manufacture, recovery and purification. Types of detergents, their cleansing action.

Surface Coating Iindustries: Paints, Pigments, Varnishes, Industrial coatings.

Food Industries: Food processing, Food additives and preservatives, food processing equipments.

Fermentation and Enzyme Industries: Production of industrial alcohol, acetic acid, citric acid and lactic acid. Introduction to enzymes and their applications.

Polymers: Monomers, Thermoplastic and Thermosetting materials (such as polythylene, polypropylene, polyvinyl chloride, polystyrene) and PF resins; Epoxy and polyesters - Natural rubber; Synthetic rubber such as SBR, NBR, CR - Fundamental methods of processing of synthetic Rubbers.

Synthetic Fibre and Film Industries: Viscose rayon, cuprammonium and cellulose acetate, nylons, polyesters, acrylics.

Pharmaceutical Industries: Introduction to pharmaceutical products - Synthesis and recovery,

Course Learning Outcomes (CLO)

The students will be able to:

1. identify various operations involved in the manufacturing of different organic chemicals.
2. know the important process parameters and solve engineering problems during production.
3. identify the limitations and advantages of various manufacturing processes.

Text Books

1. *Rao, M.G. and, Sittig, M., Dryden's Outlines of Chemical Technology for the 21st century, Affiliated East West (1998) 3rd ed.*
2. *Austin, G.T., Shreve's Chemical Process Industries, McGraw Hill (1998) 5thed.*
3. *Groggins, P.H., Unit Processes in Organic Synthesis, Tata McGraw Hill (2003) 5thed.*

Reference Book

1. *Faith, W.L., Clark, R.L. and Keyes, D.B., Industrial Chemicals, John Wiley (1980) 4thed.*
2. *Garry, James H., Handwerk, G. E. and Kaiser, M.J., Petroleum Refining Technology and Economics, Taylor & Francis (2007).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1	MST	30
2	EST	50
3	Sessional (may include assignments/ quizzes)	20

UCH501 CHEMICAL REACTION ENGINEERING-I

L	T	P	Cr
3	1	2	4.5

Course Objective:

To understand the kinetics of single and multiple reactions and the effect of temperature on reaction systems.

Introduction: Overview of chemical reaction engineering, Classification of reactions, Variables affecting rate,Definition of reaction rate, single and multiple reactions, Elementary and non-elementary reactions, Molecularity and order of reaction,Reaction pathways, Effects of temperature, pressure,Heat and mass transfer on rate,Arrhenius law, Activation energy,Reversible and irreversible reactions,Reaction equilibrium.

Kinetics: Constant volume and variable volume batch, CSTR and PFR reactor data, Analysis of total pressure data obtained from a constant-volume batch reactor, Integral and differential methods of analysis of data, Autocatalytic reactions, Reversiblereactions, and Bio-chemical reactions.

Homogeneous Single Reactions: Performance equations for ideal batch, Plug flow, Back-mix flow and semi batch reactors for isothermal condition, Size comparison of single reactors, Multiple-reactor systems, Recycle reactor, Autocatalytic reactions, Optimum recycle operations.

Multiple Reactions: Parallel reactions of different orders, Yield and selectivity, Product distribution and design for single and multiple-reactors, Series reactions: first-order reactions and zero-order reactions,Mixed series parallel complex reactions, Choice of reactors for simple and complex reactions.

Temperature Effects for Single and Multiple Reactions: Thermal stability of reactors and optimal temperature progression for first order reversible reactions, Adiabatic and heat regulated reactions, Design of non-isothermal reactors, Effect of temperature on product distribution for series and parallel reactions.

Laboratory work: Experiments on batch reactors, Semi-batch reactors, Continuous stirred tank reactors, Tubular reactors, RTD, Fluid-solid reactions.

Course Learning Outcomes (CLO):

The students will be able to:

1. develop rate laws for homogeneous reactions.
2. analyze batch reactor data by integral and differential methods.
3. design ideal reactors for homogeneous single and multiple reactions.
4. select the appropriate type reactor/scheme.
5. demonstrate the temperature effect on reaction rate and design non-isothermal reactors..

Text Books:

1. *Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India (2003).*
2. *Levenspiel, O., Chemical Reaction Engineering, John Wiley & Sons (1998).*

Reference Books:

1. *Smith, J.M., Chemical Engineering Kinetics, McGraw Hill, New York (1990).*
2. *Denbigh, K.G., and Turner, J.C.R., Chemical Reactor Theory - An Introduction, Cambridge University Press, UK (1984).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (May includes lab/tutorials/ assignments/ quiz's etc)	40

UCH502 MASS TRANSFER-I

L	T	P	Cr
3	1	0	3.5

Course Objectives:

To impart the knowledge of mass transfer operations and equipment.

Introduction: Overview of separation processes.

Diffusion: Steady statemolecular diffusion in gases and liquids, Fick's first Law of diffusion, Fick's second Law of diffusion,Correlation for diffusivity in gases and liquids for binary and multi-component systems, Diffusivity measurement and prediction, Diffusion in solids, Types of solid diffusion.

Mass Transfer Coefficients: Concept of mass transfer coefficients, Mass transfer coefficients in laminar flow and turbulent flow, Mass, heat and momentum transfer analogy, etc, Simultaneous heat and mass transfer.

Interphase Mass Transfer: Equilibrium curve, Diffusion between phases, Overall mass transfer coefficient, Two film theory in mass transfer, Steady state concurrent and counter current Process, Stages and Multistage cascade, Kremser equation for dilute gas mixtures.

Mass transfer equipment: Gas dispersed: bubble column, Mechanically agitated vessels, Mechanical agitation of single phase liquid, Mechanical agitation of gas liquid contact, Venturi scrubber, Wetted Wall tower, Spray tower, Tray tower, Packed tower, Classification of packing materials, Cooling tower.

Gas Absorption: Equilibrium solubility of gases in liquids, isothermal and adiabatic gas-liquid contact, Choice of solvents, Material balance in absorber, Counter-current multistage operations, Continuous contact equipment, Design of absorption towers, Gas absorption with chemical reaction.

Crystallization: Solid liquid phase equilibrium, Nucleation and crystal growth, Batch crystallization, crystallization equipment.

Drying: Drying Equilibria, The drying rate curve, calculations of the drying time from drying rate data, Classification of the drying equipment, Dryer selection, Different type of dryer.

Course Learning Outcomes (CLO):

The students will be able to:

1. solve problems related to diffusion and interphase mass transfer and mass transfer equipments
2. perform design calculation related to absorption and humidification.
3. solve problems related to drying and crystallization

Text Books:

1. *Treybal, R.E., Mass Transfer Operations, McGraw Hill (1980) 3rd Ed.*
2. *McCabe, W.L., and Smith, J.C., Unit Operations of Chemical Engineering, McGraw Hill, 3rd Ed. (1993).*

Reference Books:

1. *Sherwood, T.K, Pigford, R.L., and Wilkes, C.R, Mass Transfer, McGraw Hill (1975).*
2. *Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India (1993) 4th Ed.*
3. *Seader, H., Henley, J. E., Seperation Process Principles,Wiley India (2007) 2nd Ed.*
4. *Skelland, A.H.P., Diffusional Mass Transfer, John Wiley & Sons (1985).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH503 INDUSTRIAL POLLUTION ABATEMENT

L	T	P	Cr
3	**1**	**2**	**4.5**

Course Objectives:

To understand the important issues and their abatement principles of industrial pollution.

Introduction: Industrial pollution, Different types of wastes generated in an industry, Different water pollutants, Air pollutants and solid wastes from industry, Their effects on living and non-living things, Environmental regulatory legislations and standards, Importance of industrial pollution abatement, Concept of sustainable development, Green house gases, Global warming and climate change, Mass and energy balance with and without reaction.

Water Pollution: Identification, quantification and analysis of wastewater, Classification of different treatment methods into physico-chemical and biochemical techniques, Physico-chemical methods, General concept of primary treatment, Liquid-solid separation, Design of a settling tank, Neutralization and flocculation, Disinfection, Biological methods,Concept of aerobic digestion, Design of activated sludge process, Concept of anaerobic digestion, Biogas plant layout, Different unit operations and unit processes involved in conversion of polluted water to potable standards.

Air Pollution: Classification of air pollutants, Nature and characteristics of gaseous and particulate pollutants, Analysis of different air pollutants, Description of stack monitoring kit and high volume sampler, Atmospheric dispersion of air pollutants, Gaussian model for prediction of concentration of pollutant down wind direction, Plume and its behavior, Operating principles and simple design calculations of particulate control devices, Brief concepts of control of gaseous emissions by absorption, adsorption, chemical transformation and combustion.

Solid Wastes: Analysis and quantification of hazardous and non-hazardous wastes, Treatment and disposal of solid wastes, Land filling, Leachate treatment, Incineration.

Environmental Management System: Environment impact assessment, Its concept and constituents, Environmental audit, ISO-14000 system.

Laboratory work: Characterization of wastewater (pH, BOD, COD, Nitrate, Phosphate, Solids, Turbidity, Alkalinity, Hardness, Dissolved oxygen and fluoride), Ambient air quality measurement by high volume sampler (Particulate, SO_X, NO_X), Gas analysis with Orsat apparatus, Determination of sludge volume index.

Course Learning Outcomes (CLO):

The students will be able to:

1. quantify and analyze the pollution load.
2. analyze/design of suitable treatment for wastewater

3. model the atmospheric dispersion of air pollutants.
4. Selection and design of air pollution control devices.
5. analyze the characteristics of solid waste and its handling & management..

Text Books:

1. *Peavy, H.S., Rowe, D.R., and Tchobanoglous, G. Environmental Engineering, McGraw Hill International (1985).*

2. *Metcalf & Eddy, Wastewater Engineering, Tata McGraw-Hill Education Private Limited (2009).*

Reference Books:

1. *Masters, G.M., Introduction to Environmental Engineering and Science, Prentice Hall off India, (2008).*
2. *Rao, C.S., Environmental Pollution Control Engineering, Wiley Eastern (2010).*
3. *De Nevers, N., Air Pollution Control Engineering, McGraw-Hill (2000).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (May includes lab/ tutorials/ assignments/ quiz's etc)	40

UCH 504 ENERGY TECHNOLOGY

L	T	P	Cr
3	1	2	4.5

Course Objective:
To study various types of conventional and non-conventional energy resources including solid, liquid and gaseous fuels.

