COURSE SCHEME AND SYLLABUS

FOR

B.E. (Chemical Engineering)

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

2023

Approved in 109th meeting of the Senate held on March 16, 2023

SEMESTER-I

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1.	UPH013	PHYSICS	BSC	3	1	2	**4.5**
2.	UES101	ENGINEERING DRAWING	ESC	2	4	0	**4.0**
3.	UHU003	PROFESSIONAL COMMUNICATION	HSS	2	0	2	**3.0**
4.	UES102	MANUFACTURING PROCESSES	ESC	2	0	2	**3.0**
5.	UMA010	MATHEMATICS–I	BSC	3	1	0	**3.5**
		TOTAL		12	6	6	**18.0**

SEMESTER-II

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1.	UCB009	CHEMISTRY	BSC	3	0	2	**4.0**
2.	UES103	PROGRAMMING FOR PROBLEM SOLVING	ESC	3	0	2	**4.0**
3.	UES013	ELECTRICAL & ELECTRONICS ENGINEERING	ESC	3	1	2	**4.5**
4.	UEN008	ENERGY AND ENVIRONMENT	ESC	2	0	0	**2.0**
5.	UMA004	MATHEMATICS–II	BSC	3	1	0	**3.5**
		TOTAL		14	2	6	**18.0**

Note: EL activity in the semester-II will be carried out as per schedule.

SEMESTER – III

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH404	CHEMICAL PROCESS INDUSTRIES	PCC	3	0	0	3.0
2	UCH305	CHEMICAL ENGINEERING THERMODYNAMICS-I	PCC	3	1	0	3.5
3	UCH301	MATERIAL AND ENERGY BALANCES	PCC	3	1	0	3.5
4	UCH302	PROCESS FLUID MECHANICS	PCC	3	1	2	4.5
5	UES012	ENGINEERING MATERIALS	ESC	3	1	2	4.5
6	UCH503	INDUSTRIAL POLLUTION ABATEMENT	PCC	3	1	2	4.5
7	UTD002	EMPLOYABILITY DEVELOPMENT SKILLS	HSS	2	0	0	2.0
TOTAL				**20**	**5**	**6**	**25.5**

1	UES020	THERMO-FLUIDS *(To be offered to only IEP students)*	ESC	2	0	2	3.0

Note: EL activity in the semester-III will be carried out as per schedule.

SEMESTER – IV

S. No.	Course Code	Course Name	CODE **	L	T	P	Cr
1	UCH410	NUMERICAL METHODS IN CHEMICAL ENGINEERING	BSC	3	0	2	4.0
2	UCH408	CHEMICAL ENGINEERING THERMODYNAMICS-II	PCC	3	1	0	3.5
3	UCH402	HEAT TRANSFER	PCC	3	1	2	4.5
4	UCH502	MASS TRANSFER-I	PCC	3	1	0	3.5
5	UCH409	PROCESS ENGINEERING SIMULATION SOFTWARES	PCC	2	0	2	3.0
6	UTA027	ARTIFICIAL INTELLIGENCE	ESC	3	0	2	4.0
7	UTA016	ENGINEERING DESIGN PROJECT – I	PRJ	1	0	2	3.0
8	UHU050	EVOLUTIONARY PSYCHOLOGY (1 Self Effort Hour)	HSS	1*	0	0	1.0
TOTAL				**18 + 1***	**3**	**10**	**26.5**

***** Alternate Week

Note: EL activity in the semester-IV will be carried out as per schedule.

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SEMESTER-V

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH501	CHEMICAL REACTION ENGINEERING-I	PCC	3	1	2	4.5
2	UCH401	FLUID AND PARTICLE MECHANICS	PCC	3	1	2	4.5
3	UCH506	PROCESS INSTRUMENTATION AND CONTROL	PCC	3	1	2	4.5
4	UCH405	ENERGY RESOURCES	PCC	3	1	2	4.5
5	UTA025	INNOVATION & ENTREPRENEURSHIP	HSS	1	0	2*	2.0
6		GENERIC ELECTIVE	OEC	2	0	0	2.0
TOTAL				**15**	**4**	**10**	**22.0**

Note: EL activity in the semester-V will be carried out as per schedule.

SEMESTER-VI

S. No.	Course Code	Course Name	CODE **	L	T	P	Cr
1	UCH601	CHEMICAL REACTION ENGINEERING-II	PCC	3	1	0	3.5
2	UCH602	MASS TRANSFER-II	PCC	3	1	2	4.5
3	UCH603	TRANSPORT PHENOMENA	PCC	3	1	0	3.5
4	UCH605	PROCESS UTILITY AND INDUSTRIAL SAFETY	PCC	3	1	0	3.5
5	UCH802	PROCESS MODELING AND SIMULATION	PCC	3	0	2	4.0
6	UCH612	PROCESS EQUIPMENT DESIGN PROJECT	PRJ	2	0	2	3.0
7	UCH893	CAPSTONE PROJECT (STARTS)	PRJ	0	0	2	–
TOTAL				**17**	**4**	**8**	**22.0**

SEMESTER-VII

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH796	PROJECT SEMESTER#	PRJ	-			15
TOTAL							**15**

#TO BE CARRIED OUT IN INDUSTRY/RESEARCH INSTITUTION

OR

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH797	PROJECT	PRJ	-			8.0
2		ELECTIVE-I	PEC	3	1	0	3.5
3		ELECTIVE-II	PEC	3	1	0	3.5
TOTAL				**6**	**2**	**0**	**15.0**

OR

S. No.	Course Code	Course Name	CODE **	L	T	P	Cr
1	UCH798	START- UP SEMESTER**	PRJ	-			15.0
		TOTAL					**15.0**

**BASED ON HANDS ON WORK ON INNOVATIONS AND ENTREPRENEURSHIP.

SEMESTER-VIII

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH804	CHEMICAL PROCESS OPTIMIZATION AND STATISTICAL ANALYSIS	BSC	3	1	0	3.5
2	UHU005	HUMANITIES FOR ENGINEERS	HSS	2	0	2	3.0
3	UCH801	PROCESS ENGINEERING AND PLANT DESIGN	PCC	3	1	0	3.5
4	UCH893	CAPSTONE PROJECT	PRJ	0	0	2	8.0
5		ELECTIVE-III***	PEC	3	0	0	3.0
6		ELECTIVE-IV***	PEC	3	0	0	3.0
TOTAL				**14**	**2**	**4**	**24.0**

***SELECTION OF SUBJECT FROM EACH ELECTIVE AS PER ELECTIVE FOCUS AREA (ENERGY/MATERIALS/PETROLEUM/CHEMICAL PROCESS ENGINEERING)

LIST OF PROFESSIONAL ELECTIVES (PEC)

ELECTIVE I

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH833	FLUIDIZATION ENGINEERING	PEC	3	1	0	3.5
2	UCH725	ADVANCED SEPARATION PROCESSES	PEC	3	1	0	3.5
3	UCH851	CORROSION ENGINEERING	PEC	3	1	0	3.5
4	UCH702	NANOMATERIALS FOR CHEMICAL ENGINEERS	PEC	3	1	0	3.5

ELECTIVE II

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH701	CATALYTIC PROCESSES	PEC	3	1	0	3.5
2	UCH716	FOOD ENGINERING AND SCIENCE	PEC	3	1	0	3.5
3	UCH834	PROCESS INTEGRATION	PEC	3	1	0	3.5
4	UCH726	BIOCHEMICAL ENGINEERING	PEC	3	1	0	3.5

ELECTIVE-III

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH852	BIOENERGY ENGINEERING (ENERGY ELECTIVE)	PEC	3	0	0	3.0
2	UCH853	FUEL CELL TECHNOLOGY (ENERGY ELECTIVE)	PEC	3	0	0	3.0
3	UCH854	POLYMER SCIENCE AND TECHNOLOGY (MATERIALS ELECTIVE)	PEC	3	0	0	3.0
4	UCH855	POLYMER BLENDS AND COMPOSITES (MATERIALS ELECTIVE)	PEC	3	0	0	3.0
5	UCH856	PETROLEUM DRILLING AND PRODUCTION ENGINEERING (PETROLEUM ELECTIVE)	PEC	3	0	0	3.0
6	UCH850	PETROLEUM AND PETROCHEMICALS (PETROLEUM ELECTIVE)	PEC	3	0	0	3.0
7	UCH805	CLEAN TECHNOLOGY IN PROCESS INDUSTRIES	PEC	3	0	0	3.0
8	UCH806	PROCESS INTENSIFICATION	PEC	3	0	0	3.0

