SCHEME AND SYLLABUS

B.TECH.-IV (CHEMICAL) 7th SEMESTER SCHEME FOR TEACHING AND EXAMINATION

Sr. No.	Course	Code	Credits	Teaching Scheme Hours per Week			Examination Scheme						Total Marks
							Theory				Practicals		
				L	Tu	Pr	Hr	Sessional	Tu	End Sem	Sessional	End Sem	
1	General Chemical Technology (Core-14)	CH401	5	4	0	2	2	50	---	50	25	25	150
2	Elements of Transport Phenomena (Core-15)	CH403	4	3	1	0	2	50	25	50	---	---	125
3	Core Elective – 3	CH4AA	3	3	0	0	2	50	---	50	---	---	100
4	Core Elective – 4	CH4BB	3	3	0	0	2	50	---	50	---	---	100
5	Summer Training	CH405	2	0	0	0	---	---	---	---	---	---	50
6	Project Preliminaries (Mini Project)	CH407	3	0	0	6	---	---	---	---	40	60	100
	TOTAL		20	13	1	8		200	25	200	65	85	625
Total contact hours per week = 22					**Total Credit = 20**								**Total marks = 625**
$ Refer Table 3													

Core Elective – 3 and Core Elective – 4 (CH4AA, CH4BB)		
Sr. No	**Code**	**Elective Course**
1.	CH421	Sustainability , Green Chemistry and Engineering
2.	CH423	Advances in Chemical Engineering
3.	CH425	Enzyme science and Technology
4.	CH427	Nanomaterials Synthesis by Chemical Methods
5.	CH429	Biomass and Fuel Cell Technology
6.	CH431	Computer Aided Design in Chemical Engineering
7.	CH433	Chemical Process Development and Design
8.	CH435	Green Technology
10.	CH437	Process Intensification
11.	CH439	Rheology of Complex Fluids
12.	CH441	Optimization

B.TECH.-IV (CHEMICAL) 8th SEMESTER SCHEME FOR TEACHING AND EXAMINATION

Sr. No.	Course	Code	Credits	Teaching Scheme Hours per Week			Examination Scheme						Total Marks
							Theory				Practicals		
				L	Tu	Pr	Hr	Sessional	Tu	End Sem	Sessional	End Sem	
1	Core Elective – 5	CH4XX	3	3	0	0	2	50	0	50	---	---	100
2	Core Elective -6	CH4YY	3	3	0	0	2	50	0	50	---	---	100
3	Core Elective - 7	CH4ZZ	3	3	0	0	2	50	0	50	---	---	100
4	Innovation Incubation and Entrepreneurship	HU410	3	3	0	0	2	50	0	50	---	---	100
5	Project	CH402	6	0	0	12	---	---	---	---	80	120	200
	TOTAL		18	12	0	12	---	200	0	200	80	120	600

Total contact hours per week = 24 **Total Credit = 18** **Total marks = 600**

$ Refer Table 3

Core Elective – 5, Core Elective – 6 and Core Elective – 7 (CH4XX, CH4YY, CH4ZZ)		
Sr. No	**Code**	**Elective**
1.	CH422	Advanced Particle Technology
2.	CH424	Advanced Process Control
3.	CH426	Computational Fluid Dynamics
4.	CH428	Design of Experiments
5.	CH432	Fluidization Engineering
6.	CH434	Heterogeneous Catalysis
7.	CH436	Interfacial Science and Engineering
8.	CH438	New Separation Techniques
9.	CH442	Chemical Engineering Plant design and Economics
10.	CH444	Safety and Pollution Control in Chemical Process Industries
11.	CH446	Safety , Hazard and risk analysis

General Chemical Technology

L	T	P	Credit
4	0	2	05

Core – 14: CH401 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Review the practical significance and relevance of processes in chemical industries.
CO2	Prepare organic and inorganic compounds using standard synthetic and purification procedures.
CO3	Recognize the importance of Unit processes and Unit operations in industrial chemical systems.
CO4	Analyze the operation of industrial chemical processes.
CO5	Assess and propose how raw materials are converted into useful products.
CO6	Decide technological solutions to problems arising in industrial plants.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Chemical Process Industries – Facts and Figures, Types of Chemical Process Diagrams, Preparation of Process Flow Diagrams, Equipment Symbols

- **CHLOR-ALKALI INDUSTRIES** **(5 Hours)**
  Manufacturing of Soda Ash by Solvay Process, Dual salt Process, Natural Soda Ash Process, Manufacturing of Caustic Soda, Chlorine, Hydrogen

- **INORGANIC ACIDS** **(5 Hours)**
  Manufacturing of Sulphuric Acid, Nitric Acid, Hydrochloric Acid, Phosphoric Acid

- **FERTILIZERS** **(4 Hours)**
  Types of Fertilizers, Manufacturing of Ammonia, Urea, Ammonium Nitrates, Ammonium Phosphates, Superphosphates, NPK

- **OILS, FATS, SOAPS, DETERGENTS** **(5 Hours)**
  Vegetable Oils, Animal Fats, Fatty Acids and Alcohols, Extraction Methods, Hydrogenation of Oils, Soaps and Glycerine, Detergents

- **SUGAR & STARCH INDUSTRIES** **(4 Hours)**
  Manufacturing of Sugar from Sugarcane, Starch, Ethanol by Fermentation

- **BIOMASS BASED CHEMICALS & BIOFUELS** **(4 Hours)**
  Concept of Lignocellulosic Biorefinery, Biomass Platform Molecules, Manufacturing of Furan Derivatives, Lignin Derivatives, Biobutanol, Biodiesel

- **PULP & PAPER INDUSTRIES** **(4 Hours)**
  Pulp and Paper, Cellulose and its Derivatives, Rayon

- **PETROLEUM REFINING** **(4 Hours)**
  Types of Crude Oils, Petroleum Refining Products, Refinery Unit Processes

- **PETROCHEMICALS** **(10 Hours)**
  Feedstocks, C_1 Derivatives, C_2 Derivatives, C_3 Derivatives, BTX Derivatives