Energy Scenario: Indian and global, Present and future energy demands, Energy crisis, Classification of various energy sources, Renewable and non-renewable energy sources, Pattern of energy consumption.

Solid Fuels: Coal: Origin, formation, analysis, classification, washing and carbonization, Treatment of coal gas, Recovery of chemicals from coal tar, Coal gasification, Liquid fuel synthesis from coal, Carbonization of coal, Briquetting of fines.

Liquid and Gaseous Fuels: Crude petroleum, Physical processing of crude petroleum, Fuels from petroleum, Storage and handling of liquid fuels, Natural and liquefied petroleum gases, Gas hydrates, Gasification of liquid fuels, Carbureted water gas.

Fuel Characterization: Viscosity, Viscosity index, Flash point, Cloud point, Pour point, Fire point, Smoke point and Char value, Carbon residue, Octane number, Cetane number, Aniline point and Performance number, Acid value, ASTM distillation, Calorific value, Proximate and ultimate analysis.

Alternate Energy Sources: Solar energy: Radiation measurement, applications and types of collectors and storage, Wind power, Geothermal energy, Tidal energy, Nuclear power, Fuel cells, Biogas, Biomass.

Laboratory Work:
Experiments on proximate and ultimate analysis of fuels, Orsat analysis, Surface tension, Cloud & pour point, Flash point, Viscosity, Melting point, Reid vapor pressure, ASTM distillation, Saponification value.

Course Learning Outcomes (CLO):

The students will be able to:

1. analyze the energy scenario of the world.
2. carry out a comparative analysis of different types of coal, including their treatment, liquefaction and gasification.

3. compare the liquid and gaseous fuels sourced from petroleum including their characterization.
4. analyze the potential of alternate energy sources and their scope and limitations.
5. solve energy related problems related to combustion and non-combustion.

Text Books:

1. *Rao, S. and Parulekar, B.B., Energy Technology-Non-conventional, Renewable and Conventional, Khanna Publishers (2000).*
2. *Gupta, O.P., Elements of Fuel, Furnaces and Refractories, Khanna Publishers (1996).*
3. *Rai, G.D., Non-Conventional Energy Sources, Khanna Publishers (2001).*

Reference Books:

1. *Brame J.S.S. and King J.G., Edward Arnold "Fuel Solid, Liquid and Gases" Edward Arnold (1967).*

2. *Sukhatme S.P, Solar Energy - Principles of Thermal Collection and Storage, Tata McGraw-Hill (1996).*

3. *I.S. Code 770, Classification of Coal.*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (May includes lab/ tutorials/ assignments/ quiz's etc)	40

UCH505 PROCESS EQUIPMENT DESIGN-I

L	T	P	Cr
3	1	0	3.5

Design Preliminaries: Introduction, General design procedure, Equipment classification, Design codes, Design considerations, Design pressure, Design temperature, Design stress, Factor of safety, Design wall thickness, Corrosion allowance, Weld joint efficiency factor, Design loadings, Stress concentration, Thermal stress and Criteria of failure.

Design of process vessels under internal pressure: Thin wall vessels, Cylindrical vessels, Tubes, Pipes, Spherical vessels, Design of heads and closures such as different heads, Nozzle, Flange joints, Gaskets, Types & design of non- standard flanges and Bolts.

Design of process vessels under external pressures: Introduction, Determination of safe pressure against elastic failure, Circumferential stiffeners, Spherical shells, Pipes and tubes under external pressure.

Design of tall vessels: Introduction, Equivalent stress under combined loadings and Longitudinal stresses.

Design of support for process vessels: Introduction, Different types of supports, Design of supports.

Design of thick walled higher pressure vessels: Introduction, Stresses and theories of elastic failure.

Equipment fabrication and testing: Welding joints, Inspection and Non-destructive testing of equipment.

Design of some special parts: Introduction, Expansion joints and its design, Expansion loop in piping system, Design equations for expansive forces in pipe lines, Shafts and Keys.

Storage tanks: Introduction, Classification of storage tanks, Filling & breathing looses, Design of liquid and gas storage tanks.

Course Learning Outcomes (CLO):

The students will be able to:

1. determine the parameters of equipment design and important steps involved in equipment's fabrication.
2. design internal pressure vessels and their heads.
3. design flange joints, vessel supports, expansion joints, expansion loop, etc.
4. design internal pressure thick vessels and external pressure vessels.
5. design tall vessels and storage vessels.

Text Books:

1. *Bhattacharyya, B.C., Introduction to Chemical Equipment Design, Mechanical Aspects, CBS Publishers and Distributors (1998).*
2. *Joshi, M.V. and Mahajani, V.V., Process Equipment Design, Macmillan India Limited (1997).*

Reference Books:

1. *Brownell, L.E. and Young, E.H., Process Equipment Design, Wiley Eastern India Limited (1991).*
2. *I.S.: 803 – 1962, Code of practice for Design, Fabrication and Erection of vertical Mild steel cylindrical welded oil storage tanks.*
3. *I.S.: 2852-1969, Code for unfired pressure vessel.*
4. *Bhandari, V.B., Design of Machine Elements, Tata McGraw-Hill Publishing Company Limited (2002).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH 506 PROCESS INSTRUMENTATION AND CONTROL

L	T	P	Cr
3	**1**	**2**	**4.5**

Course Objectives:
To analyze the system behavior for the design of various control schemes, and to gain knowledge of different process instruments.

Introduction: General Principles of process control, Time domain, Laplace domain and frequency domain dynamics and control.

Linear Open-loop Systems: Laplace domain analysis of first and second orders systems, Linearization, Response to step, pulse, impulse and ramp inputs, Physical examples of first and second order systems such as thermocouple, level tank, U-tube manometer, etc., Interacting and non-interacting systems, Distributed and lumped parameter systems, Dead time.

Linear Closed-loop Systems: Controllers and final control elements, Different types of control valves and their characteristics, Development of block diagram, Transient response of simple control systems, Stability in Laplace domain.

Frequency Response: Frequency domain analysis, Control system design by frequency response, Bode stability criterion, Different methods of tuning of controllers.

Process Applications: Introduction to advanced control techniques as feed forward, feedback, cascade, ratio, etc., Application to equipment such as distillation-columns, reactors, etc.

Instrumentation: Classification of measuring instruments, Elements of measuring instruments, Instruments for the measurement of temperature, pressure, flow, liquid level, and moisture content, Instruments and sensors for online measurements.

Laboratory Work: Dynamics of first order and second order systems, Valve characteristics, Interacting and non-interacting systems, Flow, level and temperature measurement and their control using proportional, proportional-integral and proportional-integral-derivative control action, Manual and closed loop controls, Positive and negative feedback control, Tuning of controller, Step, pulse, impulse and frequency response.

Course Learning Outcomes (CLO):

The students will be able to:

1. set up a model, analyse and solve the first and second order system for its dynamic behaviour
2. evaluate the process stability in Laplace domain
3. design control system using frequency response analysis
4. identify advanced control techniques for chemical process.

Text Books:

1. *Coughanowr, D.R. and LeBlanc, S.E., Process Systems Analysis and Control, McGraw Hill (2009).*

2. *Eckman, D.P., Industrial Instrumentation, John Wiley & Sons (2004).*

Reference Books:

1. *Stephanopoulous, G., Chemical Process Control: An Introduction to Theory and Practice, Prentice Hall of India (1984).*
2. *Harriott, P., Process Control, Tata McGraw Hill (1972).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (May includes lab/ tutorials/ assignments/ quiz's etc)	40

UCH601 CHEMICAL REACTION ENGINEERING II

L	T	P	Cr
3	**1**	**2**	**4.5**

Prerequisite(s): None

Course Objectives:

To understand the effect of non-ideal flow on reactor performance and to design reactors for heterogeneous reaction systems.

Non-ideal Flow: Residence time distribution (RTD) of fluids in vessels, RTD models - dispersion, tanks-in-series and multi-parameter models, Conversion calculations using RTD data for first order reactions.

Non-catalytic Heterogeneous Reactions: Fluid-solid reaction models, Fluid-Solid reaction kinetics, Determination of rate controlling step, Prediction of mean conversion in flow reactors, Fluid-solid contacting schemes, Reactor design.

Solid-catalyzed Reactions: Interaction of physical and chemical rate processes, Kinetics of catalytic reactions and application to reactor design for isothermal and adiabatic operations, Design of packed bed and fluidized bed reactors, Introduction to slurry and trickle-bed reactors.

Fluid-fluid Reactions: Introduction to fluid-fluid reaction systems, Rate equations, Reactor design with and without mass transfer considerations.

Laboratory work: Experiments on Batch reactor, Semi-batch reactor, Continuous stirred tank reactor, Tubular reactor, RTD studies, Fluid-solid reaction.

Course Learning Outcomes (CLO):

The students will be able to:

1. predict the conversion in a non-ideal reactor using tracer information.
2. design reactors for fluid-solid reactions.
3. design reactors for catalytic reactions.
4. design towers for gas–liquid reactions with and without mass transfer considerations.

Text Books:

1. *Levenspiel, O., Chemical Reaction Engineering, John Wiley & Sons (2010).*
2. *Smith, J.M., Chemical Engineering Kinetics, McGraw Hill (1990).*

Reference Books:

1. *Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India (2009).*
2. *Denbigh, K.G., and Turner,J.C.R., Chemical Reactor Theory - An Introduction, Cambridge University Press (1984).*
3. *Nauman, E.B., Chemical Reactor Design, John Wiley & Sons (1987).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (May includes lab/ tutorials/ assignments/ quiz's etc)	40

UCH602 MASS TRANSFER-II

L	T	P	Cr
3	1	3	5.0

Course Objectives:

To impart the knowledge of separation processes like distillation, adsorption, and extraction.

Distillation: Vapor-liquid equilibria, Flash distillation, Differential distillation, Continuous Rectification- Binary system, Steam distillation, Multistage tray tower- McCabe-Thiele method, Ponchon-Savarit method, Distillation in a packed tower, Principles of azeotropic and extractive distillation, Bubble point and dew point calculation of multi-component system, Introduction to multi-component distillation.

Liquid-Liquid Extraction: Equilibrium relationship for partially miscible and immiscible systems, Selectivity and choice of solvent, Stage wise contact, Single stage and multistage extraction, Determination of number of equilibrium stages by graphical methods, Different types of extraction equipment.

Adsorption: Adsorption equilibria, Batch and continuous adsorption, Selection of adsorbent, Specific surface area of an adsorbent, Break-through curve, Introduction to ion-exchange processes.

