THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY

COURSE SCHEME

&

SYLLABUS

FOR

B.E.

CHEMICAL ENGINEERING

2016

Approved by the 90th meeting of the senate (May 30, 2016)

Applicable from July 2016 to undergraduate engineering

CHEMICAL ENGINEERING DEPARTMENT – COURSE SCHEME

SEMESTER – I (Group-A)

S.No.	COURSE NO.	TITLE	L	T	P	CR
1	UMA003	MATHEMATICS-I	3	1	0	3.5
2	UTA007	COMPUTER PROGRAMMING - I	3	0	2	4.0
3	UPH004	APPLIED PHYSICS	3	1	2	4.5
4	UEE001	ELECTRICAL ENGINEERING	3	1	2	4.5
5	UHU003	PROFESSIONAL COMMUNICATION	2	0	2	3.0
6	UTA008	ENGINEERING DESIGN-I	2	4	0	4.0
TOTAL			**16**	**7**	**8**	**23.5**

SEMESTER – II (Group-A)

S.No.	COURSE NO.	TITLE	L	T	P	CR
1	UMA004	MATHEMATICS-II	3	1	0	3.5
2	UTA009	COMPUTER PROGRAMMING-II	3	0	2	4.0
3	UES009	MECHANICS	2	1	2*	2.5
4	UEC001	ELECTRONIC ENGINEERING	3	1	2	4.5
5	UCB008	APPLIED CHEMISTRY	3	1	2	4.5
6	UTA010	ENGINEERING DESIGN-II (CATAPULT AND MORE SUCH PROJECTS) (5 SELF EFFORT HOURS)	1	0	3	5.0
TOTAL			**15**	**4**	**8**	**24**

* EACH STUDENT WILL ATTEND ONE LAB SESSION OF 2 HRS IN A SEMESTER FOR A BRIDGE PROJECT IN THIS COURSE (MECHANICS).

SEMESTER – III (Group-A)

S.No.	COURSE NO.	TITLE	L	T	P	CR
1	UMA031	OPTIMIZATION TECHNIQUES	3	1	0	3.5
2	UTA002	MANUFACTURING PROCESS	2	0	3	3.5
3	UES010	SOLIDS AND STRUCTURES	3	1	2	4.5
4	UES011	THERMO-FLUIDS	3	1	2	4.5
5	UTA011	ENGINEERING DESIGN-III (BUGGY AND MORE SUCH PROJECTS) (6 SELF EFFORT HOURS)	1	0	4	6.0
6	UCH301	MATERIAL AND ENERGY BALANCES	3	1	0	3.5
TOTAL			**16**	**4**	**9**	**25.5**

SEMESTER – IV (GROUP-A)

S.NO.	COURSE NO.	TITLE	L	T	P	CR
1	UMA007	NUMERICAL ANALYSIS	3	1	2	4.5
2	UES012	ENGINEERING MATERIALS	3	1	2	4.5
3	UEN002	ENERGY AND ENVIRONMENT	3	0	0	3.0
4	UCH401	FLUID AND PARTICLE MECHANICS (WITH PROJECT) (INCLUDES 7 SELF EFFORT HOURS)	3	1	2	8.0
5	UCH303	CHEMICAL ENGINEERING THERMODYNAMICS	3	1	0	3.5
6	UCH405	ENERGY RESOURCES	3	1	2	4.5
TOTAL			**17**	**4**	**8**	**28.0**

SEMESTER - V

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	UCH507	CHEMICAL PROCESS INDUSTRIES	4	0	0	4.0
5	UCH402	HEAT TRANSFER	3	1	2	4.5
6	UCH506	PROCESS INSTRUMENTATION AND CONTROL	3	1	2	4.5
		TOTAL	**19**	**5**	**8**	**25.5**

SEMESTER - VI

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	UCH802	PROCESS MODELING AND SIMULATION	3	0	2	4.0
5	UCH605	PROCESS UTILITIES AND INDUSTRIAL SAFETY	3	1	0	3.5
6	UCH610	PROCESS EQUIPMENT DESIGN	3	2	0	4.0
7	UTA012	INNOVATION & ENTREPRENEURSHIP (5 SELF EFFORT HOURS)	1	0	2	4.5
		TOTAL	**19**	**6**	**7**	**28.0**

SEMESTER - VII

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH793	PROJECT SEMESTER*				20.0
		TOTAL				**20.0**

*TO BE CARRIED OUT IN INDUSTRY/RESEARCH INSTITUTION

OR

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH794	PROJECT				13.0
2		ELECTIVE-I	3	1	0	3.5
3		ELECTIVE-II	3	1	0	3.5
		TOTAL	**6**	**2**	**0**	**20.0**

OR

START- UP SEMESTER BASED ON HANDS ON WORK ON INNOVATIONS AND ENTREPRENEURSHIP OF 20 CREDITS.