- **POLYMERS & SYNTHETIC FIBERS** **(4 Hours)**
  Manufacturing of Phenol and Urea Formaldehyde Resins, Polyester, Nylons, Synthetic Rubbers

- **DRUGS & PHARMACEUTICALS** **(5 Hours)**
  Classification of Drugs, Manufacturing of Drugs, Aspirin, Antibiotics, Vitamins

(Total Lecture Hours: 56)

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3. Practicals:

1. Preparation of Boric acid
2. Preparation of $CaCl_2$
3. Preparation of Detergent
4. Preparation of Nitro naphthalene
5. Preparation of Potash alum
6. Preparation of Soap
7. Determination of Kinematic Viscosity of given oil sample
8. Determination of Aniline point
9. Determination of Smoke point
10. Measurement of Softening point
11. Determination of Penetration index
12. Determination of Flash point and Fire point

4. Books Recommended:

1. Gopala Rao M. & Sittig M., "Dryden's Outlines of Chemical Technology", 3rd Ed., Affiliated East-West Press Pvt. Ltd., New Delhi, 1997.
2. Austin G. T., "Shreve's Chemical Process Industries", 5th Ed., Tata McGraw-Hill Education Pvt. Ltd., 2012.
3. Rao B.K.B., "Modern Petroleum Refining Processes", 6th Ed.,Oxford & IBH Publishers, New Delhi, 2017.
4. Mall I.D., "Petrochemical Process Technology", 2nd Ed., Trinity Press, New Delhi, 2017.
5. Mall I.D., "Petroleum Refining Technology", 1st Ed., CBS Publishers, New Delhi, 2017.

Elements of Transport Phenomena

L	T	P	Credit
3	1	0	04

Core – 15: CH403 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Describe basics of momentum, heat and mass transfer
CO2	Write shell balance equations for conservation of momentum, energy, and mass; to obtain desired profiles for velocity, temperature and concentration
CO3	Solve and analyze generalized macroscopic balances for conservation of momentum, energy and mass to obtain engineering quantities of interest
CO4	Solve and analyze appropriate equations of change to obtain desired profiles for velocity, temperature and concentration
CO5	Recognize and apply analogies among momentum, heat and mass transfer
CO6	Explain interphase transport

2. Syllabus:

- **INTRODUCTION** **(1 Hour)**
  Introduction to different transport processes such as momentum, heat and energy.

- **TRANSPORT BY MOLECULAR MOTION** **(12 Hours)**
  Momentum transport by viscosity and momentum-flux. Energy transport by thermal conductivity and heat-flux. Mass transport by diffusivity and mass-flux.

- **TRANSPORT IN ONE DIMENSION (SHELL BALANCE METHODS)** **(16 Hours)**
  Shell momentum balances and velocity distributions. Shell energy balances and temperature distributions. Shell mass balances and concentration distributions.

- **USE OF GENERAL TRANSPORT EQUATIONS** **(6 Hours)**
  Equations of change and their use in momentum transport (isothermal).

- **VELOCITY DISTRIBUTIONS IN TURBULENT FLOW** **(1 Hour)**
  Comparisons of laminar and turbulent flows. Time-smoothed equations of change for incompressible fluids.

- **INTERPHASE TRANSPORT IN ISOTHERMAL SYSTEMS** **(2 Hours)**
  Friction factors for flow in tubes, flow around spheres, and packed columns.

- **MACROSCOPIC BALANCES FOR ISOTHERMAL FLOW SYSTEMS** **(2 Hours)**
  Macroscopic mass balance for steady and unsteady-state problems.

- **INTRODUCTION TO EQUATIONS OF CHANGE FOR NON-ISOTHERMAL SYSTEMS AND MULTICOMPONENT SYSTEMS (2 Hours)**
  Energy transport and mass transport.

(Total Lecture Hours: 42 + Tutorial Hours: 14)

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3. Books Recommended:

1. Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 1st and 2nd Eds., John Wiley & Sons, Singapore, 1960 & 2002.
2. Bird R.B., Stewart W.E., Lightfoot E.N. and Klingenberg D.J., "Introductory Transport Phenomena", John Wiley & Sons, Hoboken, NJ, USA, 2014.
3. Plawsky J.L., "Tranport Phenomena Fundamentals", 3rd Ed., CRC Press, Boca Raton, FL, USA, 2014.
4. Geankoplis C.J., "Transport Processes and Separation Process Principles", 4th Ed., PHI, New Delhi, India, 2009.
5. Welty J.R., Rorrer G.L., and. Foster D.G., "Fundamentals of Momentum, Heat, and Mass Transfer", 7th Ed., John Wiley & Sons, Hoboken, NJ, USA, 2019.

Elective: Sustainability, Green Chemistry and Engineering

L	T	P	Credit
3	0	0	03

CH421 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Apply the concepts of sustainability in professional life.
CO2	Explain the importance of twelve principles of green chemistry and engineering.
CO3	Evaluate various techniques based on twelve principles of green chemistry and engineering.
CO4	Appraise novel concepts (new techniques and novel solvents) in processes in line with sustainable and green concepts.
CO5	Infer the given conventional process and operations and recommend modification required in the system.
CO6	Analyze various processes/products based on life cycle assessment.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Chemistry- from past to future, Importance of sustainability, Need of green chemistry

- **CONCEPT OF SUSTAINABILITY** **(4 Hours)**
  Fundamentals of sustainable development, growth, consumption and natural wealth, Sustainable development at different scales, Ten commandments, Sustainable development goals

- **GREEN CHEMISTRY AND ENGINEERING** **(5 Hours)**
  Principles and applications in green chemistry, green engineering, green extraction

- **SYNTHESIS AND GREEN CHEMISTRY** **(4 Hours)**
  Micro-reactor technology, Solvent-less reactions, Use of green solvents, Role of catalyst

- **ALTERNATE SOLVENTS** **(4 Hours)**
  Green solvents, Water as a solvent, Amphiphillic compounds

- **CONVENTIONAL PROCESS AND OPERATIONS** **(9 Hours)**
  Current status and modification (reactive distillation, divided wall distillation column, heat integration using pinch analysis)

- **NEW DEVELOPMENT IN PROCESSES** **(9 Hours)**
  Overview of green separation processes, Distillation, Chromatography, Membrane processes, Extraction using neoteric solvents, Nanotechnology in separation, etc.