Solid-Liquid Extraction: Classification of solid liquid extraction systems, Solid liquid extraction equilibria, Determination of number of equilibrium stages by graphical methods, Solid liquid contacting equipment.

Laboratory work: Study of vapour liquid equilibria, Cross current leaching, HETP in a packed distillation column operating under total reflux, Liquid in air diffusion, Liquid-liquid extraction apparatus, Absorption in packed bed apparatus, Wetted wall column, Solid in air diffusion apparatus, Batch drying unit, Batch distillation apparatus, Batch crystallizer, Water cooling tower, Steam distillation apparatus.

Course Learning Outcomes (CLO):

The students will be able to:

1. use the phase equilibrium concepts in mass transfer related problems.
2. design staged /packed column for mass transfer operations.
3. solve problems related to adsorption.
4. solve problems related to liquid-liquid and solid-liquid extraction.

Text Books:

1. *Treybal, R.E., Mass Transfer Operations, McGraw Hill (1980).*
2. *McCabe, W.L., and Smith, J.C., Unit Operations of Chemical Engineering, McGraw Hill (1993).*
3. *Sieder J.D., Ernest J.Henley. Separation Process Principles (2011).*

Reference Books:

1. *Holland C.D., Fundamentals of multicomponent distillation, Prentice-Hall of India (1963).*
2. *Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India (1993).*
3. *Sherwood, T.K., Pigford, R.L., and Wilkes, C.R, Mass Transfer, McGraw Hill (1975).*
4. *Skelland, A.H.P., Diffusional Mass Transfer, John Wiley & Sons (1985).*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1	MST	25
2	EST	35
3	Sessional (May includes lab/ tutorials/ assignments/ quiz's etc)	40

UCH 603 TRANSPORT PHENOMENA

	L	T	P	Cr
	3	**1**	**0**	**3.5**

Course Objectives:

To impart knowledge about individual and simultaneous momentum, heat and mass transfer, model development along with appropriate boundary conditions.

Introduction: Viscosity and generalization of Newton's law of viscosity,Thermal conductivity and mechanism of energy transport, Diffusivity and mechanism of mass transport, Basic concept and review of classical momentum, heat and mass transfer problems.

Momentum Transport: Shell momentum balance, velocity distribution in laminar incompressible flow, The equations of change for isothermal flow: Equations of continuity, motion, conservation of mechanical energy in fluids, Application of Navier-Stokes equation, , Stream function, Potential flow, Boundary layer theory, Velocity and pressure distributions with more than one independent variables, Unsteady flow.

Turbulent flow: Velocity distribution in turbulent flow,fluctuations and time smoothened equations for velocity, Time smoothed of equation of change for incompressible fluids, Reynolds stress, Empirical relations.

Energy Transport: Shell energy balance, temperature distribution in solids and laminar flow, Equations of change for non-isothermal flow - Equations of energy, Energy equation in curvilinear coordinates, set-up of steady state heat transfer problems, Temperature distributions with more than one independent variables, Unsteady heat transfer.

Mass Transfer: Shell mass balance and concentration distribution in solids and laminar flow, Equations of change for multi-component systems: Equations of continuity for a binary mixture, Equation of continuity in curvilinear coordinates, Multi-component equations of change in terms of the flows, Multi component fluxes in terms of the transport properties, Use of equations of change to setup diffusion problems, Unsteady mass transfer.

Simulations momentum, heat and mass transfer: Simultaneous momentum, heat and mass transfer in laminar and turbulent flow regimes, Temperature and concentration distribution in turbulent flow, time smoothed equations of change for incompressible non-isothermal flow, Concentration fluctuation and time smoothed concentration, time smoothed equation of continuity.

Course Learning Outcomes (CLO):

The students will be able to:

1. analyze heat, mass, and momentum transport in a process.
2. formulate problems along with appropriate boundary conditions.
3. develop steady and transient solution for problems involving heat, mass, and momentum transport.

Text Book:

1. *Bird, R. B., Stewart, W. E., Lightfoot, E. N., Transport Phenomena, Wiley (2002).*

Reference Books:

1. *Geankoplis, C. J., Transport Processes and Unit Operations, Prentice-Hall (1993).*
2. *Deen, W. D., Analysis of Transport Phenomena, Oxford University Press (1998).*
3. *Griskey, R. G., Transport Phenomena and Unit Operations: A Combined Approach, Jon Wiley (2002).*
4. *Batchelor, G. K., An Introduction to Fluid Dynamics, Cambridge University Press (1967).*
5. *Salterry, J. C., Momentum Energy and Mass Transfer in Continua Robert e. Kridger (1981).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz’s etc)	25

UCH604 BIOCHEMICAL ENGINEERING

L	T	P	Cr
3	1	2	4.5

Course Objectives:
To apply the chemical engineering principles in biological systems.

Introduction to Biochemical Engineering: Comparative study of chemical and biochemical processes, Basic concepts of microbiology.

Sterilization: Sterilization of air and medium; sterilization of fermentor, thermal death kinetics of microorganisms.

Biochemical Kinetics: Enzyme Kinetics with one or two substrates, modulation and regulation of enzyme activity, enzyme reactions in heterogeneous systems, Immobilized enzyme technology, Industrial application of enzymes.

Microbial Fermentation Kinetics: Fermentation and its classification, Growth-cycle phases (for batch cultivation), Continuous culture, Biomass production in cell culture, Mathematical modeling of batch growth, Product synthesis kinetics, Overall kinetics and thermal death kinetics of cells and spores, Analysis of multiple interacting microbial population.

Bioreactors: Classification and characterization of different bioreactors e.g. batch and continuous, mechanically and non-mechanically agitated, CST type, tower, continuous, rotating, anaerobic etc., Design and analysis of Bioreactors - CSTR and Air Lift Reactor, Scale up considerations of bioprocesses.

Transport Phenomenon in Bioprocess Systems: Agitation and aeration-gas-liquid mass transfer, oxygen transfer rates, determination of k_La, Heat balance and heat transfer correlations – sterilization etc.

Commercial production of bioproducts: Concept of primary and secondary metabolites, Production processes for yeast biomass, antibiotics, alcoholic beverages and other products.

Laboratory work:
Sterilization in steam autoclave, Estimation of reducing sugars (Glucose) by di-Nitro Salicylic Acid (DNS) method in a sample broth; Estimation of dimensionless mixing time in a batch reactor Understanding of dissolved oxygen (DO) measurement system of a bioreactor and its calibration, Estimation of volumetric oxygen transfer coefficient in a fermenter by dynamic gassing out technique; Understanding the functioning of bioreactor and to carry out blank sterilization of the reactor Operation of pH control system of a bioreactor and evaluation of response of the controller to different control settings; Enzyme assay; Enzyme kinetic studies; Demonstration & Examination of different organisms; Determination of microbial cell biomass using spectrophotometer; Microbial growth kinetic study; Immobilization of enzymes, Immobilization of microbial cells

Course Learning Outcomes (CLO):

The students will be able to:

1. calculate the kinetic parameters of enzymatic reactions.
2. calculate and analyze the kinetic parameters for microbial growth.
3. analyze bioprocess design and operation.
4. select suitable bioreactor.

Text Books

1. *Shuler M., Kargi F., Bioprocess Engineering: Basic Concepts, PHI (2012).*
2. *Bailey, J.E. and Ollis, D.F, Biochemical Engineering Fundamentals, McGraw Hill, New York (1986)*

Reference Books

1. *Doran, P.M Bioprocess Engineering Principles,., Academic Press (2012)*
2. *Aiba, S., Humphrey, A.E and Millis, N.F., Biochemical Engineering, Academic Press (1973)*
3. *Weith, John W.F., Biochemical Engineering – Kinetics, Mass Transport, Reactors and Gene Expression, Wiley and Sons Inc. (1994).*
4. *Stanbury P. F., Whittaker, A. and Hall, S. J., Principles of Fermentation Technology, Butterworth-Heinemann (2007).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	35
3	Sessional (May includes lab/tutorials/ assignments/ quiz's etc)	40

UCH605 PROCESS UTILITIES AND INDUSTRIAL SAFETY

L	T	P	Cr
3	1	0	3.5

Course Objectives:
To gain knowledge about different process utilities used in the chemical process industry and issues related to hazards & safety.

Water: Water resources, Storage and characterization, Conditioning.

Steam: Boilers, Steam Handling and distribution, Steam nozzles, Condensate utilization, Steam traps, Flash tank analysis, Safety valves, Pressure reduction valves, Desuperheaters.

Air: Air compressors, Vacuum pumps, Air receivers, Distribution systems, Different types of ejectors, Air dryers.

Hazards and Safety: Classifications and assessment of various types of hazards, Risk assessment methods, General principles of industrial safety, Hazards due to fire, explosions, toxicity and radiations, Industrial hygiene, Maximum allowable concentration and threshold limit value, Protective and preventive measures in hazards control, Introduction to industrial safety regulations.

Case studies of hazardous incidents in industries using HAZOP.

Course Learning Outcomes (CLO):

The students will be able to:

1. calculate the requirements of water and air and their applications as utilities.
2. calculate the steam requirement and its applications as utility.
3. evaluate and apply the various risk assessment methods in industries.
4. do the hazard analysis for different industries using HAZOP.

Text Books:

1. *Vasandhani, V. P., and Kumar, D. S, Heat Engineering, Metropolitan Book Co. Pvt. Ltd. (2009).*
2. *Crowl, D.A. and Louvar, J.F., Chemical Process Safety-Fundamentals with Applications, Prentice Hall, (2002).*

Reference Books:

1. *Lees, F.P., Prevention in Process Industries. Butterworth's (1996).*
2. *Peavy, H. S., and Rowe, D. R, Environmental Engineering, McGraw Hill (1985).*
3. *Banerjee, S., Industrial Hazards and Plant Safety, Taylor & Francis 2003).*
4. *Sanders, R. E. Chemical Process Safety-Learning from Case Histories, Oxford (2005).*
5. *Perry, R.H., and Green, D. W, Chemical Engineer's Handbook, McGraw Hill (1997).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz’s etc)	25

UCH606PROCESS EQUIPMENT DESIGN-II

L	T	P	Cr
2	2	0	3.0

Process Equipment Design: Introduction, General design procedure.