SEMESTER - VIII

S.NO.	COURSE NO.	COURSE NAME	L	T	P	CR
1	UCH801	PROCESS ENGINEERING AND PLANT DESIGN	3	1	0	3.5
2	UCH604	BIOCHEMICAL ENGINEERING	3	1	2	4.5
3	UHU005	HUMANITIES FOR ENGINEERS	2	0	2	3.0
4		ELECTIVE-III	3	1	0	3.5
5		ELECTIVE-IV	3	0	0	3.0
6	UCH893	CAPSTONE PROJECT	0	0	2	8.0
		TOTAL	**15**	**4**	**6**	**25.5**

LIST OF PROFESSIONAL ELECTIVES

ELECTIVE I

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1	UCH711	FLUIDIZATION ENGINEERING	3	1	0	3.5
2	UCH712	DISTILLATION PROCESSES	3	1	0	3.5
3	UCH713	CORROSION ENGINEERING	3	1	0	3.5

ELECTIVE II

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1	UBT704	TRENDS IN FOOD BIOTECHNOLOGY	3	1	0	3.5
2	UCH716	FOOD ENGINERING AND SCIENCE	3	1	0	3.5
3	UCH701	CATALYTIC PROCESSES	3	1	0	3.5

ELECTIVE III

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1	UCH831	NOVEL SEPARATION PROCESSES	3	1	0	3.5
2	UCH840	POLYMER SCIENCE AND TECHNOLOGY	3	1	0	3.5
3	UCH833	CHEMICAL PROCESS OPTIMIZATION	3	1	0	3.5
4	UCH834	PROCESS INTEGRATION	3	1	0	3.5
5	UCH836	ENERGY MANAGEMENT IN PROCESS INDUSTRIES	3	1	0	3.5

ELECTIVE IV

S.NO.	COURSE	COURSE NAME	L	T	P	CR
1	UCH841	NANO-MATERIALS FOR CHEMICAL ENGINEERS	3	0	0	3.0
2	UCH848	COMPUTATIONAL FLUID DYNAMICS	2	0	2	3.0
3	UCH849	SCALE-UP AND PILOT-PLANTS METHODS	3	0	0	3.0
4	UCH844	PETROLEUM AND PETROCHEMICALS	3	0	0	3.0

Total credits: 200

UES011 THERMO-FLUIDS

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

Course Objective

To understand basic concepts of fluid flow and thermodynamics and their applications in solving engineering problems

Fluid Mechanics

- **Introduction**: Definition of a fluid and its properties
- **Hydrostatics**: Measurement of pressure, thrust on submerged surfaces
- **Principles of Fluid Motion**: Description of fluid flow; continuity equation; Euler and Bernoulli equations; Pitot total head and static tubes, venturi-meter, orifice-meter, rotameter; Momentum equation and its applications
- **Pipe Flow**: Fully developed flow; laminar pipe flow; turbulent pipe flow, major and minor losses; Hydraulic gradient line (HGL) and total energy line (TEL)
- **Boundary Layer**: Boundary layer profile; displacement, momentum and energy thickness

Thermodynamics

- **Introduction**: Properties of matter, the state postulate, energy, processes and thermodynamic systems;
- **Properties of Pure Substances**: property tables, property diagrams, phase change, equations of state (ideal gas);
- **Energy**: Energy transfer by heat, work and mass;
- **First Law of Thermodynamics**: Closed system, open system, steady-flow engineering devices;
- **Second Law of Thermodynamics**: Statements of the Second Law, heat engines, refrigeration devices, reversible versus irreversible processes, the Carnot cycle.

Laboratory/Project programme

List of Experiments

1. Verification of Bernoulli's theorem
2. Determination of hydrostatic force and its location on a vertically immersed surface
3. Determination of friction factor for pipes of different materials

4. Determination of loss coefficients for various pipe fittings
5. Verification of momentum equation
6. Visualization of laminar and turbulent flow, and rotameter
7. Calibration of a venturi-meter
8. Boundary layer over a flat plate

Sample List of Micro-Projects

Students in a group of 4/5 members will be assigned a micro project.