- **LIFE CYCLE ASSESSMENT** **(5 Hours)**
  Basics and case studies

(Total Lecture Hours: 42)

3. Books Recommended:

1. Doble, M., Kruthiventi, A. K., "Green Chemistry and Processes", Academic Press, London, UK, 2007.
2. Manahan S. E., "Green Chemistry and The Ten Commandments of Sustainability", 2nd Ed. Chem Char Research, Inc Publishers, Missouri USA, 2006.
3. Afonso C. A. M., Crespo J. G. (Ed), "Green Separation Processes", Wiley-VCH Verlag GmbH & Co., Weinheim, Germany, 2005.
4. Clark J., Macquarrie D. (Ed), "Handbook of Green Chemistry and Technology", Blackwell Series, UK, 2002.
5. Atkinson G., Dietz S., Neumayer E. (Ed), "Handbook of Sustainable Development", Edward Elgar Publishing Limited, Cheltenham, UK, 2007.

Elective: Advances in Chemical Engineering

L	T	P	Credit
3	0	0	03

CH423 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Analyze the effects of pollutants on the environment and health impacts.
CO2	Express the knowledge of basic principles of different characterization methods.
CO3	Analyze treatment technologies for water/wastewater/solid waste.
CO4	Evaluate the usefulness of nanomaterials in treatment technologies.
CO5	Classify different types of smart polymers and membranes for environment.
CO6	Estimate most advanced methods for treatment for water/wastewater/solid waste.

2. Syllabus:

- **ADVANCE SEPARATION TECHNIQUES** **(12 Hours)**
  Reverse osmosis, Forward osmosis (FO), Pressure retarded osmosis (PRO), Osmotic microbial fuel cell (OMFC), benthic microbial fuel cell (BMFC), Osmotic Membrane bio reactor (OsMBR).

- **ADVANCE CHARACTERIZATION METHODS** **(4 Hours)**
  XRD, SEM, TGA, FT-IR, EDX, Gel permeation chromatography (GPC) etc.

- **ADVANCE POLYMER** **(10 Hours)**
  Smart polymer, advanced polymer nanocomposite, Conductive polymer, bio-route prepared nano polymer, Blended polymer, self-cleaning polymer surfaces

- **RECENT ADVANCES IN MEMBRANES** **(11 Hours)**
  Principles of membrane separation, Membrane Materials, Transport phenomena of species, molecular and ionic, in porous or dense, charged or not, membranes, Layer by layer membrane, Proton exchange membrane, biopolymer based membrane, nanocomposite membrane, coated membrane, different subtract and active layer membrane.

- **SMART HYDROGELS** **(5 Hours)**
  Hydrogel, Core and shell hydrogel, shell and core hydrogel, green hydrogel, stimuli responsiveness hydrogel

(Total Lecture Hours: 42)

3. Books Recommended:

1. Jornitz, M. W. and Meltzer, T. H., "Filtration and purification in biopharmaceutical industry", Second edition by, Informa Healthcare, Vol. 174. 2007.
2. Bungay P.M., Lonsdale H.K. and de Pinho M.N. (Eds.), "Synthetic Membranes: Science, Engineering and Applications", NATO ASI Series, Vol. 181, D. Reidel Publishing Company, Dordrecht, Holland,1986.
3. Schweitzer P.A. (Ed.), "Handbook of Separation Techniques for Chemical Engineers", 3rd Edition, McGraw-Hill, New York, 1997.
4. Gowariker, V.R. Viswanathan, N.V., and Sreedhar, J., "Polymer Science, Halsted Press (John Wiley & Sons), First Edition, New York, 1986.
5. Ghosh, P. "Polymer science & technology of plastic, rubber, blends and composites", Second Edition, Tata McGraw-Hill, New Delhi, 2008.

Elective: Enzyme Science and Technology

L	T	P	Credit
3	0	0	03

CH425 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Define the enzymes in terms of classifications, characterization, purification methods etc.
CO2	Explain the various mechanisms and kinetics of enzyme action as catalyst in biochemical reactions.
CO3	Recognize the significance of various types of enzyme inhibition and its effect on enzymatic reactions.
CO4	Adapt various methods of enzyme immobilization and their significance.
CO5	Design different types of enzymatic reactors for enzymatic reactions.
CO6	Explain various applications of enzyme in chemical and biochemical industries.

2. Syllabus:

- **INTRODUCTION TO ENZYMES** **(5 Hours)**
  Historical aspects, nomenclature and their classification, cost effective production, purification and characterization of enzymes.

- **MECHANISMS AND KINETICS OF ENZYME ACTION** **(7 Hours)**
  Mechanisms of enzyme action, concept of active site and energetics of enzyme substrate complex formation, specificity of enzyme action, kinetics of single substrate reactions, turn over number, estimation of Michaelis-Menten parameters, factors affecting enzymatic reaction.

- **ENZYMES INHIBITION AND MULTI-SUBSTRATE ENZYME KINETICS** **(7 Hours)**
  Multi substrate reaction mechanisms and kinetics- Random, Ping-Pong, Ordered; Haldane Relationships; types of inhibition- Competitive, Noncompetitive, Uncompetitive, Product, Substrate; allosteric regulation of enzymes, deactivation kinetics.

- **ENZYME IMMOBILIZATION** **(8 Hours)**
  Physical and chemical techniques for enzyme immobilization, adsorption, matrix entrapment, encapsulation, cross-linking, covalent binding etc., examples advantages and disadvantages of different immobilization techniques; Effect on mass transfer resistance.