Heat Transfer Equipment: Process design calculations for heat transfer equipment, Shell and Tube heat exchangers-general description, Estimation of heat transfer coefficients and pressure drop by Kerns' and Bell's methods, Condenser and re-boiler design, Plate type heat exchanger design, Heat Transfer in stirred vessels, Codes & standards and Heat-exchanger nomenclature, Mechanical turbulators.

Mass Transfer Equipment: Process design calculations for binary and multi-component distillation, Fenske-Underwood-Gilliland Method, Selection of two key components, Fenske equation for minimum equilibrium stage, Gilliland correlations for actual reflux ratio and theoretical stages, Minimum reflux ratio by Underwood method, Feed stage location, Type of towers, types of plate contractors, Sieve tray layout and hydraulic design, Packed towers – column internals, Types of packing, General pressure drop correlation, Column diameter and height.

Piping System Design: Piping classification. Important fittings and their use, Symbols, Layouts, and Color codes for pipe lines.

Course Learning Outcomes (CLO):

The students will be able to:

1. identify important design aspects.
2. design different types of heat transfer equipment.
3. design different types of mass transfer equipment.
4. design piping system.

Text Books:

1. *Sinnott Ray and Towler Gavin, Coulson and Richardson's Chemical Engineering series Chemical Engineering Design (2010).*
2. *Kern, D.Q., Process Heat Transfer, International Student Edition, McGraw Hill (2002).*

Reference Books:

1. *Ludwig E.E., Applied Process Design in Chemical and Petrochemical Plants Vol I, II, III, Gulf Publishing Co. (1995).*
2. *Brownell, L.E. and Young, E.H., Process Equipment Design, Wiley Eastern India Limited (1991).*
3. *Perry, R.H. and Green, D, Chemical Engineer's Handbook, 8th Edition, McGraw Hill, New York. (2008).*

4. *Seader, J. D., Henley, E. J., Separation Process Principles, Wiley (2001).*
5. *Bausbacher Ed. And Hunt Roger, Process Plant Layout and Piping Design, PTR Prentice Hall, (1993).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH701CATALYTIC PROCESSES

L	T	P	Cr
3	1	0	3.5

Course Objectives:
To gain the knowledge of catalyst characteristics, mechanism of catalytic reactions, and design of catalytic reactors.

Introduction: Catalysis and catalysts – homogeneous & heterogeneous, Classification of catalytic reactions and catalysts, Commercial chemical catalysts, Steps in catalytic reactions.

Preparation and Properties of Catalysts: Methods of catalyst preparation, Physical properties of catalyst – surface area, pore volume, pore size distribution, solid density, particle density, bulk density, void volume, Catalyst promoters & inhibitors, Catalyst accelerators & poisons.

Adsorption and Catalytic Reactions: Adsorption isotherms, Surface reaction, Single site and dual site mechanism, Desorption, Catalyst deactivation, Pore structure and surface area estimation and their significance.

External Transport Processes: Fluid particle mass and heat transfer, Mass transfer-limited reactions in packed beds, Non-isothermal behavior of packed-bed reactors, Staged packed-bed reactors for approaching optimum temperature progression, Stable operating conditions in reactors and hot spot formation, Effect of external transport processes on selectivity under non-isothermal conditions.

Diffusion and Reaction in Porous Catalysts: Intra-pellet mass transfer and diffusion in cylindrical and spherical porous catalyst particles, Thiele modulus, Diffusion controlled and surface reaction controlled kinetics, Effectiveness factor for catalysts, Effects of heat transfer – temperature gradients across fluid-solid film and across catalyst pellet, Fluidized bed reactors, Three phase reactors – slurry and trickle bed reactors.

Generalized Design: Design of catalytic reactors under adiabatic and non-adiabatic conditions, Design of industrial fixed-bed, fluidized-bed and slurry reactors.

Course Learning Outcomes (CLO):

The students will be able to:

1. develop various catalytic reaction mechanisms.
2. characterize a catalyst.
3. assess the effects of external heat and mass transfer effects in heterogeneous catalysis.
4. calculate the effectiveness of a porous catalyst.
5. design different types of reactors for catalytic reactions.

Text Books:

1. *Smith, J.M., Chemical Engineering Kinetics, McGraw-Hill (1981).*
2. *Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice-Hall India (2009).*

Reference Books:

1. *Denbigh, K.G., and Turner, J.C.R., Chemical Reactor Theory: An Introduction, Cambridge University Press (1984).*
2. *Carberry, J.J., Chemical and Catalytic Reaction Engineering, McGraw-Hill, (2001).*
3. *Levenspiel, O., Chemical Reaction Engineering, John Wiley (2006).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz’s etc)	25

UCH801 PROCESS ENGINEERING AND PLANT DESIGN

L	T	P	Cr
3	1	0	3.5

Course Objectives:
To provide comprehensive knowledge of various process parameters and economics involved in the development of process and plant design.

Basic Concepts: General design considerations, Process design development, Layout of plant items, Flow sheets and PI diagrams, Economic aspects and Optimum design, Practical considerations in design and engineering ethics, Degrees of freedom analysis in interconnected systems, Network analysis, PERT/CPM, Direct and Indirect costs, Optimum scheduling and crashing of activities.

Flow-sheetSynthesis: Propositional logic and semantic equations, Deduction theorem, Algorithmic flow sheet generation using P-graph theory, Sequencing of operating units, Feasibility and optimization of flow sheet using various algorithms viz, Solution Structure Generation (SSG), Maximal Structure Generation (MSG), Simplex, Branch-and-bound.

Analysis of Cost estimation: Factors affecting Investment and production costs, Estimation of capital investment and total product costs, Interest, Time value of money, Taxes and Fixed charges, Salvage value, Methods of calculating depreciation, Profitability, Alternative investments and replacements.

Optimum Design and Design Strategy: Break-even analysis, Optimum production rates in plant operation, Optimum batch cycle time applied to evaporator and filter press, Economic pipe diameter, Optimum insulation thickness, Optimum cooling water flow rate and optimum distillation reflux ratio.

Course Learning Outcomes (CLO):

The students will be able to:

1. apply various algorithms to synthesize a process flow sheet.
2. calculate different costs involved in a process plant.
3. calculate interest and time value of investments.
4. measure profitability on investments.
5. perform breakeven analysis and optimum design of a process.

Text Books:
1. Peters, M.A. and Timmerhaus, K.D., Plant Design and Economics for Chemical Engineers, McGraw Hill (2003).

Reference Books:
1. Anil Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1982).
2. Ulrich, G.D., A Guide to Chemical Engineering Process Design and Economics, John Wiley & Sons (1984).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

Revised scheme approved by the 90th meeting of the senate (May 30, 2016)

UCH 802 PROCESS MODELING AND SIMULATION

L	T	P	Cr
3	0	2	4.0

Course Objectives:
To study the modeling & simulation techniques of chemical processes and to gain skills in using process simulators.

Introduction: Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables, Review of numerical techniques, Model simulation.

Fundamental Laws: Equations of continuity, energy, momentum, and state, Transport properties, Equilibrium and chemical kinetics, Review of thermodynamic correlations for the estimation of physical properties like phase equilibria, bubble and dew points.

Modeling of Specific Systems: Constant and variable holdup CSTRs under isothermal and non-isothermal conditions, Stability analysis, Gas phase pressurized CSTR, Two phase CSTR, Non-isothermal PFR, Batch and semi-batch reactors, Heat conduction in a bar, Laminar flow of Newtonian liquid in a pipe, Gravity flow tank, Single component vaporizer, Multi-component flash drum, Absorption column, Ideal binary distillation column and non-ideal multi-component distillation column, Batch distillation with holdup etc.

Simulation: Simulation of the models, Sequential modular approach, Equation oriented approach, Partitioning and tearing, Introduction and use of process simulation software (Aspen Plus/ Aspen Hysys) for flow sheet simulation.

Laboratory:
Writing and solving models for simple chemical processes, use of process simulator for solving models for mixer, pump, compressor, heat exchanger, reactor, absorption/distillation column and steady state flow sheet simulation.

Course Learning Outcomes (CLO):

The students will be able to:

1. analyze physical and chemical phenomena involved in various process.
2. develop mathematical models for various chemical processes.
3. use various simulation approaches.
4. Simulate a process using process simulators (ASPEN Plus/ ASPEN Hysys).

Text Book:
1. *Luyben W.L., Process Modeling, Simulation, and Control for Chemical Engineering, McGraw-Hill (1998).*
2. *Babu, B.V., Process Plant Simulation, Oxford University Press (2004).*

Reference Books:

1. *Denn, M. M., Process Modeling, Longman Sc & Tech. (1987).*
2. *Himmelblau, D.M and Bischoff, K.B., Process Analysis and Simulation: Deterministic Systems, John Wiley (1968).*
3. *Holland, C. D., Fundamentals and Modeling of Separation Processes: Absorption, Distillation, Evaporation and Extraction, Englewood Cliffs, Prentice-Hall (1974).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	40
3	Sessional (may includes tutorials/ assignments/ quiz's etc)	35

UCH893 CAPSTONE PROJECT

L	T	P	Cr
0	0	2	8.0

Course Objectives:
A design project based course to implement integrated approach to the process and plant design of chemical process system/plant using chemical engineering courses studied in the previous semesters.

Scope of work:

Capstone project is focused on an integrated approach to the design of chemical process/plant using concepts of chemical engineering courses studied in the previous semesters. Chemical process/plant systems are to be designed satisfying requirements like reliability, optimized design, installation, maintenance, economic, environmental, social, ethical, health,safety and sustainability considerations.

In this course, students are separated in groups. Each student group shall develop a process/system design project related to chemical process/plant involving need analysis, problem definition, analysis, synthesis and optimization. Software like ANSYS, HYSYS, FLUENT and ASPEN etc. along with a spread sheet may be used for the design modeling, synthesis, optimization and analysis.The course concludes with a report submission by the group, final showcase using poster/presentation along with comprehensive viva by a committee.

Course Learning Outcomes (CLOs):

The students will be able to:

1. design a chemical process/plant system implementing an integrated approach applying knowledge accrued in various professional courses.

2. work in a team and demonstrate their role in the team work.

3. design, analyze and optimize the design of a chemical process/plant considering various requirements like reliability, optimized design, manufacturing, assembly, installation, maintenance, cost and use of design standards and industry standards.

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	Faculty mentor	30
2	Final report	30
3	Presentation/Viva	40

UCH 711 MATHEMATICAL TECHNIQUES IN CHEMICAL ENGINEERING

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives:
To learn various computational techniques for analysing and solving chemical engineering problems.