1. Design a physical system to demonstrate the applicability of Bernoulli's equation
2. Determine the pressure distribution around the airfoil body with the help of wind tunnel
3. Demonstrate the first law of thermodynamics for an open system, for example: a ordinary hair dryer
4. Develop a computer program for solving pipe flow network.

Course Learning Outcomes (CLO):

Upon completion of this course, the students will be able to:

1. analyze and solve problems of simple fluid based engineering systems including pressures and forces on submerged surfaces
2. analyze fluid flow problems with the application of the mass, momentum and energy equations
3. evaluate practical problems associated with pipe flow systems
4. conceptualize and describe practical flow systems such as boundary layers and their importance in engineering analysis
5. estimate fluid properties and solve basic problems using property tables, property diagrams and equations of state
6. analyze and solve problems related to closed systems and steady-flow devices by applying the conservation of energy principle
7. analyze the second law of thermodynamics for various systems and to evaluate the performance of heat engines, refrigerators and heat pumps.

Text Books

1. *Kumar, D. S, Fluid Mechanics and Fluid Power Engineering, S. K. Kataria (2009)*
2. *Cengel and Boles, Thermodynamics: an Engineering Approach, McGraw-Hill (2011)*

Reference Books

1. *Jain, A. K. , Fluid Mechanics: including Hydraulic Machines, Khanna Publishers (2003)*
2. *Rao, Y.V. C, An Introduction to Thermodynamics, Universities Press (2004*

Evaluation Scheme:

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

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.

Sample List of Micro-Projects

Students in a group of 4/5 members will be assigned a micro project.

1. Complete material balances on a process flow sheet
2. Energy balances on a complete process flow sheet
3. Analyze the degrees of freedom for a complete process

Course Learning Outcomes (CLO)

Upon completion of this course, 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. perform 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 (may be tutorials/ quizs/ assignments/ project)	25

UCH401 FLUID AND PARTICLE MECHANICS (WITH PROJECT)

L	T	P	Cr
3	**1**	**2**	**8.0**

Course Objective:
To understand basic principles of fluid and particle mechanics including construction and working of the equipments.

Particle Characterization and Handling: Determination of mean particle size, Particle shape and size distribution, Screen analysis, Storage of solids, conveying systems

Size Reduction: Laws of size reduction, Industrial size reduction equipment.

Fluid-Solid Separations: Free and hindered settling, Clarification and thickening, Froth flotation, Centrifugal separation, Theory of filtration and filtration equipment

Packed and Fluidized Bed: Friction in flow through packed beds, Mechanism of fluidization, Determination of minimum fluidization velocity, Determination of velocity range for the operation of a fluidized bed.

Agitation and Mixing of Liquids: Types of impellers, Power consumption, mixing times, Scale up.
Pumps and Compressors: Types, Working principles, Basic equations, NPSH, Cavitation, Priming.

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

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)

Upon completion of this course, 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.
5. solve the problems related to compressible fluids, and fluid machinery.

Projects based on:

- Pumps characteristics
- Solid-solid separations
- Solid-liquid separations
- Solid-gas separations
- Flow through packed and fluidized beds

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	20
2	EST	30
3	Sessional (May include may be tutorials/ quiz's/ /lab/ project)	50

UCH303 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)

Upon completion of this course, 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 (may be tutorials/ quizs/ assignments)	25

UCH405 ENERGY RESOURCES

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):

Upon completion of this course, 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

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, Reversible reactions, 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):

Upon completion of this course, 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 Objective:

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):

Upon completion of this course, 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 Objective:

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.

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.

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):

Upon completion of this course, 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 of 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

UCH507 CHEMICAL PROCESS INDUSTRIES

L	T	P	Cr
4	0	0	4.0

Course Objective:
To study process technologies of various organic and inorganic process industries.

Introduction: Production trends, Material and energy balances, Symbols and flow sheets, Waste generation and recycling, Engineering problems, Materials of construction, Environmental and energy conservation measures.

Pulp and Paper: 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: 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.

Chlor-alkali Industries: Brine electrolysis, Manufacture of caustic soda and chlorine in mercury cells, Diaphragm cells, Membrane cells, Hydrochloric acid.

Nitrogen Industries: Ammonia, Nitric acid, Ammonium sulphate, Ammonium nitrate, Urea, Calcium ammonium nitrate.