ELECTIVE – IV

S. No.	Course Code	Course Name	CODE**	L	T	P	Cr
1	UCH861	MATERIALS AND DEVICES FOR ENERGY CONVERSION (ENERGY ELECTIVE)	PEC	3	0	0	3.0
2	UCH862	ENERGY MANAGEMENT (ENERGY ELECTIVE)	PEC	3	0	0	3.0
3	UCH863	POLYMER PROCESSING (MATERIALS ELECTIVE)	PEC	3	0	0	3.0
4	UCH864	STRUCTURAL MATERIALS (MATERIALS ELECTIVE)	PEC	3	0	0	3.0
5	UCH865	PETROLEUM RESERVOIR ENGINEERING AND FIELD DEVELOPMENT (PETROLEUM ELECTIVE)	PEC	3	0	0	3.0
6	UCH866	ENHANCED OIL RECOVERY TECHNIQUES (PETROLEUM ELECTIVE)	PEC	3	0	0	3.0
7	UCH811	FLUID MACHINERY	PEC	3	0	0	3.0
8	UCH849	SCALE-UP AND PILOT- PLANT METHODS IN CHEMICAL ENGINEERING	PEC	3	0	0	3.0

GENERIC ELECTIVE (GE)

S. No.	Course Code	Course Name	CODE**	L	T	P	CR
1	UHU016	INTRODUCTORY COURSE IN FRENCH	OTH	2	0	0	2.0
2	UHU017	INTRODUCTION TO COGNITIVE SCIENCE	OTH	2	0	0	2.0
3	UHU018	INTRODUCTION TO CORPORATE FINANCE	OTH	2	0	0	2.0
4	UCS002	INTRODUCTION TO CYBER SECURITY	OTH	2	0	0	2.0
5	UPH064	NANOSCIENCE AND NANOMATERIALS	OTH	2	0	0	2.0
6	UEN006	TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT	OTH	2	0	0	2.0
7	UMA069	GRAPH THEORY AND APPLICATIONS	OTH	2	0	0	2.0
8	UMA070	ADVANCED NUMERICAL METHODS	OTH	2	0	0	2.0
9	UBT510	BIOLOGY FOR ENGINEERS	OTH	2	0	0	2.0

List of EL Activities

Semester	EL Activity****
I	Hydro-distillation of biomass (rose pellets, raw turmeric, mint, etc.) to obtain essential oil. Production of edible oil from oil seeds (solvent extraction).
II	Production of liquid soap/detergent
III	Thermodynamics experiment to design experimental set-ups to study the P-V-T behaviour of air for: (i) Isobaric process (ii) Isothermal process (iii) Adiabatic Process
IV	Packed bed reactor design. Dissection of centrifugal pump. VLE data generation for acetone-water binary mixture.
V	Design and fabrication of double pipe /plate heat exchangers

****These EL activities can be changed in subsequent years, if required.

Table: Nature of course and code

Nature of the course	CODE**
Basic Science Courses	BSC
Engineering Science Courses	ESC
Humanities and Social Science Courses	HSS
Professional Core Courses	PCC
Professional Elective Courses	PEC
Open Elective Courses	OEC
Project	PRJ
Others	OTH

SEMESTER WISE CREDITS FOR B.E. (CHEMICAL ENGINEERING)

SEMESTER	CREDITS
FIRST	18.0
SECOND	18.0
THIRD	25.5
FOURTH	26.5
FIFTH	22.0
SIXTH	22.0
SEVENTH	15.0
EIGHTH	24.0
TOTAL CREDITS	**171.0**

Table: Total Credit Score for specific Nature of course/s

Nature of the course	CODE	Total Credits	Semester and Course Name
Basic Science Courses	BSC	23.0	Semester-I: Applied physics; Mathematics–I Semester-II: Applied chemistry; Mathematics–II Semester-IV: Numerical methods in chemical engineering Semester-VIII: Chemical process optimization and statistical analysis
Engineering Science Courses	ESC	26.0	Semester-I: Engineering drawing; Manufacturing processes Semester-II: Programming for problem solving; Electrical & Electronics engineering; Energy and environment Semester-III: Engineering materials Semester-IV: Artificial intelligence
Humanities and Social Science Courses	HSS	11.0	Semester-I: Professional communication Semester-III: Employability development skills Semester-IV: Evolutionary psychology Semester-V: Innovation & entrepreneurship Semester-VIII: Humanities for engineers
Professional Core Courses	PCC	74.0	Semester-III: Chemical Process Industries; Chemical Engineering Thermodynamics-I; Material and Energy Balances; Process Fluid Mechanics; Industrial Pollution Abatement Semester-IV: Chemical Engineering Thermodynamics-II; Heat Transfer; Mass Transfer-I; Process Engineering Simulation Softwares Semester-V: Chemical Reaction Engineering-I; Fluid and Particle Mechanics; Process Instrumentation and Control; Energy Resources Semester-VI: Chemical Reaction Engineering-II; Mass Transfer-II; Transport Phenomena; Process Utility and Industrial Safety; Process Modeling and Simulation Semester-VIII: Process Engineering and Plant Design
Open Elective Courses	OEC	15.0	Semester-V: Generic Elective Semester-VII: Elective-I; Elective-II Semester-VIII: Elective-III; Elective-IV
Project	PRJ	29.0	Semester-IV: Engineering Design Project – I Semester-VI: Process Equipment Design Project Semester-VII: Project Semester Semester-VIII: Capstone Project

SEMESTER-III

UES020: THERMO-FLUIDS

(*Only for IEP students*)

L	T	P	Cr
2	0	2*	3.0

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 tube, 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 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, Mollier diagram, 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, entropy and entropy change.

Laboratory work *(Lab to be conducted every alternate week)***:**

Verification of Bernoulli's theorem, Determination of hydrostatic force and its location on a vertically immersed surface, Determination of friction factor for pipes of different materials, Determination of loss coefficients for various pipe fittings, Verification of momentum equation, Visualization of laminar and turbulent flow, Calibration of Venturimeter and Rotameter.

Course Learning Outcomes (CLO):

Upon completion of the course, 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. estimate vapor-liquid properties and solve basic problems using steam tables, Mollier diagrams and equation of state
5. analyze and solve problems related to closed systems and steady-flow devices by applying the conservation of energy principle
6. 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 Quizzes/Lab/Assignments evaluations)	35

UCH404: CHEMICAL PROCESS INDUSTRIES

L	T	P	Cr
3	0	0	3.0

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 the course, 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. GopalRao 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 be Quizzes/Lab/Assignments evaluations)	20

UCH305: CHEMICAL ENGINEERING THERMODYNAMICS-I

L	T	P	Cr
3	1	0	3.5

Course Objective:
To understand the laws of thermodynamics, availability, the concept of entropy change, entropy generation and thermodynamic cycles as applied to a variety of engineering systems**.**

Introduction and Basic Concepts: Role of thermodynamics in engineering and science, Applications of Thermodynamics, Concept of Continuum, Macroscopic approach, Thermodynamics system and properties, Various processes, Thermodynamic equilibrium, Ideal gas, Vander Waals equation of state, Compressibility chart, Process: Flow and non-flow process, Cycle concept of work and heat, Specific heats, Zeroth law, Energy and its form, Pure substance, Thermodynamic diagrams, Triple point, Steam tables and their use.

First Law of Thermodynamics: Concept of internal energy & enthalpy, Energy equation as applied to a close and open system, PMMI, Transient flow processes.

Second Law of Thermodynamics & its Corollaries: Kelvin Plank and Clausius statements, Reversible and Irreversible processes, Carnot cycle, Clausius theorem and concept of entropy, Principle of increase of entropy, PMM2, Thermodynamic temperature scale, Second law analysis of control volume, Availability, Irreversibility, Availability function for open and closed system & second law efficiency.

Thermodynamic Cycles: Rankine cycle, Air standard cycles: Otto, Diesel, Dual and Brayton cycles.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. estimate properties of pure substance using steam tables, property diagrams and equation of states.
2. analyze and solve problems involving closed system and open systems for both steady state and transient processes.
3. analyze the second law of thermodynamics for various systems and to evaluate the performance of heat engines, refrigerators and heat pumps.
4. analyze the performance of various power cycles and to identify methods for improving thermodynamic performance.