- **ENZYME REACTORS AND PROCESS DESIGN** **(7 Hours)**
  Types of bioreactors for enzymatic reactions (i.e. continuous, batch, fed-batch etc.)

- **APPLICATIONS OF ENZYMES** **(8 Hours)**
  Commercial applications of enzymes in food, pharmaceutical and other industries, enzymes for analytical, diagnostic and bioremediation applications, enzymes for green technology, enzymes as biosensors.

(Total Lecture hours: 42 hours)

3. Books Recommended:

1. Bisswanger, H., "Enzyme Kinetics: Principles and Methods", 3rd Ed.Wiley-VCH Verlag GmbH, Weinheim, 2017.
2. Marangoni, A.G., "Enzyme Kinetics: A Modern Approach", John Wiley & Sons, Inc., Hoboken, New Jersey, 2003
3. Dutta, R., "Fundamental of Biochemical Engineering", Springer, New York, 2008.
4. Sathishkumar, T., Shanmugaprakash, M. and Shanmugam, S., “Enzyme Technology”, 2nd Ed. I.K. International Publishing House, 2012
5. Kirst, H.A., Yeh, W.-K. and Zmijewski, M.J., “ Enzyme Technologies for Pharmaceutical and Biotechnological Applications”, Marcel DeKKerr, Inc.,2001

Elective: Nanomaterials Synthesis by Chemical Methods

L	T	P	Credit
3	0	0	03

CH427 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Recognize the importance of nanomaterials, compare types of synthesis methods and their applications, analyze various fields of applications, enhanced properties, concepts of surface to volume ratio and surface atoms
CO2	Recognize wet chemical methods of nanomaterial synthesis like Colloidal synthesis of various nanostructures, micro emulsion method for nanomaterial synthesis,
CO3	Analyze the nanomaterials prepared with various techniques such as XRD, SEM, TEM, DLS, UV-VIS etc.
CO4	Evaluate aspects involved in Nanomaterial synthesis and thin film preparation methods for energy sectors and aspects and controlling operating parameter
CO5	Apply aspects involved in Nano catalyst preparation methods and applications, Nano catalysts vs heterogeneous catalyst, Evaluate nanomaterials synthesis for other applications of nanomaterials
CO6	Evaluate Optimization technique for finding the best optimum parameters, the effect of each control parameter using DOE, Analyze Issues related to scale-up in nanomaterials synthesis including downstream processing

2. Syllabus:

- **OVERVIEW** **(2 Hours)**
  Importance of nanomaterials, and types of synthesis methods and their applications.

- **FUNDAMENTALS OF CHEMICAL SYNTHESIS AND ENHANCED PROPERTIES** **(3 Hours)**
  Advantages of chemical synthesis methods of nanomaterials and Aspects involved in chemical methods of nanomaterials synthesis, Enhanced Properties at nanoscale and various fields of applications, concepts of surface to volume ratio and surface atoms

- **COLLOIDAL SYNTHESIS OF NANOMATERIALS** **(3 Hours)**
  Colloidal synthesis of various nanostructures. Microemulsion method for nanomaterial synthesis, channels of zeolites, Phase behavior of synthesis systems such as colloidal systems.

- **NANOCATALYSIS: NANOMATERIALS SYNTHESIS FOR NANOCATALYSIS** **(8 Hours)**
  Nanocatalysts vs heterogeneous catalyst, Nano catalyst preparation methods and applications, Aspects involved in aqueous methods of nanomaterials, coprecipitation, observation and measurement of size and structure at the nanoscale by XRD, AFM,TEM, etc.Nano catalyst preparation methods and applications,

- **ENERGY SECTORS: NANOMATERIALS SYNTHESIS** **(9 Hours)**
- Nanomaterials synthesis and thin film preparation for energy sectors, various types of thin film synthesis methods, Coater and CVD, aspects and controlling operating parameter involved, Applications of nanomaterials in Energy sectors such as various types of solar cell,

- **OTHER APPLICATIONS OF NANOMATERIALS: NANOMATERIALS SYNTHESIS** **(8 Hours)**
  Applications of nanomaterials in various types of fuel cell, water splitting, energy storage etc. Nanowires/nanorods/nanotubes synthesis.

- **OPTIMIZATION OF NANOMATERIALS FORMATION** **(8 Hours)**
  Optimization of operating parameters, finding the best optimum parameters, use of DOE

- **SCALE-UP ISSUES IN NANOMATERIALS SYNTHESIS** **(1 Hour)**
  Issues related to scale-up in nanomaterials synthesis including downstream processing

(Total Lecture Hours: 42)

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4. Books Recommended:

1. Hornyak G.L., Tibbals, H.F., Dutta, J., Moorne J. J. “Introduction to Nanoscience and Nanotechnology”, CRC Press, Taylor and Francis, US, 2009.
2. Ozin G.A, Arsenault A.C., “Nanochemistry: A chemical approach to nanomaterials”, Royal society of chemistry, UK, 2nd Edition, 2015.
3. Philips J. Ross,“Taguchi Techniques for Quality Engineering”, McGraw-Hill, 2nd Edition, 1996.
4. Ratner M., Ratner D., “Nanotechnology: A gentle introduction to the next big idea”, Prentice-Hall, New Jersey, 2002.
5. Chatopadhyay K. K., Banerjee A. N., “Introduction to Nanoscience and Nanotechnology”, PHI Learning Pvt. Ltd., New Delhi, India 2009.

Elective: Biomass & Fuel Cell Technology

L	T	P	Credit
3	0	0	03

CH429 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Describe about the origin of Biomass and its scope.
CO2	Explain the conversion of biomass into liquid as a fuel.
CO3	Explain about basics of fuel cells, and their working principle.
CO4	Estimate various types of fuel cells, their applications and performance parameters.
CO5	Analyse the potential of energy storage devices and new opportunity
CO6	Design the commercialization of fuel cell technology for resource recovery.