Phosphorus Industries: Phosphorus, Phosphoric acid, Phosphatic fertilizers.

Mixed Fertilizers: SSP, TSP, NPK, KAP, DAP, Nitrophosphate, Bio fertilizers.

Sulphur Industries: Sulphur dioxide, Sulphuric acid, Oleum.

Ceramic Industries: Portland cement, Lime, Gypsum.

Course Learning Outcomes (CLO)

Upon completion of this course, the students will be able to:

1. understand the processes involved in manufacturing of various inorganic and organic chemicals.

2. prepare the process flow diagrams.
3. analyze important process parameters and engineering problems during production.

Text Books:

1. *Dryden, C.E., Outlines of Chemical Technology (Edited and Revised by M. Gopal Rao and Sittig. M), East West Press Pvt. Ltd, New Delhi (1997).*
2. *Austin, G.T., Shreve's Chemical Process Industries, McGraw Hill (1984).*

Reference Books:

1. *Faith, W.L., Keyes, D.B. and Clark, R.L., Industrial Chemicals, Wiley (1980).*
2. *Kirk and Othmer, Encyclopaedia of Chemical Technology, Wiley (2004).*
3. *Groggins, P.H., Unit Processes in Organic Synthesis, Tata McGraw-Hill (2003).*

Evaluation Scheme:

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

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)

Upon completion of this course, 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

UCH506 PROCESS INSTRUMENTATION AND CONTROL

L	T	P	Cr
3	1	2	4.5

Course Objective:
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):

Upon completion of this course, 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**	**0**	**3.5**

Course Objective:

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.

Course Learning Outcomes (CLO):

Upon completion of this course, 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 Objective:

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):

Upon completion of this course, 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

UCH603 TRANSPORT PHENOMENA

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

Course Objective:

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):

Upon completion of this course, 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

UCH802 PROCESS MODELING AND SIMULATION

L	T	P	Cr
3	**0**	**2**	**4.0**

Course Objective:
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):

Upon completion of this course, 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 Books:

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).*

Approved by the 90th meeting of the senate (May 30, 2016)

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

UCH605 PROCESS UTILITIES AND INDUSTRIAL SAFETY

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

Course Objective:
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):

Upon completion of this course, 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

UCH610 PROCESS EQUIPMENT DESIGN

L	T	P	Cr
3	2	0	4.0

Prerequisite(s): None

Course Objective:
To understand the mechanical and process design methods for various process equipment.

Introduction: General design procedure, Equipment classification, Design codes, Design pressure, Design temperature, Design stress, Factor of safety, Design wall thickness, Corrosion allowance, Weld joint efficiency factor.

Pressure vessels: Design of thin& thick wall cylindrical and spherical vessels, Tall vessels, Storage vessels, Different types of heads.

Heat Transfer Equipment: Process design calculations for heat transfer equipment, Design of shell and tube heat exchangers, Estimation of heat transfer coefficients and pressure drop by Kerns' and Bell's methods, Condenser design, Plate type heat exchanger design.

Mass Transfer Equipment: Process design calculations for multi-component distillation, Fenske-Underwood-Gilliland Method, Selection of 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, types of plate contractors, tray layout and hydraulic design, Packed towers – column internals, Types of packing, General pressure drop correlation, Column diameter and height.

Course Learning Outcomes (CLO):

Upon completion of this course, the students will be able to:

1. determine the parameters of equipment design and important steps involved in design.
2. design pressure vessels.
3. design different types of heat transfer equipment.
4. design different types of mass transfer equipment.

Text Books:

1. *Bhattacharyya, B.C., Introduction to Chemical Equipment Design, Mechanical Aspects, CBS Publishers and Distributors (2009).*
2. *Sinnott Ray and Towler Gavin, Coulson and Richardson's Chemical Engineering series Chemical Engineering Design Volume 6, 5th edition (2013).*
3. *Kern, D.Q., Process Heat Transfer, International Student Edition, McGraw Hill (2002).*

Reference Books:

1. *Mahajani, V.V. and Umarji, S.B., Joshi's Process Equipment Design, 4th edition, Macmillan Publishers India Limited, New Delhi (2010).*
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. *Ludwig E.E., Applied Process Design in Chemical and Petrochemical Plants Vol.II, III, Gulf Publishing Co. (1995).*
5. *Brownell, L.E. and Young, E.H., Process Equipment Design, Wiley India (P.) Limited (2004).*
6. *Perry, R.H. and Green, D, Chemical Engineer's Handbook, 8th Edition, McGraw Hill, New York. (2008).*
7. *Seader, J. D., Henley, E. J., Separation Process Principles, Wiley (2001).*
8. *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