Text Books:

1. *Rao, Y.V.C., Thermodynamics, Universities Press (2004).*
2. *Smith J. M. and Van Ness H. C., Chemical Engineering Thermodynamics, Tata McGraw-Hill (2007).*

3. *Nag, P.K., Engineering Thermodynamics, Tata McGraw Hill (2008) 3rd ed.*

Reference Books:

1. *Cengel, Y. A. and Boles, M., Thermodynamics: An Engineering Approach, Tata McGraw Hill (2008).*
2. *Sonntag, R.E., Borgnakke, C. and Van Wylen, G.J., Fundamentals of Thermodynamics, John Wiley (2007) 6th ed.*
3. *Rogers, G. and Mayhew, Y., Engineering Thermodynamics, Pearson Education (2007) 4th ed.*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may include Quizzes/Assignments evaluations)	25

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 the course, 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 include tutorials/quizzes/ assignments/project evaluations)	25

UCH302: PROCESS FLUID MECHANICS

L	T	P	Cr
3	1	2	4.5

Course Objective:
To introduce the principles of fluid mechanics and illustrate their applications in the pipe networking, fluid machinery and various flow measuring devices.

Introduction: Definition of a fluid and its properties; Classification of fluids

Hydrostatics: Measurement of pressure: Manometers; Thrust on submerged surfaces

Fluid flow phenomena: Description of fluid flow; Velocity and acceleration of a fluid particle; Continuity equation; Circulation, potential function and stream function; Energy equation: Euler and Bernoulli equations; Navier-Stokes equation; Flow measuring devices: Pitot tube, Orifice meter, Venturimeter, Rotameter; Momentum equation and its applications.

Flow through Pipe: Fully developed flow; Laminar pipe flow: Hagen-Poiseuille law; Introduction to turbulent pipe flow; Major and minor energy losses, Pipe networks: Pipes in series and parallel, Concept of equivalent pipe.

Pumps and Compressors: Types, Working principles, Basic equations, characteristic curve, Net positive suction head (NPSH), Cavitation, Priming.

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

Dimensional analysis: Methods of dimensional analysis

Laboratory work:
Verification of Bernoulli's theorem, Calibration of Venturimeter, Calibration of orifice meter, Rheology of non-Newtonian fluids, Determination of friction factor for pipes of different materials, Determination of hydraulic coefficients of an orifice, Verification of momentum equation, Determination of loss coefficients for various types of pipe fittings, Calibration of rotameter, Visualization of laminar and turbulent flow.

Course Learning Outcomes (CLO)
Upon completion of the course, students will be able to:

1. capability to analyze and solve problems of 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. analyze and solve the problems related to compressible fluids, and fluid machinery.

Text Books

1. *McCabe, W., Smith, J. and Harriot, P., Unit Operations of Chemical Engineering, McGraw-Hill (2005) 7th ed.*

Reference Books

1. *Fox, R.W., McDonald, A.T, and Pritchard, P.J., Introduction to Fluid Mechanics, John Wiley (2008) 6th ed.*
2. *Wilkes, J.O., Fluid Mechanics for Chemical Engineers with Microfluidics and CFD, Prentice Hall of India (2005)2nd ed.*
3. *Denn, M., Process Fluid Mechanics, Prentice Hall (1979).*
4. Cengel Y., Cimbala J., Fluid Mechanics: Fundamentals and Applications, *McGraw-Hill (2005) 4th ed.*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	45
3.	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

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 the course, students will be able to:

1. quantify and analyze the pollution load.
2. analyze/design of suitable treatment for wastewater
3. model the atmospheric dispersion of air pollutants.
4. Selection and design of air pollution control devices.
5. analyze the characteristics of solid waste and its handling & management.

Text Books:

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

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

Reference Books:

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

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

SEMESTER-IV

UCH410: NUMERICAL METHODS IN CHEMICAL ENGINEERING

(For Chemical Engineering Students only)

L	T	P	Cr
3	0	2	4.0

Course Objective:
The main objective of this course is to motivate the students to understand and learn various numerical techniques to solve chemical engineering problems.

Linear Algebraic Equations: Introduction, Tridiagonal matrix algorithm, Gauss elimination method, Gauss-Seidel method.

Nonlinear Algebraic Equations: Fixed-point iteration, Newton's methods and their convergence analysis, Newton-Raphson technique, System of nonlinear equations, Solution of cubic equations of state (EoS), Vapour pressure calculation using cubic equations of state, Pressure drop in pipe, minimum fluidization velocity, Terminal velocity.

Ordinary Differential Equations (Initial value and boundary value problems): Solution of single ordinary differential equation using Picard, Taylor series, Predictor-corrector techniques and Runge-Kutta methods, Solution of simultaneous ordinary differential equation, The finite difference technique, Orthogonal collocation, Discretization in one-dimensional space, Double pipe heat exchanger, One-dimensional steady heat conduction, Convection-diffusion problems for the transport of a component.

Partial differential equations: Classification of partial differential equation,The finite difference technique (method of lines), Explicit and implicit discretization, Crank-Nicolson discretization, Von Neumann stability analysis, Transient heat conduction in rectangular, cylindrical and spherical geometry, Transient diffusion in sphere, Discretization in two-dimensional space, Relaxation parameter, Red-Black Gauss-Seidel method, Two-dimensional steady and transient heat conduction.

Course learning outcomes (CLOs):
Upon completion of the course, students will be able to:

1. solve linear and nonlinear algebraic equations encountered in various chemical engineering problems.
2. learn how to solve ordinary differential equations encountered in one-dimensional steady heat conduction and convection-diffusion problems of the transport.
3. solve partial differential equations numerically and using different techniques, and solve the chemical engineering problems on transient heat conduction in different geometries and diffusion-based problems.

Text Books:

1. Ahuja. P., Introduction to Numerical Methods in Chemical Engineering, Prentice Hall India Pvt., Limited, New Delhi (2020), 6thedition.

2. Gupta S.K., Numerical Methods for Engineers, New Age International Publisher; (1995) 3rd edition.

Reference Books:

1. Mathew H. J., Numerical Methods for Mathematics, Science and Engineering, Prentice Hall, (1992) 2nd edition.
2. Burden L. R. and Faires D. J. Numerical Analysis, Brooks Cole (2011), 9thedition.
3. Atkinson K. and Han H., Elementary Numerical Analysis, John Willey & Sons (2004), 3rd edition.
4. Gerald F. C. and Wheatley O. P., Applied Numerical Analysis, Pearson, (2003) 7thEdition, 2. Jain K. M., Iyengar K. R. S. and Jain K. R., Numerical Methods for Scientific and Engineering Computation, New Age International Publishers (2012), 6thedition.
5. Steven C. Chappra, Numerical Methods for Engineers, McGraw-Hill Higher Education; 7th edition (1 March 2014)

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	45
3.	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

UCH408: CHEMICAL ENGINEERING THERMODYNAMICS-II

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 (CLOs):
Upon completion of the course, 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. estimate thermodynamic parameters for solutions, vapor-liquid equilibria and chemical reaction equilibria.
4. determine efficiency/coefficient of performance of thermodynamic cycles.

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 include Quizzes/Assignments/Tutorials evaluations)	25

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 optimumthickness, 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 □ -NTU methods, Heat exchangers: Double pipe, shell and tube, air-cooled, plate type, Fouling, Concept of pinch technology and its application.

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

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 the course, students will be able to:

1. solve conduction, convection and radiation problems
2. design and analyse the performance of heat exchangers
3. analyse the steam economy and performance of evaporators

***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).*

Approved in 109th meeting of the Senate held on March 16, 2023

3. *Sinnott Ray and Towler Gavin, Coulson and Richardson's Chemical Engineering series Chemical Engineering Design Volume 6, 5th edition (2013).*

***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	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

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 state molecular 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. Packed towers and column internals, Types of packing, general pressure drop correlation, Column diameter and height.

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, and Different type of dryer.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:
1. solve problems related to diffusion and interphase mass transfer and mass transfer equipment
2. perform design calculation related to absorption.
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, 3 rd Ed. (1993).*
3. *Bhattacharyya, B.C., Introduction to Chemical Equipment Design, Mechanical Aspects, CBS Publishers and Distributors (2009).*

***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)*
5. *Mahajani, V.V. and Umarji, S.B., Joshi's Process Equipment Design, 4th edition, Macmillan Publishers India Limited, New Delhi (2010).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials evaluations)	25

UCH409: PROCESS ENGINEERING SIMULATION SOFTWARES

L	T	P	Cr
2	0	2	3.0

Course Objective:
To impart the basic knowledge and handling of the software used in simulation, design, and optimization of a chemical process plant. It includes the software related to the material and energy balancing, equipment sizing, and costing calculation and core activities in process engineering.

Introduction: The role of process Modeling, simulation, and optimization in the chemical and process industries. Idea about general software tool such as Excel, MATLAB, etc. for chemical engineers.