2. Syllabus:

- **INTRODUCTION** **(3 Hours)**
  Biomass, formation on the earth, photosynthesis, Chemistry and composition of Biomass, conversion, utilization for energy and its requirement, current scenario and its scope, fuel cell technology systems and their importance, resource recovery and future of fuel cells

- **BIOMASS CONVERSION TECHNOLOGIES** **(5 Hours)**
  Pre-treatment technologies, Biomass to liquid fuels. Biomass degrading enzymes and microorganisms. Bioethanol production from lignocellulosic feed stocks, algae and sea weeds. Algae Biodiesel; Technical challenges in biodiesels production. Biomass to gaseous fuel production, Bio hydrogen Production, Concept of Bio refinery.

- **WASTE AS BIOMASS** **(6 Hours)**
  Types of liquid and solid waste, origin and its current scenario. Conventional treatment systems/schemes and associated problems. Public perception.

- **VARIOUS BIOENERGETICS** **(5 Hours)**
  Glycolysis; TCA (TriCarboxylicacid) Cycle, Respiration, Control Sites in Aerobic Glucose Metabolism, Overview of Biosynthesis, Overview of Anaerobic Metabolism, Overview of Autotrophic Metabolism.

- **OVERVIEW OF FUEL CELLS** **(8 Hours)**
  What is a fuel cell, brief history, classification, how does it work, why do we need fuel cells, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency. Types of fuel cells, Microbial fuel cells and their types, Hydrogen fuel cells, their components, conditions, and advancements.

- **FUEL CELL ELECTROCHEMISTRY** **(5 Hours)**
  Electrochemical techniques, Electrochemical impedance spectroscopy (EIS) and its application, cycling voltammetry and linear polarization, galvanostatic intermittent titration, electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents. Bio-electrochemistry.

- **ENERGY STORAGE DEVICES** **(5 Hours)**
  Principle of battery, advanced rechargeable battery, Li-ion batteries, nanostructured materials for Li-ion batteries, Power management system, capacitors, and supercapicators.

- **ADVANCEMENT SCHEMES** **(5 Hours)**
  Commercialization aspects of fuel cell technology, stacking, integration and feasibility study. Resource recovery systems.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Dahiya, A. “Bioenergy: Biomass to Biofuels”, Academic Press; 1st Edition, USA, 2014.
2. Rogoff, M.J. and Screve, F., “Waste-to-Energy: Technologies and Project Implementation”, Elsevier Store, 2nd Edition, Kindle Edition, USA, 2011.
3. Logan, B.E., “Microbial Fuel Cells”, 1st Edition, Wiley, New Jersey, 2007.
4. Hoogers, G, “Fuel Cell Technology Hand Book”, CRC Press, New York, 2003.
5. Bard, A.J., Faulkner, L. R. “Electrochemical Methods” 2nd Edition, John Wiley & Sons, New York, 2000.

Elective: Computer Aided Design in Chemical Engineering

L	T	P	Credit
3	0	0	03

CH431 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	**Simulate** steady state process with process simulation program, such as ASPEN PLUS, Decide and select appropriate separation synthesis/process and Decide and select appropriate separation Equipments.
CO2	**Analyze** Multicomponent Distillation, Evaluate Heuristics for best sequence selection, Evaluate retrofitting concepts
CO3	**Design** of Column, **Evaluate** Column Diameter and **Decide** the effect of flooding, weeping, entrainment etc.
CO4	**Perform** heat integration with pinch technology, **Estimate** heat exchanger network design. **Apply** CAD in heat integration of distillation column, **Apply** CAD in heat integration of reactors
CO5	**Develop** process design/synthesis, **create** flow-sheet with input output structure, recycle structure etc.
CO6	**Design** and schedule the batch processes for optimal design.

2. Syllabus:

- **INTRODUCTION** **(3 Hours)**
  Introduction to Computer aided design in chemical engineering, Steady state and dynamic Simulation, Process simulation program (ASPEN PLUS), grass root design and retrofitting.

- **CAD IN CHEMICAL PROCESS EQUIPMENT** **(9 Hours)**
  Multicomponent distillation column design, Methods including Heuristics for Best sequence selection, Column Design for Distillation and Absorption, optimum design, parameter optimization etc. Computer aided design of chemical process equipment's,

- **CHEMICAL PROCESS DESIGN AND FLOW SHEETING** **(4 Hours)**
  Process synthesis/synthesis, Spread sheeting, Flow sheeting, Conceptual Process Design input output structure, Decision for the input output structure, Flow sheet alternatives: guidelines, Number of product streams, Gas recycle and purge.

- **SEPARATION PROCESS SELECTION** **(4 Hours)**
  Separation process selection criteria's and general thumb rules

- **EQUIPMENT SELECTION** **(3 Hours)**
  Equipment selection criteria's and general thumb rules

- **APPLICATION OF CAD IN HEAT EXCHANGER NETWORK DESIGN** **(8 Hours)**
  Pinch technology, Heat integration, and Optimum number of heat exchanger.

- **APPLICATION OF CAD IN HEAT INTEGRATION OF DISTILLATION COLUMN AND REACTORS** **(3 Hours)**
  Characteristics, Appropriate placement of column, Distillation across pinch, Grand composite curve, Design of simple distillation column to improve heat integration, heat integration of reactors

- **DESIGN AND SCHEDULING OF BATCH PROCESSES** **(5 Hours)**
  Design and scheduling of batch processes, transfer policy, size factor and multicomponent process design

- **APPLICATIONS OF CAD IN OTHER AREAS** **(3 Hours)**
  Applications of CAD in other areas such as heat transfer, mass transfer etc.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Smith R., "Chemical Process Design", McGraw-Hill, New York, 2nd Edition, 2016.
2. Douglas J., "Conceptual Design of Chemical Processes", McGraw-Hill, New York, 1989.
3. Biegler L. T., Grossmann E. I., Westerberg A. W., "Systematic Methods of Chemical Process Design", Prentice-Hall, New Jersey, 1997.
4. Sinnott R. K., "Coulson & Richardson's Chemical Engineering", Vol. 6, 4th Ed., Elsevier Publications, New York, 2005.
5. W.D.Sieder, J. D. Seader, D.R. Lewin, "Product and Process Design Principles", John-Wiley, New York, 4th Edition, 2016.