UCH801 PROCESS ENGINEERING AND PLANT DESIGN

L	T	P	Cr
3	1	0	3.5

Course Objective:
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-sheet Synthesis: 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):

Upon completion of this course, 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

UCH604 BIOCHEMICAL ENGINEERING

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

Course Objective:
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):

Upon completion of this course, 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

UCH893 CAPSTONE PROJECT

L	T	P	Cr
0	**0**	**2**	**8.0**

Course Objective:
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 (CLO):

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

UCH711 FLUIDIZATION ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective:
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):

Upon completion of this course, 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

UCH712 DISTILLATION PROCESSES

L	T	P	Cr
3	1	0	3.5

Course Objective:
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):

Upon completion of this course, 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

UCH713 CORROSION ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective:
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

UCH716 FOOD ENGINERING AND SCIENCE

L	T	P	Cr
3	1	0	3.5

Course Objective

To impart knowledge to the students about food process engineering, preservation, packaging, related hazards and safety.

Introduction: Genaral aspects of food industry, Composition of foods, quality and nutritive aspects, Characteristic features of processed and natural food, Mass and energy balance in food processing operation.

Food Rheology: Characteristics of non-Newtonian fluids, Time-independent and time-dependent non-Newtonian fluids, linear viscoelastic fluids.

Thermal Processing: Canning/retort processing – process design and equipments. Equipment design aspects of pasteurizer, sterilizers, evaporators and concentrators, Dryers and their design parameters – tray dryer, spray dryer, fluidized bed dryer.

Food Preservation: Microbial Survivor Curves, thermal death of microorganisms and D, Z and F value calculation, Spoilage probability, Food preservation by dehydration, irradiation, Food preservation by adding preservatives.

Food Production, Packaging and Storage: Process design aspects for liquid foods such as milk and juices. Concentration with thermal and membranes processes,.Food packaging & product shelf life, Modified atmosphere and controlled atmosphere storage, Aseptic packaging,Freezing and Thawing calculations

Food laws: Legislation, safety and quality control.

Course Outcome

The students will be able to:

1. calculate rheological properties of foods.
2. identify and evaluate various design parameters for equipment involved in thermal processing of food.
3. quantify thermal death of micro-organism and calculate spoilage probability
4. evaluate effect of food processing and packaging /storage on food quality
5. 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. Heldman D.R. and Singh R.P., Food Process Engineering,Chapman and Hall (1984)
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

UCH701 CATALYTIC PROCESSES

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

Course Objective:
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):

Upon completion of this course, 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

UCH831 NOVEL SEPARATION PROCESSES

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

Course Objective:

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):

Upon completion of this course, the students will be able to:

- develop models and the solutions for adsorptive separation processes.
- characterize the membrane.
- use the concepts of membrane separation techniques for industrial separations.
- solve problems involving separation based on liquid membrane.
- 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

UCH840 POLYMER SCIENCE AND TECHNOLOGY

L	T	P	Cr
3	1	0	3.5

Course Objective:
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):

Upon completion of this course, the students will be able to:

1. Identify the synthesis technique for different polymers.
2. Differentiate various polymers on the basis of their thermal transitions and molecular weight.
3. Analyze the various polymer processing techniques.
4. Carry out a comparative analysis of the properties and applications of 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

UCH833 CHEMICAL PROCESS OPTIMIZATION

L	T	P	Cr
3	1	0	3.5

Course Objective:
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):

Upon completion of this course, 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

UCH834 PROCESS INTEGRATION

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

Course Objective:
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):

Upon completion of this course, 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

UCH836 ENERGY MANAGEMENT IN PROCESS INDUSTRIES

L	T	P	Cr
3	1	0	3.5

Course Objective:
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):

Upon completion of this course, 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

UCH841 NANOMATERIALS FOR CHEMICAL ENGINEERS

L	T	P	Cr
3	0	0	3.0

Course Objective:
To learnaboutvarious kinds of nanomaterials, their properties, synthesis routes and applications in Chemical Engineering and allied fields.

Introduction: Definition, Classification, Synthetic routes and general applications.

Surface: Solid-vapor interface, Surface defects and crystal defects, Effect of surface curvature and solid-liquid interface.