Solution of Algebraic Equations: Solution of Non-linear and transcendental equations in one or more than one variable (bisection, false position , iteration, Newton Raphson, Secant methods)
Solution of linear simultaneous equations (Matrix inversion, Gauss elimination, Gauss Jordan, LU decomposition methods, ill-conditioned systems).

Solution of Ordinary Differential Equations: Initial Value Problem (Euler, Modified Euler, RK class and predictor corrector class methods, Stiff ODE's and Gear's methods;
Boundary Value Problem- Shooting methods, Finite difference method, Use of Method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs.

Solution of Partial Differential Equations: Classification of PDEs- Parabolic, elliptical and hyperbolic equation,Finite difference techniques to solve partial differential equation; Application to chemical engineering systems.
Concept of finite element; Finite element methods to solve PDEs with application to Chemical Engineering systems.

Use of EXCEL Sheet and MATLAB: Application of EXCEL Sheet and MATLAB to solve the Chemical Engineering problems.

Course learning outcomes (CLOs):
The students will be able to:

1. solve problems of algebraic and differential equations, simultaneous equation, partial differential equations
2. convert problem solving strategies to procedural algorithms and to write program structures
3. solve engineering problems using computational techniques
4. assess reasonableness of solutions, and select appropriate levels of solution sophistication

Text Books:

1. *Gerald, C. F., Wheatley P. O., Applied Numerical Analysis, Pearson Education (2006).*
2. *Gupta, S. K., Numerical Methods for Engineers, New Age Publishers (2005).*

Reference Books:

1. *Finlayson, B. A., Introduction to Chemical Engineering Computing, Wiley Interscience (2006).*
2. *Loney, N. M., Applied Mathematical Methods for Chemical Engineers, CRC Press (2006).*
3. *Davis, M., Numerical Methods and Modeling for Chemical Engineers, John Wiley (1984).*

4. *Jain, M. K., Iyengar, S. R. K. and Jain, R.K., Computational Methods for PDE, Wiley Eastern (1994).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may includes tutorials/ assignments/ quiz's etc)	25

UCH 712 DISTILLATION PROCESSES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives:
To understand the principles and operation of various distillation processes.

Basic Concepts: Review of distillation processes. Phase equilibria in multi-component mixtures.

Batch Distillation: Shortcut methods for multi-component batch distillation, Stage-by-stage methods for multi-component batch rectification.

Multi-component Multistage Distillation: Approximate methods, Equilibrium-based methods, Rate based models for Distillation, Pseudocomponents based distillation.

Enhanced Distillation: Azeotropic and extractive distillation, Salt distillation, Pressure-swing distillation, Reactive distillation, Thermally coupled distillation, Dividing wall distillation.

Column Sequencing: Sequencing of simple columns, Marginal vapour rate method, Synthesis for complex columns.

Course Learning Outcomes (CLO):

The students will be able to:

1. use the shortcut method for binary and multicomponent distillation.
2. solve problems related to binary and multi-component distillation.
3. use of operational and design aspects of enhanced distillation processes.
4. use the concepts of column sequencing for efficient separation.

Text Books:
1. Seader, J.D., and Henley, E.J., Separation Process Principles (2007).

Reference Books:
1. Doherty, M.F. and Malone, M.F., Conceptual Design of Distillation Systems, McGraw Hill (2001).
2. Holland, C.D., Fundamentals of Multicomponent Distllation, McGraw-Hill (1982)
3. Watkins, R.N., Petroleum Refinery Distillation, Gulf Publishing Co. (1973).
4. Stichlmair, J. G., Fair, J.R., Distillation: Principles and Practice, Wiley-VCH (1998).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes lab/tutorials/ assignments/ quiz's etc)	25

UCH 713 NON-NEWTONIAN FLUID MECHANICS

L	T	P	Cr
3	1	0	3.5

Course Objectives: Tolearn the mathematical treatment of non-Newtonian fluids including the rheology.

Introduction: Flow phenomena, Vectors operations, Tensor operations, Integral theorems, Curvilinear coordinates, Review of Newtonian fluids.

Material functions for polymeric liquids: Stress tensor, Shear and shear free flows, Material functions

Rheometry overview & generalized Newtonian fluids: Shear and extensional rheometers, Empiricisms for viscosity; Solution to flow problems

Linear visco-elasticity: Linear visco-elastic models, Predictions of models, Flow problems

Differential constitutive equations: Convected derivatives, Quasi-linear models, Non-linear models, Flow problems.

Single-Integral constitutive equations: Finite strain tensors, Quasi-linear models, Non-linear models, Flow problems

Course Learning Outcomes (CLO):

The students will be able to:

1. understand the different types of flows and their mathematical treatment.
2. obtain rheological parameters through different kinds of rheometers.
3. formulate the differential and integral constitutive equations and their applications for solving fundamentals and engineering problems.

Text Books:

1. *R. P. Chhabra, R. P. and Richardson, J.F., Non-Newtonian flow in the process industries: fundamentals and engineering applications, Butterworth-Heinemann (1999).*
2. *Bird, R. B., Armstrong R.C., Hassager, O., Dynamics of Polymeric liquids, Fluid Mechanics: Volume1, John Wiley & Sons (1987).*

Reference Book:

1. *Bohme G., Non-Newtonian Fluid Mechanics, Volume 31, North-Holland series in applied mathematics and mechanics (1987).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may includes tutorials/ assignments/ quiz's etc)	25

UCH714 MEMBRANE SEPARATION PROCESSES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives: To be able to understand the preparation and characterizationof membranes for different applications.

Overview of membrane science and technology: Classification of membrane and membrane based processes, Advantages of membrane processes, Membrane materials

Preparation and characterization of membranes: Fundamental theory and application of membrane processes, Membrane modules, General method of membrane manufacture.

Different membrane processes: Reverse osmosis, Microfiltration, Ultra-filtration, Nano-filtration, Electro-dialysis, Dialysis, Per-evaporation, Gas separation, Membrane distillation, Liquid membrane technology, Transport through membrane, Membrane reactor, Membrane chromatography.

Application of membranes: Application of membranes in bio-separation, Bio-catalytic membrane reactors, Biomedical application of membranes.

Course Learning Outcomes (CLO):

The students will be able to:

1. understand the principles and materials properties for different membrane separation processes
2. Identify the best membrane modules and manufacturing process for different applications
3. identify and design the suitable membrane separation technique for intended problem

Text Books:

1. *R.W. Baker, Membrane Technology and Application, John Wiley and Sons Ltd. (2004).*
2. *Hoffman, E.J., Membrane Separation Technology: Single stage, Multistage and Differential Permeation, (2009).*

Reference Books*:*

1. *Porter, M.C., Handbook of Industrial Membrane Technology, Crest Publishing House (2005).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may includes tutorials/ assignments/ quiz’s etc)	25

Revised scheme approved by the 90th meeting of the senate (May 30, 2016)

UCH715 ALTERNATE ENERGY SOURCES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives: To learn and appreciatethe various alternate energy sources.

Introduction: Energy, Present and future trends of energy consumption, Resources in India and worldwide, Introduction to different non conventional energy sources, Detailed study of following sources with particular reference to India.

Solar energy: Solar radiation and its measurement, Limitation in application of solar energy, Solar collectors- types and constructional details, Solar water heating, Application of solar energy for residential and industrial heating, Drying, Space cooling, Water desalination, Photovoltaic power generation using silicon cells.

Bio-Fuels: Importance, Combustion, Pyrolysis and other thermo chemical processes for biomass utilization- performance analysis, Alcoholic fermentation, Anaerobic digestion for biogas production

Wind Power: Principle of energy from wind, Windmill construction, Operational details, Electricity generation, Mechanical power production.

Tidal Power: Introduction, Causes of tides and their energy potential, Enhancement of tides, Power generation from tides and problems, Principles of ocean thermal energy conversion (OTEC) analysis.

Geothermal Energy: Geo thermal wells and other resources dry rock and hot aquifer analysis, Harnessing geothermal energy resources.

Energy Storage and Distribution: Importance, Biochemical, Chemical, Thermal, Electrical storage, Fuel cells, distribution of energy.

Scope and Economics: Calculation of energy cost from renewable, Comparison with conventional fuel driven systems, Calculation of CO reduction, Incremental costs for renewable options.

Course Learning Outcomes (CLO):

The students will be able to:

1. Calculate energy demand and availability from various resources
2. Calculate the parameters associated with the use of solar energy and its harnessing
3. Identify effective utilization of bio-fuels and geothermal energy resources
4. Identify and analyze the ways of harnessing wind and tidal power
5. Identify energy storage and distribution methods
6. Analyze the economic and environmental aspects of conventional and renewable energy resources.

Text Books:

1. *Rai, G.D., Non-Conventional Energy Sources, Khanna Publishers (2001).*
2. *Twiddle, J. Weir, T., Renewable Energy Resources, Cambridge University Press (1986).*
3. *Duffie, J. A., Beckman, W. A., Solar Engineering of Thermal Processes, John Wiley (1980).*

Reference Books:

1. *Sukhatme, S. P., Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill, (2001).*
2. *Garg, H.P. and Prakash, J., Solar Energy: Fundamentals and Applications, Tata McGraw-Hill (2001).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may includes tutorials/ assignments/ quiz's etc)	25

UCH721 FOOD TECHNOLOGY

L	T	P	Cr
3	**0**	**0**	**3.0**

Course Objectives
To impart knowledge of food processing, preservation, packaging, related hazards and safety.

Introduction: Chemical composition of foods, their properties and functions, Characteristic features of processed and natural food, Chemical and biochemical reactions in storage and handling of foods.

Unit Operations in Food Processing: Evaporation, Drying, Size reduction, Filtration, Freezing etc.

Methods for Food Preservation: Food spoilage-causes: mold, yeast, bacteria, enzymes, Food poisons: bacterial toxins, food borne illnesses, Food preservation by dehydration, concentration, fermentation, pickling and curdling, irradiation, Food preservation by adding preservatives, Classification and mode of action of food preservatives, Toxicity and safety of preservatives used in food.

Case Studies of a Few Food Processing Sectors: Dairy/milk products, Fruits and vegetables, Poultry, Meat and fish, Confectionary and/or other sectors, Methods for utilization of by-products and waste of food industries.

Food Packaging: Methods for packaging and storage of food materials, Modified atmosphere and controlled atmosphere storage, Canning, Aseptic packaging, Materials for food packaging, Test methods (Drop test etc.) for checking integrity of food packaging.