Elective: Chemical Process Development and Design

L	T	P	Credit
3	0	0	03

CH433 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Interpret concepts of process design and development.
CO2	Develop the process based on the data available.
CO3	Evaluate the sequencing of distillation column.
CO4	Identify the importance of various unit operations and their sequence.
CO5	Describe the importance of the intensification of the process.
CO6	Evaluate the design of process based on the given data.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Introduction to chemical process design. Product design and development. Product life cycle.

- **PROCESS DEVELOPMENT** **(8 Hours)**
  Process design and development, General considerations for chemical process design, Basics of process scale-up, Process synthesis, Flow sheeting, Process planning and scheduling, Optimization approaches to optimal design.

- **PROCESS INTENSIFICATION** **(8 Hours)**
  Principles of process intensification, process integration. Various ways of process intensification, Process intensification for safety, Methodology, and techniques of process intensification in industrial practice.

- **REACTIVE SEPARATIONS IN FLUID SYSTEMS** **(7 Hours)**
  Techniques of reactive absorption, reactive distillation and reactive extraction and their applications.

- **SEQUENCING OF DISTILLATION COLUMNS** **(6 Hours)**
  Basic features of tall vertical equipments/ towers, Towers/Column Internal, Sequencing of distillation towers, Heat integration in distillation columns.

- **PIPING DESIGN AND RATING** **(8 Hours)**
  Basics of piping design, Pipe sizing for single phase flow and multiphase flow.

- **RADIOGRAPHIC TESTING PROCEDURE FOR PRESSURE VESSELS** **(3 Hours)**
  Surface treatment and radiographic procedure, Quality and sensitivity of radiograph, Typical radiographic examination report.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Coker A.K., "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol.1, 4th Ed., Gulf Professional Publishing, 2007.
2. Douglas J., Conceptual Design of Chemical Processes, McGraw Hill, New York, 1989.
3. Soares C., "Process Engineering Equipment Handbook", McGraw-Hill, New York, 2002.
4. Cheremisinoff N.P., "Handbook of Chemical Processing Equipment", Butterworth Heinemann, Oxford, 2000.
5. Coulson & Richardson's Chemical Engineering, Vol. 6, 4th Ed., Elsevier, Oxford, 2006.

Elective: Green Technology

L	T	P	Credit
3	0	0	03

CH435 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Express smart energy, green infrastructure and non-renewable energy challenges.
CO2	Analyse models that simulate sustainable and renewable green technology systems.
CO3	Describe history, global environmental & economic impacts of green technology.
CO4	Develop nanoparticles by various biological methods.
CO5	Classify the usage of microorganism for the bioremediation.
CO6	Propose the green techniques for the production of renewable.

2. Syllabus:

- **GREEN TECHNOLOGY** **(7 Hours)**
  Definition, factors affecting green technologies, co/green technologies for addressing the problems of Water, Energy, Health, Agriculture, phyto-remediation, ecological sanitation, renewable energy technologies, industrial ecology, agro ecology and other appropriate green technologies, reuse, recovery, recycle, raw material substitution, cleaner production, wealth from waste, Some case studies.

- **CLEAN TECHNOLOGY** **(13 Hours)**
  Biotechnology and Microbiology for Degradation – Aerobic and Anaerobic pathway of wastewater degradation, Biogas technology, Microbial and biochemical aspects i,e., microbial fuel cell, forward osmosis, Osmotic microbial fuel cell for industrial waste water treatment. Operating parameters for biogas production.

- **BIOMASS ENERGY** **(10 Hours)**
  Concept of biomass energy utilization, types of biomass energy, conversion processes, Wind Energy, energy conversion technologies, their principles, equipment and suitability in Indian context; Fuel-wood use in rural households. Consequences for ecosystems. Future energy scenario in rural areas. Utilization of biomass in industrial and semi-industrial settings. Future utilization of biomass in India. Future of landscape management: optimal management.

- **GREEN NANOMATERIALS** **(5 Hours)**
  Greener Synthetic Methods for Functionalized Metal Nan particles, Greener Preparations of Semiconductor and Inorganic Oxide Nano particles, green synthesis of Metal nanoparticles, Nanoparticle characterization methods.

- **BIO-POLYMER AND GREEN HYDROGEL FOR WASTEWATER** **(7 Hours)**
  Green materials: biomaterials, biopolymers, bioplastics, and composites. Natural polymer, hydrogel and its application in wastewater treatment, Shell and core hydrogel and core and shell hydrogel.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Heinloth K., Energy Technologies: Renewable Energy, Springer-Verlag Berlin Heidelberg 2006,1st Edition.
2. Hammer, M.J. and Hammer M.J. Jr." Water and Wastewater Technology", 6th Ed. Prentice Hall Inc., 2008. 3. Bhatia, S.C., "Managing Industrial Pollution", Macmillan India Ltd., 2003.
3. Poole C., and Owens F., Introduction to Nanotechnology, John-Wiley, New Jersey, 2003,2nd Edition.
4. Clark J., Macquarrie D., Handbook of Green Chemistry and Technology Blackwell Series, 2002, UK, 1st Edition.
5. Ristinen, Robert Kraushaar, Jack J.A Kraushaar, Jack P. Ristinen, Robert A.,Energy and the Environment, 2nd Edition, John Wiley, 2006. 2. B. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic PressInc, 2005. 3. Sarkar S, Fuels and combustion, 2nd ed., University Press, 2009.

Elective: Process Intensification

L	T	P	Credit
3	0	0	03

CH437 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Identify the scope for process intensification in chemical processes & operations.
CO2	Explain the concept of process intensification and the methodologies for PI.
CO3	Explain the operating principle of intensified technologies and its implementation.
CO4	Analyse the range of potential applications of intensified equipment.
CO5	Analyse the range of potential applications of intensified operation/process.
CO6	Appraise process challenges using intensification technologies and solve case studies.