Zero Dimension Nanoparticles: Size dependent properties, review of some topics related to physics covering free electron model in solids, band gap and band structure in metals and semiconducting nanomaterials, energy levels and discretization based on quantum mechanics.

Zero-Dimension Nanostructure Colloids and Colloidal Structure: Van der Waals interaction, effect of particle geometry, surface charge, zeta potential and electro static stabilization.

Carbon Nanostructures: Structure, preparation of carbon nanotubes, graphene, electrical and mechanical properties and applications.

One-Dimension Nanostructures: Growth of one-dimensional structures using various processes and selected properties and applications.

Two-Dimension Nanostructures: Various thin film deposition techniques: atomic layer deposition, layer-by-layer deposition, multilayer techniques and mechanisms of nanocomposite coating.

Polymers Nanocomposites: Synthesis, processing, properties and applications of polymer-CNT nanocomposites, and polymer-clay nanocomposites.

Course Learning Outcomes (CLO):

The students will be able to:

- select an appropriate nanomaterials (zero, one and two dimension) with regard to their preparation, properties and applications.
- identify various synthesis and processing methods for nanomaterials and polymer nanocomposites.
- identify nanomaterials for Chemical Engineering applications.

Text Book:
Dinesh C. Agrawal, Introduction to Nanoscience and Nanomaterials, World Scientific Publishing (2013).

Reference Book:
GuoZhong Cao, Nanostructures & Nanomaterials, synthesis, properties & applications, Imperial College Press (2008).

Evaluation Scheme:

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

UCH848 COMPUTATIONAL FLUID DYNAMICS

L	T	P	Cr
2	**0**	**2**	**3.0**

Course Objective:
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):

Upon completion of this course, 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

UCH849 SCALE-UP AND PILOT-PLANTS METHODS

L	T	P	Cr
3	0	0	3.0

Course Objective:

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):

Upon completion of this course, 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).*

Evaluation Scheme:

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

UCH844 PETROLEUM AND PETROCHEMICALS

L	T	P	Cr
3	0	0	3.0

Course Objective:

To impart knowledge of petroleum refining, hydrocarbon processing, and derived petrochemicals.

Introduction: World petroleum resources, Petroleum industries in India, Chemistry and composition of crude oil, Transportation and pretreatment of crude oil, New trends in refinery.

Classification and Characterization: Classification of petroleum, Characterization of petroleum fractions.

Crude oil distillation: Impurities in crude oil, Desalting of crude oil, Atmospheric distillation and vacuum distillation units.

Conversion Processes: Thermal conversion processes, Conventional vis-breaking and soaker visbreaking process, Coking processes, Catalytic conversion processes, Fluid catalytic cracking, Catalytic reforming, Hydrocracking, Catalytic alkylation, Catalytic isomerization and catalytic polymerization.

Finishing Processes: Sulphur conversion processes, Sweetening processes, Solvent extraction process, Hydrotreating process.

Lube oil manufacturing Processes: Solvent extraction of lube oil fractions**,** Manufacture of petroleum wax, Hydrofinishing process.

Petrochemicals: Primary petrochemicals such as ethylene, propylene, butadiene, benzene, toluene, xylene and their derived polymers.

Course Learning Outcomes (CLO):

Upon completion of this course, the students will be able to:

1. select the appropriate characterization parameters.
2. specify the properties of petroleum products.
3. attain knowledge of various separation & conversion processes involved in petroleum refining.
4. attain knowledge of manufacturing of various petrochemical products.

***Text Books*:**

1. *Bhaskara Rao, B.K. Modern Petroleum Refining Processes. Oxford & IBH Publishing Company Pvt. Ltd. New Delhi, (2007) 3rd Ed.*

2. *Prasad, R. Petroleum Refining Technology, Khanna Publishers, (2011) 1st Ed.*
3. *Mall, I.D. Petrochemical Process Technology, Mecmillan Publishers, (2006) 1st Ed.*

***Reference Books*:**

1. *Nelson, W. L. Petroleum Refinery Engineering, Tata McGraw Hill Publishing Company Limited, (1958) 4th Ed.*
2. *Garry,J.H. Petroleum Refining Technology and Economics, Marcel Dekker Inc., (2001) 4th Ed.*
3. *Wells G. M.Handbook of petrochemicals and processes, Ashgate Publishing Ltd, (1999) 2nd Ed.*
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 seminar/ assignments/ quiz's etc)	20