Food laws: Legislation, safety and quality control, Hazard Analysis and Critical Control Points (***HACCP)***.

Course Learning Outcomes (CLO):

The students will be able to:

1. identify causes of food spoilage and selection of suitable food preservation method .
2. identify and evaluate various parameters associated with unit operation involved in food industries.
3. analyze food quality and effect of processing technique and packaging/storage on it.
4. analyze food related hazards and HACCP method.

Text Books:
1. *Potter Norman N., Hotchkiss Joseph, Food science, CBS (2005).*
2. *Toledo Romeo, Fundamentals of Food Process Engineering, CBS (2007).*

Reference Books:
1. *Potty V.H. and Mulky, M.J., Food Processing, Oxford and IBH (1993).*
2. *Desrosier and Desrosier, Technology of Food Preservation, CBS publication (2006).*
3. *Frazier, Food Microbiology, Tata McGraw Hill, (2007).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (May includes assignments/ quiz's etc)	20

UCH722 FERMENTATION TECHNOLOGY

L	T	P	Cr
3	**0**	**0**	**3.0**

Course Objectives:
To impact knowledge about biological and biochemical technology, with a focus on biological products, the design and operation of industrial practices.

Introduction to Fermentation Technology: History, types of fermentation, examples of fermentation industry.

Microbial Growth Kinetics: Growth, substrate utilization and product formation.

Fermentation Media: Formulation, carbon, nitrogen, oxygen, minerals sources, etc.

Sterilization: Sterilization of air and medium; sterilization of fermentor, thermal death kinetics of microorganisms.

Bioreactor Design: Material and energy balances in bioprocess: open and closed systems, steady-state and non-steady state systems, reacting and non-reacting systems, stoichiometry.

Bioreactor Operation Systems: stirred tank reactor (batch, semi-batch, continuous), bubble column, airlift and packed bed.

Physical Processes in Fermentation System: fluid flow and mixing, mass and heat transfer.

Course Learning Outcomes (CLO):

The students will be able to:

1. evaluate factors that contribute in enhancement of cell and product formation during fermentation process.
2. analyse kinetics of cell and product formation in batch, continuous and fed-batch cultures
3. differentiate the rheological changes during fermentation process

Text Books:

1. *Stanbury, P.F. and Whitaker, A., and Hall S. J. Principles of Fermentation Technology, Pergamon Press (2007).*
2. *Doran, P.M Bioprocess Engineering Principles, Academic Press (2012).*

Reference Books:

1. *Aiba, S., Humphrey, A.E and Millis, N.F., Biochemical Engineering, Academic Press (1973).*
2. *Bailey, J.E. and Ollis, D.F., Biochemical Engineering Fundamentals, McGraw-Hill (1986).*
3. *Shuler, M.L. and Kargi, F., Bioprocess Engineering: Basic Concepts, Prentice-Hall (1992).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30

2	EST	50
3	Sessional (May includes assignments/ quiz's etc)	20

UCH 723 PULP AND PAPER TECHNOLOGY

L	T	P	Cr
3	**0**	**0**	**3.0**

Course Objectives:
To provide a comprehensive overview of pulp & paper industry, mill operations, products, process variables, equipment, and terminology and complex environmental challenges.

Introduction: Present status of pulp and paper manufacture, Fibrous raw materials, wood composition, Fibre chemistry, Overview of paper manufacturing.

Paper Properties: Physical (optical, strength, and resistance), Chemical and electrical properties, Paper defects, Variables affecting paper properties.

Raw Material Preparation: Debarking, Chipping, Chip screening, Storage.
Pulping: Chemical, Semi-chemical, Mechanical, Chemi-mechanical, Non-conventional, Secondary fibre pulping, Advances and recent trends in pulping.

Chemical Recovery: Composition and properties of black liquor, Oxidation and desilication, Concentration of black liquor and its incineration, Causticizing and clarification, Sludge washing and burning.

Bleaching: Objectives of bleaching, Bleachability measurement, Bleaching chemicals and their production, single and multi-stage bleaching processes, Bleaching of chemical and mechanical pulp, Colour reversion of bleached pulp, Control procedures in bleaching, Biobleaching, Recent trends in bleaching technology, Water reuse and recycle in bleaching.

Pulp Processing: Deknotting, Defibering, Brown stock washing, Screening, Cleaning, Thickening, Blending, Beating and refining, Specific edge load concept in refining.

Papermaking: Approach flow system, Wire part, Sheet-forming process, Sheet transfer mechanism, Press part, Theory of pressing, Dryer part, Paper drying process, Calendaring, Cylinder mould machine, Finishing, Fibre recovery systems, Recent developments in paper making, Coating and lamination.

Biotech Applications in Pulp and Paper Making: Use of enzymes in debarking, Pulping, Bleaching, Pulp refining, Fibre modification, Improving fibre drainage, Biopulping, Effluent treatment for xenobiotic compounds.

Course Learning Outcomes (CLO):

The students will be able to:

1. understand the pulp & paper making processes
2. get the basic information on chemical & energy recovery
3. have general information on different grades of paper and paper properties
4. know the environmental considerations of pulp & paper industry

***Text Books*:**

1. *J.P. Casey, Pulp and Paper Chemistry and Chemical Technology, Wiley Interscience (1983).*
2. *R.G. MacDonald, Pulp and Paper Manufacture, McGraw Hill (1969).*
3. *G.A. Smook, Handbook for Pulp and Paper Technologists, Atlantic Books (2002).*

***Reference Books**:*

1. *S.A. Rydholm, Pulping Processes, Wiley Interscience (1965).*
2. *C.J. Biermann, Essentials of Pulping and Paper Making, Academic Press (1996).*
3. *J.D.A. Clark, Pulp Technology and Treatment for Paper, Miller Freeman (1985).*
4. *P. Bajpai, P.K. Bajpai and R. Kondo, Biotechnology for Environmental Protection in the Pulp and Paper Industry, Springer-Verlag Berlin Heidelberg (1999).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (May includes assignments/ quiz's etc)	20

UCH724 NUCLEAR TECHNOLOGY

L	T	P	Cr
3	0	0	3.0

Course Objectives: To learn the fundamentals of nuclear reaction, neutron transport and operation of nuclear reactor.

Nuclear Reactions: Nuclear stability, Decay-ratio, Half-life, Fusion and fission reactions, Scattering, Cross-section, Absorption, Mean-free path, Chain reaction, Conversion and breeding, Neutronic cross section and core design.

Neutron Transport: Neutron current density, Steady-state diffusion equation, Diffusion length, Reciprocity theorem, Fermi-age theory, Reactivity and its dependence on various factors, Criticality of an infinite homogeneous reactor, Application of critical equation, Quasi-homogeneous reactors

Dynamic and Stability of Nuclear Reactor: Point kinetics, Exact and approximate solution without feedback, Feedback model, Concept of stability, Asymptotic stability with feedback.

Course Learning Outcomes (CLO):

The students will be able to:

1. understandthe nuclear reactor terminology, definitions, and concepts associated with design and operation of a pressurized water reactor (PWR).
2. apply basic engineering principles in analyzing the design and operation of various PWR plant systems and components, including the primary system, reactor vessel, reactor core, reactor coolant pumps, steam generators, emergency core cooling system, and auxiliary systems.
3. apply basic nuclear theory, thermodynamics, fluid dynamics, and heat transfer to understand how energy is produced, converted, and transferred within the power plant.

Text Books:

1. John R. Lamarsh, J. R. and Anthony R. Baratta, A. R., Introduction to Nuclear Engineering, Prentice-Hall (2001).
2. El-Wakil, M. M., Nuclear Power Engineering, McGraw-Hill (1962).

Reference Books:

1. Glasstone, S. and Sesonske, A., Nuclear Reactor Engineering: Reactor systems engineering, Volume 2, Springer (1994).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (May includes assignments/ quiz's etc)	20

UCH831NOVEL SEPARATION PROCESSES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives:

To understand the underlying principles and modelling and design concepts of novel separation techniques and their applications.

Introduction: Fundamentals of separation processes and basic concepts.

Adsorptive Separation: Definition, Types of adsorption, Adsorbent types, Preparation and properties, Types of adsorption isotherms and their importance, Mathematical modeling under different conditions, Cases such as thermal swing, pressure swing, and moving bed adsorption, Desorption.

Membrane Separation:Synthesis and characterization of membranes, Transport processes in membrane, Modeling of reverse osmosis (RO), Ultrafiltration (UF) and gaseous separations, Supported liquid membrane and immobilization, Facilitated transport, Design, Operation, Maintenance and industrial applications of different membrane separation processes such as RO, UF, Nano-filtration (NF), Pervaporation through non-porous membranes, External field induced membrane separation processes for colloidal particles, Fundamentals of various colloid separation, Derivation of profile of electric field strength, Coupling with membrane separation and electrophoresis, electrodialysis.

Liquid Membranes: Fundamentals and modeling, Micellar enhanced separation processes, Cloud point extraction, Centrifugal Separation processes and their calculations, Ion exchange and chromatographic separation processes.

Surfactant Based Separation Processes: Concept, Modeling and design aspects and applications.

Supercritical FluidExtraction: Concept, Modeling and design aspects and applications.

Biofiltration: Concept, Modeling and design aspects and applications.

Course Learning Outcomes (CLO):

The students will be able to:

1. develop models and the solutions for adsorptive separation processes.
2. characterize the membrane.
3. use the concepts of membrane separation techniques for industrial separations.
4. solve problems involving separation based on liquid membrane.
5. exposure to other new separation techniques - surfactant based, supercritical fluid extraction and bio-filtration.

Text Books:

1. D. M. Ruthven, Principles of Adsorption and Adsorption Processes, John Wiley (1984).
2. M. Mulder, Basic Principles of membrane Technology, Springer (1996).

3. *M. A. McHugh and V.J. Krukonis, Supercritical Fluid Extraction, Butterworth (1985).*

Reference Books:

1. *S. Sourirajan and T. Matsuura, Reverse Osmosis and Ultra-Filtration Process Principles, NRC Canada (1985).*
2. *C.J. King, Separation Processes, Tata McGraw Hill (1981).*
3. *D. M. Ruthven, S. Farooq and K. S. Knaebel, Pressure Swing Adsorption, Wiley-VCH (1994).*
4. *W. S. Ho and K. K. Sirkar, Membrane Handbook, Kluwer (2001).*
5. *R W Rousseau, Handbook of Separation Process Technology, John Wiley & Sons (2009).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH832 CFD ANALYSIS IN CHEMICAL ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objectives:

To provide brief introduction of Computational Fluid Dynamics along with chemical engineering application specifically, analysis of fluid mechanics and heat transfer related problems.