2. Syllabus:

- **INTRODUCTION & PROCESS INTENSIFICATION TECHNIQUES (5 Hours)**
  Historical background & Philosophy, Principles and Domains of Process Intensification (PI), Benefits of Intensified Processes, PI Toolbox – Equipments and Methods, Active and Passive Techniques.

- **COMPACT HEAT EXCHANGERS (4 Hours)**
  Heat transfer intensification, Printed circuit heat exchangers, Foam heat exchangers, Micro-heat exchangers etc.

- **HIGH GRAVITY FIELDS (5 Hours)**
  Process fundamentals, Rotating packed bed, Design, Applications and Scale-up.

- **INTENSIFIED MIXING & REACTORS (10 Hours)**
  PI in stirred tanks, Spinning disc reactors, Structured reactors, Microchannel reactors.

- **REACTIVE SEPARATIONS (7 Hours)**
  Reactive distillation, Reactive absorption, Reactive extraction, Reactive membrane separations.

- **ENHANCED FIELDS (6 Hours)**
  Energy based intensifications, Sonochemistry, Microwaves, Electrostatic fields.

- **CASE STUDIES-APPLICATION AREAS (5 Hours)**
  Methodology and Applications, Typical case studies from industrial sectors.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Reay, D., Ramshaw, C. and Harvey, A., “Process Intensification: Engineering for Efficiency, Sustainability and Flexibility”, 2nd Edition, Butterworth-Heinemann , 2013.
2. Boodhoo, K. and Harvey, A., “Process Intensification Technologies for Green Chemistry”, John Wiley & Sons, 2013.
3. Stankiewicz, A. and Moulijn, J.A., “ Re-Engineering the Chemical Processing Plant: Process Intensification”, Marcel Dekker, 2004.
4. Keil, F. J., “Modeling of Process Intensification”, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2007.
5. Andrzej Stankiewicz, Tom van Gerven, Georgios Stefanidis, The Fundamentals of Process Intensification, Wiley VCH 2019.

Elective: Rheology of Complex Fluids

L	T	P	Credit
3	0	0	03

CH439 **Scheme**

1. <u>Course Outcomes (COs):</u>

At the end of the course the students will be able to:

CO1	Describe the rheological behaviour of various types of fluids like polymeric materials, dispersions, gels, etc.
CO2	Compare different methods of rheological analysis.
CO3	Justify the importance of computational rheology and rheometry.
CO4	Discuss the concepts involved and specific importanceof topics of rheology from literature.
CO5	Express the deformation of viscoelastic materials.
CO6	Estimate the rheological behaviour of complex fluids.

2. <u>Syllabus:</u>

- **INTRODUCTION TO RHEOLOGY AND COMPLEX FLUIDS** **(4 Hours)**
  Features and applications of complex fluids, non-Newtonian behavior, stresses, deformation and flow, Importance of study of rheology, rheological properties, mechanical rheological techniques, use of rheological data for development of new products

- **VISCOELASTIC BEHAVIOR** **(6Hours)**
  Characterization of viscoelastic materials, Linear viscoelasticity. Non-linear viscoelasticity: rate-dependent and time-dependent shear and extensional viscosity, time-dependent superposition,normal stresses in shear. Elementary theories of non-linear viscoelastic behavior**.**

- **METHODS OF RHEOLOGICAL STUDIES** **(6 Hours)**
  Shear and extensional rheology, compressional rheology and their applications.

- **COMPUTATIONAL RHEOLOGY** **(4Hours)**
  Methods of computational rheology, micro-macro approach, macroscopic approach, applications.

- **RHEOLOGY OF POLYMERIC MATERIALS** **(5Hours)**
  Molecular origin of polymer melts, concentrated solution, rheological behavior of polymer melts, non-linear viscoelasticity of entangled polymers, flexible polymers, linear viscoelasticity of entangled polymers, polymer gels, transient network models, fine-grained theories of polymer dynamics, kinetic theory models for dilute polymer solutions.

- **RHEOLOGY OF DISPERSIONS** **(8Hours)**
  Flow properties of suspensions, emulsions, filled systems, gels, yield stresses of particulate gels, their measurements, and applications.

- **RHEOMETRY** **(3Hours)**
  Shear and extensional rheometry, Measurement of rheology in shearing deformation and flows, techniques of measurement, features of various types of rheometers.

- **SELECTED TOPICS FROM CURRENT LITERATURE** **(6Hours)**

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Larson R.G., “The Structure and Rheology of Complex Fluids”,Oxford University Press, New York, 1999.
2. Chhabra R.P., Richardson, J.F., "Non-Newtonian Flow and Applied Rheology: Engineering Applications”, 2nd Ed., Butterworth Heinemann, Oxford, 2008.
3. Pal R., “Rheology of Particulate Dispersions and Composites”, CRC Press, New York, 2007.
4. Owens R.G., Phillips T.N., “Computational Rheology”, Imperial College Press, London, 2002.
5. Malkin, A.Y., Isayev, A.I., “Rheology: Concepts, Methods and Applications”,ChemTec Publishing, Canada, 2005.

Elective: Optimization of Chemical Process

L	T	P	Credit
3	0	0	03

CH441 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Relate the basic concept of optimization.
CO2	Formulate various process optimization problems.
CO3	Solve the chemical process optimization problems.
CO4	Relate the significance of numerical methods in linear and nonlinear programming.
CO5	Infer the application of optimization in chemical engineering.
CO6	Summarize the nontraditional optimization techniques and their applications.

2. Syllabus:

- **INTRODUCTION** **(3 Hours)**
  Maximization and minimization problems- examples, Basic concepts of optimization – Convex and concave functions, Necessary and sufficient conditions for stationary points, Degrees of freedom.

- **FORMULATION** **(4 Hours)**
  Economic objective function, Formulation of various process optimization problems and their classification.