Excel for Chemical Engineering: Basic Spreadsheet Skills, Configuring Excel for engineering calculations, Efficient spreadsheet manipulations, Formulas, cell addressing and range names, creating engineering graphs, dealing with engineering formulas and units, debugging spreadsheet calculations, Process Calculations, Flowsheet calculations with recycle, targeting calculations, etc. Case studies related to fluid mechanics, heat transfer and unit operation problems using excel such as piping design, pump design, cooling tower, etc.

MATLAB and Simulink for Chemical Engineering: Basic commands and functions, Numerical methods with MATLAB, fitting and plotting, etc. Case studies related to reaction engineering, process control, fluid mechanics, heat and mass transfer such as calculation of distillation column operation (McCabe Method), reactor design, control loop, etc.

CFD and Multiphysics Modeling and simulation: Introduction to CFD, and CFD software introduction to ANSYS Fluent and COMSOL Multiphysics, problem definition, geometry creation mesh generation and mash optimization, data input, physics selection, simulation, post-processing of the results and analysis. Case studies related to fluid mechanics, heat transfer, mass transfer, reactor design and dynamics such as pipe flow, heat exchanger, PFR, CSTR, etc.

Course learning outcomes (CLOs):
Upon completion of this course, the student will able to:

1. solve the chemical engineering problems in Excel.
2. simulate the chemical engineering problems in MATLAB.
3. simulate the chemical engineering problems in ASPEN PLUS.
4. perform the CFD simulation in ANSYS Fluent and COMSOL Multiphysics.

Text Books:

1. *Martín M.M., Introduction to Software for Chemical Engineers, CRC press, 2nd ed., 2020.*
2. *Yeo Y.K., Chemical Engineering Computation with MATLAB, CRC press, 2020.*
3. *Al-Malah K.I.M., ASPEN PLUS® Chemical Engineering Applications, Wiley, 2017.*
4. *Chaurasia A.S., Computational Fluid Dynamics and COSMOL Multiphysics - A Step-By-Step Approach for Chemical Engineers, 1st ed. CRC press, 2022.*

Reference Books:

1. *MATLAB manual.*
2. *ASPEN PLUS manual.*
3. *ANSYS Fluent manual.*
4. *COMSOL Multiphysics manual.*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	45
3.	Sessional (may include Quizzes/Assignments/Lab evaluations)	30

SEMESTER-V

UCH501: CHEMICAL REACTION ENGINEERING-I

L	T	P	Cr
3	1	2	4.5

Course Objective:
To understand the kinetics of homogeneous 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 the course, students will be able to:

1. analyze reactor by integral and differential methods.
2. design ideal reactors for homogeneous single and multiple reactions.
3. select the appropriate type reactor/scheme.
4. Analyse the effect of temperature on reactions.

***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 include Quizzes/Assignments/Tutorials/Lab evaluations)	40

UCH401: FLUID AND PARTICLE MECHANICS

L	T	P	Cr
3	1	2	4.5

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

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

Size Reduction: Principles of crushing and grinding; 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, Applications of fluidized Bed

Agitation and Mixing of Liquids and Solids: Types of impellers, Power consumption, mixing times, Scale up, mixing of solids and power index.

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 (CLOs):
Upon completion of the course, 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 and solve problems related to flow through beds of solids.
4. analyze mixing process, and solid storage in hoppers/bins.

Text Books:

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

Reference Books:

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

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

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 the course, 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).*
3. *Kravaris, C. and Kookos, I.K. Understanding Process Dynamics and Control, Cambridge university press (2021).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

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 the course, 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	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

SEMESTER-VI

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 the course, 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	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

UCH602: MASS TRANSFER-II

L	T	P	Cr
3	1	2	4.5

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 the course, students will be able to:

1. apply 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. Sinnott Ray and Towler Gavin, Coulson and Richardson's Chemical Engineering series Chemical Engineering Design Volume 6, 5th edition (2013).

Reference Books:

1. Sieder J.D., Ernest J.Henley. Separation Process Principles (2011).
2. Skelland, A.H.P., Diffusional Mass Transfer, John Wiley & Sons (1985).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	25
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials/Lab evaluations)	30

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 the course, 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 include Quizzes/Assignments/Tutorials evaluations)	25

UCH605: PROCESS UTILITY 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: Introduction to hazards, Hazards due to fire, explosions, toxicity and radiations, General principles of industrial safety, Industrial hygiene, Maximum allowable concentration and threshold limit value, Protective and preventive measures in hazards control, Hazards identifications and HAZOP studies, Risk assessment methods, Introduction to industrial safety regulations.

Course Learning Outcomes (CLO):
Upon completion of the course, 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. identify and analyse various risks in the process industries.
4. evaluate and apply the various risk assessment methods in industries.

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 include Quizzes/Assignments/Tutorials/ evaluations)	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 for flow sheet simulation.

ASPEN PLUS for Chemical Engineering: Introduction to ASPEN PLUS, Dashboard, placing a block and material stream from model palette, problem description, data input, running the simulation, convergence, adding steam table and property set, adding stream conditions, optimization and report generation, etc.

Laboratory work:
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 the course, 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).*
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 include Quizzes/Assignments/Lab evaluations)	35

UCH612: PROCESS EQUIPMENT DESIGN PROJECT

L	T	P	Cr
2	0	2	3.0

Course Objective:
The project will introduce students to the challenges of process equipment design. The design will require teamwork as a coordinated effort.

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.

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.

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

Centrifugal Pump: Performance curves, Pump Sizing, Pump design parameters, Impeller and Shaft design, blade angle, Drive (Motor) requirements, Design of Inlet and outlet connections, Material of construction, liquid sealing, Pump maintenance, and troubleshooting.

Mass Transfer Equipment: Process design calculations for multi-component distillation, Fenske-Underwood-Gilliland Method**,** 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.

The above design will also be performed by using the CAD/CAM software.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

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

PROJECT/LABORATORY WORK:

Design of Pumps, Heat Transfer Equipment, Pressure Vessels, and 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).*
4. *1Sulzer Pumps, Centrifugal Pump Handbook, Butterworth Heinemamm (2010).*
5. *Lobanoff, V. S. and Ross, R. R., Centrifugal Pumps Design and Application, Butterworth Heinemamm (1992)*

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).*

SEMESTER-VII
(Project Semester)

SEMESTER-VIII

UCH804: CHEMICAL PROCESS OPTIMIZATION AND STATISTICAL ANALYSIS

L	T	P	Cr
3	1	0	3.5

Course Objective:
To provide the skills for solving several types of optimization problems in process systems engineering.

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.

Random Variables: Definition, Probability distribution, Distribution functions, Pdf and Cdf, Expectation and Variance.

Special Probability Distributions: Binomial, Poisson, Geometric, Uniform, Normal and Exponential distributions.

Sampling Distributions: Population and samples, Concept of sampling distributions, sampling distribution of mean, Chi-square, t and F distributions (pdf only).

Curve Fitting: Various methods of curve fitting, Regression and Correlation (Two variables only).

Optimization of single variable: Direct search methods, bracketing methods, Region elimination methods, Gradient-based methods, Root-finding using optimization techniques.

Optimization of multivariable: Optimality criteria, Unidirectional search, Direct search Methods. Gradient-based methods- Cauchy's (steepest descent) method, Newton's method.

Constrained Optimization Algorithms: Kuhn-Tucker conditions, Method of multipliers, Sensitivity analysis, Successive linear and quadratic programming, Optimization of staged and discrete processes.

Application of the above optimization techniques to chemical engineering processes: Reactors, heat exchanger design, separation processes, fluid flow systems.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. apply probability and sampling distribution techniques to solve engineering problems.
2. solve problems related to curve fitting.
3. formulate the objective functions for constrained and unconstrained optimization problems.
4. use different optimization strategies.
5. use of different optimization techniques for chemical process design.

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).*
3. *Gupta, S.C and Kapoor, V.K. Fundamentals of Mathematical Statistics, Sultan Chand & Sons(2002).*

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. *Box, G. E. P., Hunter, W. G., Hunter, J. S., Statistics for Experimenters – A n Introduction to Design, Data Analysis, and Model Building, John Wiley (1978).*
4. *Nguyen, H.T. and Roger, G.S., Fundamentals of mathematical statistics: Probability for statistics, Springer-Verlag New York (1989).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials evaluations)	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.

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), integral, and linear programming algorithms.

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 the course, 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 time value and profitability of investments.
4. perform breakeven analysis and optimum design of a process.