Introduction: Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, Modeling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Chemical Engineering, CFD software packages and tools.

Principles of Solution of the Governing Equations: Finite difference and Finite volume Methods, Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation.

Mesh generation: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation.

Solution Algorithms: Discretization schemes for pressure, momentum and energy equations - Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations.

CFD Solution Procedure: Problem setup – creation of geometry, mesh generation, selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization.

Case Studies: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem.

Course Learning Outcomes (CLO):

The students will be able to:

1. Solve PDE.
2. Use Finite Difference and Finite Volume methods in CFD modeling
3. Generate and optimize the numerical mesh
4. Simulate simple CFD models and analyze its results.

Text Books:

1. *P.S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw-Hill (1998).*
2. *Muralidhar, K.,andSundararajan,T. Computational Fluid Flow and Heat Transfer, Narosa Publishing. House (1995).*

Reference Books:

1. *Niyogi, P. Chakrabarty, S.K. and Laha, M.K., Introduction to computational fluid dynamics, Pearson education (2006).*

2. *LI J., G. H. Yeoh, C Liu. A Computational Fluid Dynamics, ELSEVER (2008)*
3. *Suhas V. Patankar. Numerical Heat Transfer and Fluid Flow, Taylor and Francis (1978).*
4. *S K Gupta. Numerical Methods for Engineers, New Age Publishers, 2nd Edition (1995).*
5. *Anderson J.D. Computational Fluid Dynamics, Mc-Graw Hills (1995).*
6. *Ranade, V.V., Computational flow modeling for chemical reactor engineering, Academic Press (2002).*
7. *J H Ferziger and M Peric, Computational Methods for Fluid Dynamics, Springer (2002).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH833 FLUIDIZATION ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objectives:
To study the fluidization phenomena, fluidized bed regimes and models.

Introduction: Fluidization phenomenon, Liquid-like behaviour of a fluidized bed

Industrial Applications: Physical operations, Synthesis reaction, Cracking of hydrocarbons, Combustion, Incineration, and gasification.

Fluidization and Mapping of Regimes: Distributors, Gas jets in fluidized beds, Pressure drop in fixed beds, Geldart classification of particles, Gas fluidization with and without entrainment, Mapping of fluidization regimes.

Fluidized Beds: Dense beds, Bubbling fluidized beds, Entrainment from fluidized beds, High velocity fluidization, Solids mixing, segregation, and staging, Gas dispersion and interchange in bubbling beds, Heat and mass transfer, Industrial applications.

Fluidized Bed Models: CSTR model, Two region model, Kunii-Levenspiel model.

Course Learning Outcomes (CLO):

The students will be able to:

1. understand the fluidization phenomena and operational regimes.
2. design various types of gas distributors for fluidized beds and determine effectiveness of gas mixing at the bottom region.
3. analyze fluidized bed behavior with respect to the gas velocity.
4. develop and solve mathematical models of the fluidized bed.

Text Books:
1. *Kunii, D., Levenspiel, O. and Robert, E., Fluidization Engineering, Butterworth-Heinemann (1991).*
2. *Coulson, J.M., and Richardson, J.F., Chemical Engineering, Vol. 2, Asian Books Private Limited (2002).*

Reference Books:
1. *Yates, J.G., Fundamentals of Fluidized Bed Chemical Processes, Butterworth-Heinemann (Butterworth's Monographs in Chemical Engineering) (1983).*
2. *Yang, W. and Amin, N.D., Fluidization engineering: fundamentals and applications, American Institute of Chemical Engineers (1988)*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes lab/tutorials/ assignments/ quiz's etc)	25

UCH 834 PROCESS INTEGRATION

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives:
To understand the energy and mass targets in design of processes.

Introduction: Process integration, Role of thermodynamics in process design, Concept of pinch technology and its application.

Heat exchanger networks: Heat exchanger networks analysis**,** Simple design for maximum energy recovery, Loop Breaking & Path Relaxation, Targeting of energy, area, number of units and cost, Trading off energy against capital.

Network Integration: Super targeting, maximum energy recovery (MER), Network for multiple utilities and multiple pinches, Grand Composite curve (GCC).

Mass integration: Distillation sequences.

Heat and Power Integration: Columns, Evaporators, Dryers, and reactors.

Case studies: Waste and waste water minimization, Flue gas emission targeting.

Course Learning Outcomes (CLO):

The students will be able to:

1. understand of the fundamentals of process integration.
2. perform pinch analysis.
3. analyze and design heat exchanger networks.
4. minimize the water consumption and waste generation.

Text Books:
1. *Linnhoff, D.W., User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers (1994).*
2. *Smith, R., Chemical Process Design and Integration, John Wiley & Sons(2005).*

Reference Books:
1. *Shenoy, V. U., Heat Exchanger network synthesis, Gulf Publishing (1995).*
2. *Kumar, A., Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1977).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH 835 PROCESS OPTIMIZATION

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives:
To study and apply optimization techniques in the chemical process industry.

Introduction: Process optimization, Formulation of various process optimization problems and their classification, Basic concepts of optimization-convex and concave functions, Necessary and sufficient conditions for stationary points.

Optimization of One Dimensional Functions: Unconstrained multivariable optimization-direct search methods, Bracketing methods: Exhaustive search, Bounding phase, Region elimination methods- Interval halving, Fibonacci search, Golden section search, Point-Estimation, Successive quadratic estimation methods.

Indirect First Order and Second Order Methods: Gradient-based methods-Newton-Raphson, Bisection, Secant, Cubic spline, Root-finding using optimization Techniques.

Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, Direct search Methods- Evolutionary optimization, Simplex search, Powell's conjugate direction, Gradient-based methods- Cauchy's (steepest descent) method, Newton's method.

Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods, Penalty function method, Method of multipliers, Sensitivity analysis, Direct search for constraint Minimization-Variable elimination method, Complex search method, Successive linear and quadratic programming, Optimization of staged and discrete processes.

Non-traditional Optimization Techniques: Introduction to Simulated annealing, Genetic algorithms, Differential evolution.

Course Learning Outcomes (CLO):

The students will be able to:

1. formulate the objective functions for constrained and unconstrained optimization problems.
2. use different optimization strategies.
3. solve problems using non-traditional optimization techniques.
4. use of different optimization techniques for problem solving.

Text Books:

1. *Edgar, T. F., Himmelblau, D. M. and Lasdon, L.S. Optimization of Chemical Processes, McGraw-Hill (2001).*
2. *Babu, B.V., Process Plant Simulation, Oxford University Press (2004).*

Reference Books:

1. *Kalyanmoy, D., Optimization for Engineering Design, Prentice Hall (1998).*
2. *Reklaitis, G. V., Ravindran, A., and Ragsdell, K. M., Engineering Optimization - Methods and Applications, John Wiley (1983).*
3. *Pike, R. W., Optimization for Engineering Systems, Van Nostrand Reinhold (1986).*
4. *Box, G. E. P., Hunter, W. G., Hunter, J. S., Statistics for Experimenters - An Introduction to Design, Data Analysis, and Model Building, John Wiley (1978).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH 836 ENERGY MANAGEMENT IN PROCESS INDUSTRIES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives:
To introduce the energy and water management principles related to process plants.

Introduction: Energy scenario - supply and demand, Energy intensive industries, Industrial use of energy, Importance of energy in industrial promotion and employment.

Energy Audit: Definition, need and objectives; Types of energy audit; Basic components of energy audit; preparing for audit, Energy audit instruments, Data collection, safety considerations. Methodologies of conducting energy audit; Preliminary questionnaire, Review of previous records, Walk through audit, Energy flow diagram (Shankey diagram).

Energy Conservation: Analysis of scope and potential for energy conservation, Good housekeeping practice, Thermal insulation, Efficiency improvement in boilers, furnaces and heat recovery techniques, Energy conservation in HVAC systems, Electrical energy conservation; analysis of motor, analysis of pumps, Process integration as a measure of energy conservation, Optimization of steam system, Energy saving opportunities with compressed air systems and cooling towers.

Water Management: Sources of water, importance of water in industrial applications, Flow monitoring devices, Quality and cost of water, Water distribution in process industries and scope for water conservation, Reuse and recycle of water.

Case Studies

Course Learning Outcomes (CLO):

The students will be able to:

1. know the components involved in energy auditing.
2. know energy conservation and waste heat recovery techniques.
3. evaluate the performance of industrial boilers and furnaces.
4. identify the scope for recycle and reuse of water.

Text Books:

1. *Barney L. Capehart, Wayne C. Turner, William J. Kennedy, Guide to energy management, The Fairmont Press (2008).*
2. *Nagabhushan Raju, K., Industrial Energy Conservation Techniques: Concepts, Applications and Case Studies, Atlantic Publishers & Distributors (2007).*

Reference Books:

1. *Kenney, W.F., Energy Conservation in the Process Industries, Academic Press, (1984).*
2. *Reay, D.A., Industrial Energy Conservation, Pergamon Press (1979).*
3. *Giovanni Petrecca, Industrial energy management: principles and applications, Springer (1993).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (May includes tutorials/ assignments/ quiz's etc)	25

UCH 841 CORROSION ENGINEERING

L	T	P	Cr
3	0	0	3.0

Course Objectives:
To provide an understanding of the corrosion principles and engineering methods used to minimize and prevent the corrosion.

Basic concepts: Definition and importance, Electrochemical nature and forms of corrosion, Corrosion rate and its determination.

Electrochemical thermodynamics and kinetics: Electrode potentials, Potential-pH (Pourbiax) diagrams, Reference electrodes and experimental measurements, Faraday's laws, Instrumentation and experimental procedure.

Galvanic and concentration cell corrosion: Basic concepts, Experimental measurements, and determination of rates of galvanic corrosion, Concentration cells.

Corrosion measurement through polarization techniques: Tafel extrapolation plots, Polarization resistance method, Commercial corrosion probes, Other methods of determining polarization curves.

Passivity: Basic concepts of passivity, Properties of passive films, Experimental measurement, Applications of Potentiostatic Anodic Polarization, Anodic protection.

Pitting and crevice corrosion: Mechanisms of pitting and crevice corrosion, Secondary forms of crevice corrosion, Localized pitting, Metallurgical features and corrosion: Inter-granular corrosion, Weldment corrosion, De-alloying and dezincification.