Text Book:

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 include Quizzes/Assignments/Tutorials evaluations)	25

UCH893: CAPSTONE PROJECT

L	T	P	Cr
1*	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/plantsystems 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):
Upon completion of the course, 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

ELECTIVE-I

UCH833: 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 (CLOs):
Upon completion of the course, 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 include Quizzes/Assignments/Tutorials evaluations)	25

UCH725: ADVANCED SEPARATION PROCESSES

L	T	P	Cr
3	1	0	3.5

Course Objective:
To understand the underlying principles and Modeling 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 Fluid Extraction: Concept, Modeling and design aspects and applications.

Biofiltration: Concept, Modeling and design aspects and applications.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. develop models and the solutions for adsorptive separation processes.
2. characterize the membrane.
3. use the concepts of membrane separation techniques for industrial separations.
4. solve problems involving separation based on liquid membrane.
5. solve problems using 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 include Quizzes/Assignments/Tutorials evaluations)	25

UCH851: 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):
Upon completion of the course, 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	45
3	Sessional (may include Quizzes/Assignments/Tutorials evaluations)	25

UCH702: NANOMATERIALS FOR CHEMICAL ENGINEERS

L	T	P	Cr
3	1	0	3.5

Course Objective:
To learn about various kinds of nanomaterials, their properties, synthesis routes, and applications in chemical engineering and allied fields.

Introduction: History of nano-revolution and lessons from nature, definition, classification, synthetic routes and general applications.

Colloids and Colloidal Structure: Van der Waals interaction, effect of particle geometry, surface charge, zeta potential and electro static stabilization, Solid-vapor interface, Surface defects and crystal defects, Effect of surface curvature and solid-liquid interface.

Zero Dimensional Nanostructure: 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.

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

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

Two-and Three-Dimensional Nanostructures: Various thin film deposition techniques: atomic layer deposition, layer-by-layer deposition, multilayer techniques, mechanisms of nanocomposite coating, examples of size effects of properties observed in thin films, three-dimensional nanostructures and applications.

Characterization of Nanomaterials: Spectroscopy and microscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM).

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. apply basic concepts of colloids, colloidal structures to the chemical engineering applications.
2. select suitable synthesis routes for nanomaterials and its applications.
3. select suitable characterization techniques for various types of nanomaterials.

Text Books:

1. *Dinesh C. Agrawal, Introduction to Nanoscience and Nanomaterials, World Scientific Publishing (2013).*
2. *Zikang, T. and Ping, S.,Nanoscience and Technology: Novel Structures and Phenomena, Taylor and Francis (2003).*

3. *Kelsall, R., Hamley, I., and Geoghegan, M., Nanoscale Science and Technology, Wiley (2005).*

Reference Books:

1. Guo Zhong Cao, Nanostructures & Nanomaterials, synthesis, properties & applications, Imperial College Press (2008).

2. Rieth, M., Nano-Engineering in Science and Technology: An Introduction to the World of Nano design, World Scientific (2003).

3. Meyyappan, M., Carbon Nanotubes, Science and application; CRC Press (2005).

4. Watarai, H., Teramae, N., and Sawada, T., Interfacial Nano-chemistry, Kluwer Academic/Plenum Press (2005).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may include Quizzes/Assignments/Tutorials evaluations)	25

ELECTIVE-II

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, Nonisothermal 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 the course, students will be able to:

1. identify mechanism for various catalytic reactions.
2. select suitable characterization technique for different catalysts.
3. solve problems related to 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 include Quizzes/Assignments/Tutorials evaluations)	25

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, HACCP method

Course Learning Outcomes (CLOs):

Upon completion of the course, 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-organisms and calculate spoilage probability
4. evaluate effect of food processing and packaging/storage on its quality

***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 include Quizzes/Assignments/Tutorials evaluation)	20

UCH834: PROCESS INTEGRATION

L	T	P	Cr
3	1	0	3.5

Course Objective:
To achieve the mass and energy economy in process industries using different process integration techniques.

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 the course, students will be able to:

1. perform the pinch analysis.
2. analyze and design heat exchanger networks.
3. solve the problems related to distillation sequences.
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	50
3	Sessional (may include Quizzes/Assignments/Tutorials evaluations)	20

UCH726: BIO-CHEMICAL ENGINEERING

L	T	P	Cr
3	1	0	3.5

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.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

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

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	30
2	EST	50
3	Sessional (may include Quizzes/Assignments/Tutorials evaluations)	20

ELECTIVE-III (Elective Focus Energy/Materials/Petroleum/Chemical Process Engineering)

UCH852: BIOENERGY ENGINEERING

(Energy Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
To understand the fundamentals of energy conversion mechanisms in biomass and biogas.

Sources of Bioenergy and Classification. Chemical composition and properties of biomass. Energy plantations. Size reduction, Briquetting, Drying, Storage and handling of biomass.

Feedstock for biogas, Microbial and biochemical aspects- operating parameters for biogas production. Kinetics and mechanism- High rate digesters for industrial waste water treatment.

Thermochemical conversion of lignocelluloses biomass. Incineration, Processing for liquid fuel production. Pyrolysis -Effect of particle size, temperature, and products obtained.

Thermochemical Principles: Effect of pressure, temperature, steam and oxygen. Fixed and fluidized bed Gasifiers- Partial gasification of biomass.

Combustion of woody biomass and rice husk. Cogeneration using bagasse.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. identify the sources of bioenergy and their classification.
2. identify and understand the various processes for bioenergy production.
3. identify the thermochemical principles involved in gasification of biomass.

Text Books:

1. *Chakraverthy A., "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing Co, (1989).*
2. *Mital K.M., "Biogas Systems: Principles and Applications", New Age International publishers (P) Ltd., (1996).*
3. *Nijaguna, B.T., Biogas Technology, New Age International publishers (P) Ltd., (2002).*

Reference Books:

1. *VenkataRamana P and Srinivas S.N., "Biomass Energy Systems", Tata Energy Research Institute, (1996).*
2. *Rezaiyan, J. and Cheremisinoff, N. P., "Gasification Technologies, A Primer for Engineers and Scientists", Taylor & Francis, (2005).*
3. *Khandelwal. K. C. and Mahdi S. S, "Bio-Gas Technology", Tata McGraw-Hill Pub. Co. Ltd, (1986).*

4. *D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, (2003).*

Evaluation Scheme:

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

UCH853: FUEL CELL TECHNOLOGY

(Energy Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
To understand the fundamentals of fuel cell system design and applications.

Overview of Fuel Cells: Low and high temperature fuel cells; Fuel cell thermodynamics - heat, work potentials, prediction of reversible voltage, fuel cell efficiency.

Fuel Cell Reaction Kinetics: Electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electro-catalyses - design, activation kinetics, Fuel cell charge and mass transport - flow field, transport in electrode and electrolyte.

Fuel Cell Characterization: In-situ and ex-situ characterization techniques, i-V curve, frequency response analyses.

Fuel Cell Modeling and System Integration: 1D model - analytical solution and CFD models.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. solve the energy conservation equations and estimate the fuel cell efficiency.
2. solve the electrochemical kinetics of fuel cell.
3. identify the techniques for fuel cell characterization.
4. develop the analytical & CFD models of fuel cells.

Text Books:

1. *Fuel Cell System, edited by Leo J.M.J. Blomen and Michael N. Mugerwa, New York, Plenum Press, (1993).*
2. *Basu, S., Fuel Cell Science and Technology, Springer, New York, (2007).*

Reference Books:

1. *Fuel Cell Handbook, by A. J. Appleby and F. R. Foulkers, Van Nostrand, (1989).*
2. *O'Hayre, R.P., S. Cha, W. Colella, F.B. Prinz, Fuel Cell Fundamentals, Wiley, New York, (2006).*
3. *Bard, A. J., L. R., Faulkner, Electrochemical Methods, Wiley, New York, (2004).*
4. *Liu, H., Principles of fuel cells, Taylor & Francis, New York, (2006).*

Evaluation Scheme:

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

UCH854: POLYMER SCIENCE AND TECHNOLOGY
(Materials Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
To provide fundamental and applied knowledge of polymers including their synthesis, processing, characterization and manufacturing.

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

Polymerization Techniques: 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, Polymer characterisation techniques: Nuclear Magnetic Resonance (NMR), Fourier Transform Infrared (FTIR) techniques, Differential Scanning Calorimetry (DSC), Gel Permeation Chromatography (GPC), Mechanical and thermal analysis, X-ray Diffraction (XRD).

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

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

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

Manufacturing: 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 the course, students will be able to:

1. identify the synthesis technique for different polymers.
2. analyze the various polymer characteristics on the basis of their thermal transitions and molecular weight.
3. analyze the various polymer processing techniques and polymer manufacturing.
4. apply the polymer concepts to polymer blends, composites and nano-composites.