Environmental induced cracking: Stress corrosion cracking, Corrosion fatigue cracking, Hydrogen induced cracking, Methods of prevention and testing, Erosion, Fretting and Wear.

Environmental factors and corrosion: Corrosion in water and aqueous solutions, Corrosion in sulphur bearing solutions, Microbiologically induced corrosion, Corrosion in acidic and alkaline process streams.

Atmospheric and elevated temperature corrosion: Atmospheric corrosion and its prevention, Oxidation at elevated temperatures, Alloying, Oxidizing environments.

Prevention and control of corrosion: Cathodic protection, Coatings and inhibitors, Material selection and design.

Course Learning Outcomes (CLO):

The students will be able to:

1. solve problems involving various types of corrosion.

2. select corrosion resistant materials for a given application.
3. select technique for corrosion prevention.

***Text Books*:**

1. *Fontana, M.G., Corrosion Engineering, Tata McGraw-Hill (2008). 3rd ed. (seventh reprint)*
2. *Jones, D.A., Principles and Prevention of Corrosion, Prentice-Hall (1996).*

***Reference Books*:**

1. *Pierre R. Roberge, Corrosion engineering: principles and practice, McGraw-Hill (2008).*
2. *Pierre R. Roberge, Handbook of corrosion engineering, McGraw-Hill (2012). 2nd ed.*
3. *Sastri, V.S., Ghali, E. and Elboujdaini, M., Corrosion prevention and protection: Practical solutions, John Wiley and Sons (2007).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may includes assignments/ quiz's etc.)	20

UCH842 NANOFLUID ENGINEERING

L	T	P	Cr
3	0	0	3.0

Introduction: Fundamentals of cooling, Fundamentals of nanofluids, Development of nanofluids, Experimental discoveries, Mechanisms and models for enhanced thermal transport.

Synthesis of Nanofluids: General issues of concern, Synthetic methods: Common issues of concern, Variety in nanomaterials, Microemulsion-based methods for nanofluids, Solvothermal synthesis, Synthesis using supports, Magnetic nanofluids, Inert gas condensation, Anisotropic nanoparticles, Other nanofluids.

Conduction Heat Transfer in Nanofluids: Conduction heat transfer, Measurement of thermal conductivity of liquids, Thermal conductivity of oxide nanofluids, Temperature dependence of thermal conductivity enhancement, Metallic nanofluids, Nanofluids with carbon nanotubes.

Theoretical Modeling of Thermal Conductivity in Nanofluids: Simple mixture rules, Maxwell's approach, Particle distributions, Particle geometries, Symmetrical equivalent medium theory, Matrix–particle interfacial effects, Interfacial thermal resistance, Dynamic models of thermal conductivity in nanofluids, Near-field radiation model.

Convection in Nanofluids: Fundamentals of convective heat transfer, Convection in suspensions and slurries, Convection in nanofluids, Analysis of convection in nanofluids, Numerical studies of convection in nanofluids, Convective simulation for chip cooling application.

Boiling of Nanofluids: Fundamentals of boiling, Pool boiling of nanofluids, Critical heat flux in pool boiling of nanofluids, Other investigations related to boiling of nanofluids.

Applications and Future Directions: Applications of nanofluids, Liquid cooling, Tribological applications, Biomedical applications, other potential applications, Applied research in nanofluids.

Text Books:

1. Das, S. K., Choi, S. U. S., Yu, W., and Pradeep, T., Nanofluids, John Wiley & Sons (2008).
2. Surya Kumar Saripella, Nanofluid heat transfer enhancement in engineering applications, University of Illinois at Urbana-Champaign (2007).

Reference Books:

1. Wilson, M., Kannangara ,K., Smith, G., and Simmons, M., Nanotechnology: Basic Science and Emerging Technology, Chapman & Hall (2004).
2. Liqiu Wang, Advances in Transport Phenomena,Springer (2009).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may includes assignments/ quiz's etc.)	20

UCH843 SCALE-UP METHODS IN CHEMICAL ENGINEERING

L	T	P	Cr
3	0	0	3.0

Course Objectives:

To understand the importance of process equipment geometry and to provide concepts, methods and analysis to translate various chemical processes from laboratory scale to plant scale.

Scale up: Description and evolution of a process system, Introduction to Scale up procedures, Dimensional analysis, Similitude.

Reactors for Fluid Phase Processes Catalyzed by Solids: Pseudo-homogeneous and heterogeneous models, Two-dimensional models, Scale up considerations.

Fluid-fluid Reactors: Scale-up considerations in packed bed absorbers and bubble columns, Applicability of models to scale-up.

Mixing Processes: Scale-up relationships, Scale-up of polymerization units, Continuous stages gas-liquid slurry processes, Liquid-liquid emulsions.

Fluidized Beds: Major scale-up issues, Prediction of performance in large equipment, Practical commercial experience, Problem areas.

Solid-Liquid Separation Processes:Fundamental considerations, Small scale studies for equipment design and selection, Scale-up techniques, Uncertainties.

Continuous Mass Transfer Process: Fundamental considerations scale-up procedure for distillation, Absorption, Stripping and extraction units.

Course Learning Outcomes (CLO):

The students will be able to:

1. scale-up the fluid phase and fluid-fluid reactor.
2. scale-up the mixing units and separation units.
3. scale-up for mass transfer processes.

Text Books:

1. *M. Zlokarnik, Scale-up in Chemical Engineering, Wiley-VCH (2006).*
2. *R.E. Johnstone and M.W. Thring, Pilot Plants, Models and Scale-up Methods in Chemical Engineering, McGraw-Hill (1957).*

Reference Books:

1. *C. Divall, and S. Johnston, Scaling up: the Institution of Chemical Engineers and the Rise of a New Profession, Springer (2000).*
2. *A. Bisio, and R.L. Kabel, Scale-up of Chemical Processes, John Wiley (1985).*

3. Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may includes assignments/ quiz's etc)	20

UCH844 PETROLEUM TECHNOLOGY

L	T	P	Cr
3	0	0	3.0

Course Objectives:
To impart knowledge of petroleum refining and hydrocarbon processing.

Introduction: World petroleum resources, Petroleum industry in India, Origin, Exploration, Drilling and production of petroleum crude, Transportation and pretreatment of crude oil.

Characterization: Composition and classification of petroleum crude, ASTM, TBP and EFV distillation of crude oil, Properties and specifications of petroleum products - LPG, gasoline, naphtha, kerosene, diesel oil, lubricating oil, wax etc.

Separation Processes: Pretreatment of crude, Crude distillation, Vacuum distillation, Gasoline treatment and operation of topping, Tube still furnaces, Solvent extraction processes for lubricating oil base stocks and for aromatics from naphtha and kerosene, dewaxing.

Conversion Processes: Thermal and catalytic cracking, Vis-breaking and coking processes, Reforming, Hydroprocessing, Alkylation, Polymerisation and isomerisation, Product finishing processes.

Course Learning Outcomes (CLO):

The students will be able to:

1. acquired knowledge of characterization of petroleum.
2. know the properties and specification of petroleum products.
3. acquired knowledge of different separation processes involved in petroleum refinery.
4. acquired knowledge of various conversion processes involved in petroleum refinery.

Text Books:

1. *Bhaskara Rao, B.K. Modern Petroleum Refining Processes. Oxford & IBH Publishing Company Pvt. Ltd. New Delhi, (2007).*
2. *Prasad, R. Petroleum Refining Technology, Khanna Publishers, (2011).*
3. *Mall, I.D. Petrochemical Process Technology, Mecmillan Publishers, (2006).*

Reference Books:

1. *Nelson, W. L. Petroleum Refinery Engineering, Tata McGraw Hill Publishing Company Limited, (1958).*
2. *Garry,J.H. Petroleum Refining Technology and Economics, Marcel Dekker Inc., (2001).*
3. *Wells G. M.Handbook of petrochemicals and processes, Ashgate Publishing Ltd, (1999).*
4. *Spitz P. H. Petrochemicals: The rise of an industry, John Wiley & Sons, (1999).*
5. *Sarkar, G.N. Advanced Petroleum Refining, Khanna Publishers, (2000).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may includes assignments/ quiz's etc)	20

UCH845 POLYMER TECHNOLOGY

L	T	P	Cr
3	0	0	3.0

Course Objectives:
To provide fundamental and applied knowledge of polymers and their synthesis, manufacture, processing and characterization.

Introduction: Basic concepts of polymer science, Classification of polymers, Average molecular weight and Molecular weight distribution.

Polymerization: Mechanism and kinetics of: Free radical addition polymerization, Ionic addition polymerization, Coordination polymerization, Step growth polymerization.

Structure and Properties: Thermal transitions, Crystallinity, Molecular weight characterization, Nuclear Magnetic Resonance (NMR) and Fourier Transform Infrared (FTIR) techniques.

Plastic Technology: Introduction, Rheology, Mixing and Compounding, Extrusion, Compression molding, Transfer molding, Injection molding, Blow molding, Calendering, Coating, Casting, Thermoforming.

Fiber Technology: General principles, Spinning, Fiber treatment, Properties.

Elastomer Technology: Natural and synthetic elastomers, Processing, Properties.

Manufacture: Brief description of manufacture, properties and uses of Polyethylene, Polypropylene, Polyvinylchloride, Polystyrene, Nylon, Polyethylene terephthalate.

Polymer Blends: Types, Compatibility, Thermal and Mechanical Properties.

Polymer Composites: Types, Properties, Preparation, Fibre-reinforced composites, In-situ composites.

Polymer Nanocomposites: Basic concepts, Processing, Characterization.

Course Learning Outcomes (CLO):

The students will be able to:

- understand the polymer synthesis techniques.
- understand the structure-processing-property relationship of polymers.
- understand and apply the various processing and manufacturing techniques.
- understand the basic issues involved in polymer blends, composites and nanocomposites.

Text Books:

1. *Billmeyer, F.W. Jr., Text Book of Polymer Science, Wiley & Sons (2005).*
2. *Kumar, A., Gupta, R. K., Fundamentals of Polymers, McGraw Hill (1998).*

Reference Books:

1. *Tadmo, Z; Gogos, C.G., Principles of Polymer Processing, Wiley Interscience (2006).*
2. *Williams, D. J., Polymer Science and Engineering, Prentice Hall of India (1971)*

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1	MST	30
2	EST	50
3	Sessional (may includes assignments/ quiz's etc)	20