***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 include Quizzes/Assignments evaluation)	20

UCH855: POLYMER BLENDS AND COMPOSITES

(Materials Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective: To study the processing and properties of thermoplastic and thermoset blends and composites.

Introduction: Blends; Composites; Material property envelope; Different types of reinforcements; Fibres; Matrices; Interface; Compatiblizers; Polymer processing.

Fibre Architecture: Reinforcement geometry; Fibre volume fraction and voids; Packing arrangement; Orientation of reinforcement.

Reinforcement Processes: Load sharing; Elastic stress transfer (Cox shear-lag theory); Stress transfer by slip; Effect of aspect ratio; Deformation in long fibre composites (axial and transverse).

Interfacial Effects: Enhancing the compatibility between fibre and matrix interface; Measuring interfacial properties.

Elastic Deformation of Laminates: Axial and transverse stiffness of unidirectional laminae; Off-axis loading and interaction effects; Multi-ply laminates.

Mechanical Properties: Inelastic processes; Predicting the strength of composites; Structure-processing-property correlations, Toughness.

Manufacturing: Manufacturing methods for thermoset and thermoplastic matrix composites.

Course learning outcomes (CLO)

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

1. correlate fibre architecture and reinforcement properties.
2. identify compatibilizers for polymer blends for improving interfacial properties.
3. calculate the elastic and inelastic properties of laminates and composites.
4. select manufacturing methods for thermoset and thermoplastic matrix composites.

Text Book

1. *D. Hull, T.W. Clyne, "An Introduction to Composite Materials", Cambridge University Press.*

Reference Books

1. *M.R. Piggott, "Load Bearing Fibre Composites", Pergamon.*
2. *T.A. Osswald, "Polymer Processing Fundamentals", Hanser.*

Evaluation Scheme:

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

UCH856: PETROLEUM DRILLING AND PRODUCTION ENGINEERING

(Petroleum Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective: To impart knowledge of oil well drilling and its production.

OIL & GAS WELL DRILLING

Well Planning: Drilling planning approaches, Evaluation of pore & fracture pressure, Casing seat selection.

Rotary Drilling Method: Rig parts, selection and general layout. Advancements in Rig Equipment: Top drive & Bottom drive systems.

Drilling Operations & Practices: Hoisting, Circulation, Rotation, power plants and Power transmission.

Drilling Fluids: Types, function, properties, equipments & Design.

Cementing: Methods, Tools & Techniques, cementing calculations, Special Cement System.

Wire Lines: Types & Classification, service life evaluation & precautions in handling.

Drill Bits: Types and Application, selection, design & performance.

Drill String & Casing String: Parts, function & operations. Selection/ Design.

Drilling Problems, their control & Remedies: Pipe sticking, Sloughing Shales, Lost Circulation, Blow Outs.

Oil Well Fishing: Fish classification, tools and techniques.

OIL & GAS PRODUCTION

Well equipment: Well head assembly, Christmas tree, valves, hangers, flow control devices, packers, tubular and flow lines, safety & control systems.

Well completion: Systems, types and applications.

Well perforation & Well activation

Processing in oil fields: GGS/CTF - layout, sequential treatment, separation, storage and transportation of petroleum. Demulsification& desalting.

Introduction to well servicing and stimulation system: objectives and applications.

Course Learning Outcomes (CLO):

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

1. explain the basic procedures and role of all fundamental systems used in petroleum drilling.

2. explain basic concepts and methods of oil & gas production and technologies for its recovery.
3. analyze the key issues in the design and optimization of petroleum production systems.

Text Books:

1. *Drilling Engineering: A Complete Well Planning Approach by Neal J. Adams, Penn Well Publishing Company, Thlsa, Oklahoma, 1985.*

***Reference Books*:**

1. *Petroleum Engineering: Drilling and well completion by Carl Gatlin, Englewood Cliffs NJ, Prentice Hall Inc., 1960.*
2. *Applied Drilling Engineering by Bourgoyne A. D., Chenevert M. E., Millhelm K. K., Young Jr. F.S., Society of Petroleum Engineers, 1991.*

Evaluation Scheme:

S. No.	Evaluation elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may include Quizzes/Assignments evaluation)	20

UCH850 PETROLEUM AND PETROCHEMICALS

(Petroleum Elective)

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 pre-treatment 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, Vis-breaking, 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 the course, students will be able to:

1. select the appropriate characterization parameters of petroleum fractions.
2. differentiate the various petroleum fractions and the subsequent conversion and finishing technology including manufacture of lube oil.
3. compare the different processes for the production of petrochemicals and their subsequent conversion to polymers.

***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, Macmillan 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 include Quizzes/Assignments evaluation)	20

UCH805: Clean Technologies in Process Industries
(Chemical Process Engineering Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
Impart knowledge about the various aspect of clean technologies including production and sustainable development in process industries.

Introduction to Clean Technology (CT), Technology adoption for Clean Production (CP)

Cleaner Production: The basis, necessity and potential, C.P. tools, techniques, methodology and applications, Overview of Good House Keeping, Process Modification/Changes, Process Technology Innovations, Equipment Modification, Reuse and Recycle.

Principles and Concepts of Green Chemistry, Thermodynamics and Reaction Engineering for C.P., Role of Environmental Biotechnology in C.P.

Environmental Aspects: Use of clean fuels inclusive of H_2 as a clean fuel of tomorrow, Power Plants, C.P. & C.T. as Remedial Measures for Mitigating Climate Change, Ozone layer depletion and current practices to avoid depletion.

Sustainable Development: Understand the Sustainable Development, three principal dimensions: the ecological, use a systems perspective, to describe sustainability challenges and possibilities for major technical systems and for their transformation to meet sustainability requirements. Resource recovery/by-product recovery**,** Industrial waste minimization and Waste Minimization Circles, Hazard Prevention by C.P. Technology Alternatives, Designing Cleaner Production – Green Processes, Cleaner Production and Cleaner Technology implementation

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:
1. apply the clean technology tools and techniques for cleaner production.
2. aquire expertise in technology of manufacture of petroleum fractions and lube oil.
3. select an appropriate conversion and finishing technology.
4. analyse the processes and systems for transformation in a sustainable manner.

***Text Books*:**
1. *Green Chemistry : Environmentally Benign Reactions V. K. Ahluwalia, ANE Books (2009).*
2. *Chemical Process Safety: Learning from case Histories R. E. Sanders, Oxford, Gulf Professional Publishing (2011).*

***Reference Books*:**
1. *Cleaner Production: Training Resource Package, UNEP IE, Paris, (1996)*

2. *Engineers Guide to Cleaner Production Technologies Paul M. Randall, Technomic (1996)*

Evaluation Scheme:

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

UCH806: PROCESS INTENSIFICATION

(Chemical Process Engineering Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:

To provide understanding about the basic concepts of process intensification and its implementation using Cavitation, Monolith Reactor, Distillation and Extraction**.**

Introduction on Process Intensification: History, Philosophy and Concept, Principal Features, Strategies and domain-based techniques

Mechanism Involved in the Process Intensification: Intensification by fluid flow process, Mechanism of Intensification by mixing, Intensification in Reactive system

Role of Process Intensification in Sustainable Development: Problems leading to sustainable development, Concept, Issues and Challenges, Strategies in process design

Design Techniques for Process Intensifications: Scales and stages of process intensification, Methods and Tools for Achieving sustainable design, Multi-level Computer aided tools

Stochastic Optimization for Process Intensification: Introduction on Stochastic Optimization, Optimization Algorithms, Applications of Optimization Algorithms

Process Intensification by Cavitation: Introduction and Mechanism of Cavitation-based Process Intensification, Cavitational Reactor Configurations and activity, Parametric effects on cavitation

Process Intensification by Monolith Reactor: Introduction of monolith reactor, Preparation of monolithic catalyst, Application of monolithic catalyst, Hydrodynamics, transport of monolithic reactor

Interfacial area-based Process Intensification: Overview of interfacial area-based processes, Ejector induced downflow system for Process Intensification, Hydrodynamics and transport in downflow system

Process Intensification in Distillation: Introduction and Principles, Types of Intensified Distillation Units, Design of membrane-assisted distillation

Process Intensification in Extraction: Introduction and Principles, Supercritical extraction for process intensification

Process Intensification by Membrane: Introduction to membrane and its principles, Membrane engineering in process intensification

Micro Process Technology in Process Intensification: Introduction to microprocess technology, Process Intensification by Microreactors, Hydrodynamics and transport in microchannel based microreactor

Course Learning Outcomes (CLO):

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

1. analyse the mechanism and role of process intensification for sustainability
2. apply monolith reactor for process intensification
3. analyse and design the intensified distillation unit and membrane-assisted distillation.
4. apply the microreactors for the process intensification

***Text Books*:**

1. *Dandira-Chibaya Sostina Varaidzo, Design of a Cleaner Production Framework to Enhance Productivity", LAP Lambert Academic Publishing, India (2013)*
2. *Francisco José Gomes da Silva, Ronny Miguel Gouveia, Cleaner Production: Toward a better Future, 1 st Edition, Springer Cham, Switzerland (2020)*

***Reference Book*:**

1. *Francisco José Gomes da Silva, Ronny Miguel Gouveia, Cleaner Production, 1 st Edition, Springer, Germany* (2019)

Evaluation Scheme:

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

ELECTIVE-IV
(Elective Focus Energy/Materials/Petroleum/Chemical Process Engineering)

UCH861: MATERIALS AND DEVICES FOR ENERGY CONVERSION

(Energy Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:

To understand the fundamentals and scope of available materials and device fabrication techniques in energy applications.

Physics of Semiconductor Devices: Basics of solar cells High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III-V, II-VI thin-film solar cells, Nano-, micro- and poly-crystalline Si for solar cells, mono-micro silicon composite structure, crystalline silicon deposition techniques, material and solar cell characterization, advanced solar cell concepts and technologies (Porous Si layer transfer, Metal induced crystallization, etc.). Amorphous silicon thin-film (and/or flexible) technologies, multi-junction (tandem) solar cells, stacked solar cells. Conjugated polymers, organic/plastic/flexible solar cells, polymer composites for solar cells, device fabrication and characterization.

Characterization of Solar Cells: Spectral response of solar cells, quantum efficiency analysis, dark conductivity, I-V characterization.

Device fabrication technologies: diffusion, oxidation, photolithography, sputtering, physical vapor deposition, chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), hot wire CVD (HWCVD), etc.

Materials and devices for energy storage: Batteries, CNTs for hydrogen storage, CNT-polymer composites, ultra-capacitors etc. Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells.

Course Learning Outcomes (CLO):

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

1. learn the fundamentals of semiconductor devices
2. identify the parameters for characterization of solar cells
3. learn the various device fabrication techniques.
4. identify the various materials and devices for energy storage.

Text Books:

1. *Semi-conductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, (1993).*
2. *Solid State electronic devices, Ben G. Streetman, Prentice-Hall of India Pvt. Ltd., New Delhi (1995).*
3. *Carbon nanotubes and related structures: New material for twenty-first century, P. J. F. Harris, Cambridge University Press, (1999).*

Reference Books:

1. *Solar cells: Operating principles, technology and system applications, by Martin A. Green, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, (1981).*
2. *Thin-film crystalline silicon solar cells: Physics and technology, R. Brendel, Wiley-VCH, Weinheim, (2003).*
3. *Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial college press, (2001).*
4. *Organic photovoltaics: Concepts and realization, C. Barbec, V. Dyakonov, J. Parisi, N. S. Saricifttci, Springer-Verlag (2003).*
5. *Fuel cell and their applications, K. Kordesch, G. Simader, VCH, Weinheim, Germany, (1996).*
6. *Battery technology handbook, edited by H.A. Kiehne, Marcel Dekker, New York, (1989)*

Evaluation Scheme:

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

UCH862: ENERGY MANAGEMENT

(Energy Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:

To introduce the energy management principles related to process industries.

Introduction: Importance of energy management. Energy auditing: methodology, analysis of past trends plant data), closing the energy balance, laws of thermodynamics, measurements, portable and on line instruments. Energy economics - discount rate, payback period, internal rate of return, life cycle costing.

Steam Systems: Boiler-efficiency testing, excess air control, Steam distribution & use-steam traps, condensate recovery, flash steam utilisation. Thermal Insulation.

Electrical Systems: Demand control, power factor correction, load scheduling/shifting, Motor drives- motor efficiency testing, energy efficient motors, motor speed control. Lighting- lighting levels, efficient options, fixtures, daylighting, timers, Energy efficient windows.

Mechanical systems: Energy conservation in Pumps, Fans (flow control), Compressed Air Systems, Refrigeration & air conditioning systems.

Waste heat recovery: Recuperators, heat wheels, heat pipes, heat pumps.

Cogeneration: Concept, options (steam/gas turbines/diesel engine based), selection criteria, control strategy. Heat exchanger networking- concept of pinch, target setting, problem table approach, composite curves. Demand side management. Financing energy conservation

Course Learning Outcomes (CLO):

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

1. identify the components involved in energy auditing.
2. explain the energy conservation techniques.
3. evaluate the performance of electrical systems, lighting and pumps.
4. evaluate the performance of industrial boilers, furnaces, cogeneration options.

Text Books:

1. *Nagabhushan Raju, K., Industrial Energy Conservation Techniques: Concepts, Applications and Case Studies, Atlantic Publishers & Distributors (2007).*
2. *Industrial Energy Conservation Manuals, MIT Press, Mass, (1982).*

Reference Books:

1. *The Efficient Use of Energy, Ed: I.G.C. Dryden, Butterworths, London, (1982).*
2. *L.C. Witte, P.S. Schmidt, D.R. Brown, Industrial Energy Management and Utilisation, Hemisphere Publ, Washington, (1988).*

3. *W.C. Turner, Energy Management Handbook, Ed: Wiley, New York, (1982.*
4. *Technology Menu for Efficient energy use- Motor drive systems, Prepared by National Productivity Council and Centre for Environmental Studies- Princeton Univ, 1993.*

Evaluation Scheme:

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

UCH863: POLYMER PROCESSING

(Materials Elective)

L	T	P	Cr
3	0	0	3.0

Course objective:
To study processing methods for elastomers, thermoplastics, adhesives, fibres and coatings, and to be able to select an appropriate processing method for an engineering application.

Introduction: Polymer classification; Molecular weight distributions; Thermal transitions; Mechanical properties; Polymer solubility; Interfacial Properties; Properties of thermoplastics; Rubber elasticity; Crosslinking; Additives.

Polymer Rheology: Principles of rheology; Rheometry; Constitutive equations; Flow modeling; Dynamic mechanical properties; Viscoelasticity.

Polymer Processing Operations: Rubber compounding; Unit operations in polymer processing; Extrusion and injection molding; Mixing and Compounding; Compression molding, Transfer molding, Blow molding, Calendering, Coating, Casting, Thermoforming. Secondary shaping operations; Polymer blends and composites.

Processing Operation Calculations: Calculations in Extrusion and Injection molding.

Course learning outcomes (CLO):
Upon completion of the course, students will be able to:

1. Choose appropriate polymer processing operations depending on the material and final product requirements.
2. Identify methods for rheological measurements and analyze the results.
3. Relate properties required and the processing techniques used; such as injection molding, single screw extrusion, twin screw compounding, mixing, thermoforming, blown film, etc.
4. Solve simple flow problems and perform simple calculations in extrusion and injection molding.

Text Book:

1. *J.R. Fried, "Polymer Science and Technology", 3rd Ed. Prentice Hall (2014)*

Reference Books:

1. *S.L. Rosen, "Fundamental Principles of Polymeric Materials", Wiley (2012)*
2. *T.A. Osswald, "Polymer Processing Fundamentals", Hanser (1998)*

Evaluation Scheme:

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

UCH864: STRUCTURAL MATERIALS

(Materials Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
To impart knowledge about the design of microstructures to give desired properties across the full range of materials classes.

Introduction: Stress-strain relationships in linear elastic and non-linear elastic solids; plastic deformation of metals, strengthening mechanisms, micro-mechanisms of plastic deformation and fracture, creep, characteristics of the creep curve, creep mechanisms.

Mechanical Behaviour: Plastic deformation of polymers, fracture, fracture of brittle materials, brittle-ductile transition, fracture of semi-brittle materials-crack-tip plasticity, fatigue, characteristics of fatigue crack nucleation and growth, the Paris Law and lifetime predictions, rupture life predictions.

Ceramics: Structural and general considerations, oxide ceramics, silicon carbide.

Composites: Elastic behaviour, strength, toughening.

Polymers: Structural overview, structural transitions, factors affecting the glass transition temperature in amorphous polymers, crystalline polymers, liquid crystal polymers.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. quantify the properties of materials, and their origin.
2. perform simple calculations to predict the lifetime of a component subjected to fatigue or creep using data obtained from standard tests.
3. apply the processing-microstructure-property relationship to the design of alloys, ceramics, polymers and composites for structural applications.

***Text Book*:**
1. W.D. Callister, Materials Science and Engineering; John Wiley & Sons, Singapore (2002).

***Reference Book*:**
1. V. Raghavan, Introduction to Materials Science and Engineering; PHI, Delhi (2005).

Evaluation Scheme:

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

UCH865: PETROLEUM RESERVOIR ENGINEERING AND FIELD DEVELOPMENT

(Petroleum Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
To impart an in-depth knowledge of petroleum reservoir engineering including characteristics of crude oil and natural gas, reservoir rocks and fluids and field development.

Characteristics of Crude Oil and Natural Gas: Classification of crude and its physico-chemical properties.

Petrophysical Properties of Reservoir Rocks: Porosity, Permeability, Fluid saturation, Fluid flow through porous media.

Reservoir Fluids: Gas, condensate and oil reservoirs, Reservoir fluid properties, Reservoir fluid sampling and PVT studies.

Thermodynamics of Fluid System: Phase behavior of single & multiphase systems.

Reserve Estimation: Material balance, Volumetric methods, Reservoir simulation method, Decline curve analysis.

Reservoir Energies & Drives: Basic drive mechanism, Water influx, Well performance: productivity index, IPR. Water and gas coning, Open flow potential for gas wells, Applications of horizontal wells, ERD & multi-laterals.

Oil & Gas Field Development: Oil and gas field development: Principles of oil and gas filed development; rational development plan; well spacing and patterns, Reservoir drives and drive mechanism, Economics of field development.

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. analyze the characteristics of reservoir rocks and reservoir fluids.
2. analyze the thermodynamics of fluid system, and reserve estimation, reservoir energies, and drives.
3. analyze the principles for the development of oil and gas fields.

Text Books:

1. *L.P. Dake, Fundamentals of Reservoir Engineering, Elsevier, NY (2010).*
2. *R. Cosse, Basics of Reservoir Engineering, Editions Technip, Paris (1993).*

Reference Books:

1. *Tarek Ahmed, Reservoir Engineering Handbook, 3rd Edn, Gulf Professional Publishing, Elsevier, NY (2006).*
2. *Frank W Cole, Reservoir Engineering manual, Gulf Publishing Company, Houston, Texas (1983).*

3. *C R Smith, G W Tracy, R L Farrar, Applied Reservoir Engineering (Vol I & II), OGCI and Petro Skills Publications, Tulasa, Oklahoma (2008).*

Evaluation Scheme:

S. No.	Evaluation elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may include Quizzes/Assignments evaluation)	20

UCH866: ENHANCED OIL RECOVERY TECHNIQUES

(Petroleum Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:
To impart knowledge of displacement of fluid in reservoirs, and related techniques to enhance the oil recovery.

Introduction: Historical background and review of primary and secondary recovery, injection rate and pressures in secondary recovery. Flood Patterns and Coverage.

Microscopic Displacement of Fluids in Reservoirs: Capillary forces, Viscous forces, Phase trapping, mobilization of trapped phases.

Macroscopic Displacement of Fluids in Reservoirs: Areal sweep efficiency, Vertical sweep efficiency, displacement efficiency, Mobility ratio, Well spacing, Flow of immiscible fluids through porous media. Continuity equation, Equation of motion, Solution methods, Water flooding, Fractional flow equation, Frontal advance theory, Recovery efficiency, Permeability heterogeneity.

Water Flooding Performance Calculations: Frontal advance method, Viscous fingering method, Stiles method, Dykstra-Parsons Method, Water for water flooding.

Chemical Flooding: Polymer flooding and mobility control processes, Micellar/ polymer flooding, Phase behavior of micro-emulsions, Phase behavior and IFT, Wettability alterations, Alkali flooding.

Miscible Displacement Processes: Mechanism of miscible displacement, Phase behavior related to miscibility, High pressure gas injection, Enriched gas injection, LPG flooding, Carbon dioxide flooding, Alcohol flooding.

Thermal and Microbial Oil Recovery Processes: Mechanism of thermal flooding, Hot water flooding, Cyclic steam injection, Estimation of oil recovery from steam drive, In-situ combustion, Air requirement for in-situ combustion, Microbial oil recovery.

EOR Project

Course Learning Outcomes (CLO):
Upon completion of the course, students will be able to:

1. calculate the macroscopic displacement parameters of fluids in a reservoir.
2. estimate the water flooding performance and chemical flooding.
3. identify the mechanism of miscible displacement and thermal recovery processes.

Text Book:

1. *HK Van Poolen, Fundamentals of Enhanced Oil Recovery, Pennwell Corp, USA (1980).*

Reference Books:

1. *Don W. Green, G. Paul Willhite, Enhanced oil recovery, Society of Petroleum Engineers (2020).*
2. *Larry W. Lake, Enhanced Oil Recovery, Prentice Hall (1989).*

Evaluation Scheme:

S. No.	Evaluation elements	Weightage (%)
1	MST	30
2	EST	50
3	Sessional (may include Quizzes/Assignments evaluation)	20

UCH811: FLUID MACHINERY

(Chemical Process Engineering Elective)

L	T	P	Cr
3	0	0	3.0

Course Objective:

To understand the construction and working of fluid machinery and their applications in process industry.

Introduction: Physical properties of hydraulic fluids, Energy and power in hydraulic systems, Frictional losses in hydraulic pipelines, Model laws and similarity coefficients, Axial thrust, Radial thrust and rotor dynamics.

Centrifugal Pumps: Characteristics of centrifugal pumps, Control of centrifugal pumps, Startup time for centrifugal pump, Rundown time for centrifugal pump, Pumping special liquids (viscousliquids, gas-liquid mixtures, hydrocarbons, and solid liquid mixtures), Minimum flowrate, Admission temperature rise

Reciprocating pumps: Working, Design, and Applications.

Pump Selection: Parameters involved in pump selection, Types of pumps, Performance data for centrifugal pumps, Affinity laws for centrifugal pumps, The operating point of a pump and pump selection, Suction head, Net positive suction head, Net positive suction head available, Net positive suction head required, Piping system design and pump selection procedure.

Applications of Pumps in Chemical Industry: Chemical pumps, Pumps for oil and gas, Booster pumps for feed pump, Condensate pumps, Cooling water pumps, Main reactor coolant pumps and reactor circulating pumps, Safety related auxiliary pumps for nuclear power stations, Pumps for pulp and paper industry, Pumps for metallic refining industry, Pumps for fertilizer industry, Pumps for sugar industry, Pumps for water, Vibration and noise in pumps.

Fans, Blowers, Compressors: Classification of Fans, Blowers, and Compressors, Flow of Compressed Air and Other Gases in Pipes, Axial flow compressors and fans: velocity diagram of compressor stage, Thermodynamics of compressor stage, Stage loss relationships and efficiency, Reaction ratio, Choice of reaction, Stage loading, Simplified off design performance, Stage pressure rise, Pressure ratio of multistage compressors, Control of flow instabilities.

Pump Materials and Corrosion: Factors affecting the corrosion, General considerations affecting the choice of the material, Forms of corrosion.

Turbines: Types, Design, and Applications.

Course Learning Outcomes (CLOs):

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

1. perform calculations related to pumps and its operations.

2. design pumps, compressors, and turbines
3. select the pumps, compressors, and turbines for various industrial needs andoperations.

Text Books:

1. *Sulzer Pumps, Centrifugal Pump Handbook, Butterworth Heinemamm (2010).*
2. *Lobanoff, V. S. and Ross, R. R., Centrifugal Pumps Design and Application, ButterworthHeinemamm (1992).*

Reference Books:

1. *McCabe, W. L., Smith, J. C., and Harriott, P., Unit Operations of Chemical Engineering,McGraw Hill (2005).*
2. *Esposito, Anthony, Fluid Power with Applications, Prentice Hall (2008).*
3. *Finnemore, E.J. & J.B. Franzini, Fluid Mechanics with Engineering Applications,McGraw-Hill (2002).*
4. *Mott, Robert L., Untener, J.A., Applied Fluid Mechanics, Prentice Hall (2015).*
5. *Dixon, S.L., Fluid Mechanics and Thermodynamics of Turbomachinery, ButterworthHeinemamm (2005).*

Evaluation Scheme:

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

UCH849: SCALE-UP AND PILOT-PLANT METHODS IN CHEMICAL ENGINEERING

(Chemical Process Engineering Elective)

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 Processes: Fundamental considerations scale-up procedure for Distillation, Absorption, Stripping and Extraction units.

Course Learning Outcomes (CLO):

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

1. scale-up the fluid phase and fluid-fluid reactors.
2. scale-up the mixing units and solid-liquid separation units.
3. scale-up for liquid-liquid and vapor-liquid mass transfer units.

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 ofa 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 include Quizzes/Assignments evaluation)	20