- **UNCONSTRAINED AND CONSTRAINED SEARCH** **(13 Hours)**
  Numerical methods for optimization of one-dimensional function, Unconstrained multivariable optimization, direct search methods, Indirect first order and second order methods, Constrained multivariable optimization - necessary and sufficient conditions for constrained optimum.

- **NUMERICAL METHODS IN LINEAR PROGRAMMING AND APPLICATIONS** **(6 Hours)**
  Geometry of linear programs, Basic solution methods, Simplex algorithm and its applications.

- **NUMERICAL METHODS IN NON-LINEAR PROGRAMMING WITH CONSTRAINTS AND APPLICATIONS** **(6 Hours)**
  Quadratic programming, Generalized reduced gradients methods, Successive linear and successive quadratic programming, Dynamic programming, Integer and mixed integer programming.

- **APPLICATION OF OPTIMIZATION IN CHEMICAL ENGINEERING** **(6 Hours)**
  Optimization of staged and discrete processes, Optimal heat exchanger design, Optimal pipe diameter, Optimal design of an Ammonia reactor.

- **NONTRADITIONAL OPTIMIZATION TECHNIQUES** **(4 Hours)**
  Genetic Algorithm, Simulated Annealing.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Edger T. F. and Himmelblau D. M., "Optimization of Chemical Process", McGraw-Hill, New York, 2001. (Reprint)
2. Rao S. S., "Engineering Optimization", New Age International, New Delhi, 2009.
3. Deb K., "Optimization for Engineering Design: Algorithms and Examples," Prentice-Hall of India, Delhi, 2012.
4. Loney N.W., "Applied Mathematical Methods for Chemical Engineers", CRS Press, Boca Raton, FL, 2015.
5. Joshi M. C. and Moudgalya K. M "Optimization: Theory and Practice", Alpha Science International Limited, Oxford, UK, 2004.

Elective: Advanced Particle Technology

L	T	P	Credit
3	0	0	03

CH422 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Recognize the importance of powder processing and handling
CO2	Analyze the complexities involved in particles characterization
CO3	Analyze and interpret bulk powder behaviour and its interaction with surrounding.
CO4	Select and apply relevant research strategies to study behaviour and performance of particulate materials
CO5	Design particulate product based on learned concepts
CO6	Apply advanced computing techniques to understand, analyse and solve complex powder flow problems

2. Syllabus:

- **PARTICLE PROPERTIES AND MEASUREMENT – I** **(3 Hours)**
  Particle size measurement, analysis, Fine particle statistics, Different types of shape descriptors, Image processing for shape characterization, Particle Packing and Product Porosity, Rheology of Emulsions and Suspensions, dispersion of particles.

- **PARTICLE PROPERTIES AND MEASUREMENT – II** **(6 Hours)**
  Overview of advanced particle measurement techniques, size measurement by Dynamic light scattering, size measurement by sedimentation techniques, Introduction to imaging techniques and surface area measurement, XRD Line broadening analysis to determine crystallite size and strain.

- **FUNDAMENTALS AND ADVANCEMENT IN PARTICULATE MATERIALS HANDLING** **(7 Hours)**
  Powder mixing for particulate product formulations and powder flow characterization, powder flowability index, Pharmaceutical powder formulation and Tabletting operations, Stresses in powder, Storage of powder in silo and silo design.

- **FLUIDIZATION OF FINE POWDERS (MICRONIC AND NANOPARTICLES)** **(4 Hours)**
  Introduction to fundamentals of fluidization, Modified Geldart's powder classification, Modified Richardson-Zaki equation for fine particles and Fluidization of nanoparticlultes assemblies, Fluidization assistance techniques, Flow additives to improve fluidization behaviour of fine powder beds.
- **DISCRETE ELEMENT METHOD (DEM) TO MODEL PARTICULATE PROCESSES** **(9 Hours)**
  Introduction to Discrete Element analysis/simulation and application, General formulation of discrete element method, Governing equation and force models, contact and non-contact forces between particles, fluid-particle interaction forces, constitutive relations for granular materials, Integration schemes and damping algorithms for DEM, Contact Detection models

:Soft contact model, Hertz contact model, Adhesive elastic contact Model, Generalized methodology to run DEM simulation using LIGGHTS (Open source DEM software).

- **ADVANCED PARTICLES PRODUCTION AND STABILIZATION TECHNIQUES (5 Hours)**
  Introduction to Powder production techniques. Wet media milling in agitated bead mill and planetary mill, Methods of stabilization of particles dispersion, electrostatic and electrosteric stabilization, Chemical surface modification of particles in suspension, Zeta potential of suspension.

- **PREPARATION OF PARTICULATE PRODUCT (8 Hours)**
  Effects of powder and slurry properties on Preparation of advanced Ceramic materials, effects of particle size on Sintering of powders, dry powder inhalers, pigments and paints dispersions.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Rhodes M. "Introduction to Particle Technology", 2nd Edition, John Wiley & Son, Chichester, (2008).
2. Henk G. Merkus, "Particle Size Measurements: Fundamentals, Practice, Quality", Springer Particle Technology Series, Volume 17 2009.
3. Dietmar Schulze, "Powders and Bulk Solids: Behavior, Characterization, Storage and Flow", Springer-Verlag Berlin Heidelberg 2008.
4. Colin Thornton, Granular Dynamics, Contact Mechanics and Particle System Simulations: A DEM study, Particle Technology Series, Volume 24, 2015
5. Liang-Shih Fan, Chao Zhu, "Principles of Gas-Solid Flow", 1st Edition, Cambridge University Press, New York, 1998.

Elective: Advanced Process Control

L	T	P	Credit
3	0	0	03

CH424 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Explain the concept of advanced control schemes used in process control
CO2	Develop control relevant linear perturbation models
CO3	Explain the concept of digital control system
CO4	Focus the use of soft computing techniques in process control
CO5	Analyse interaction in multi loop control
CO6	Analyse stability of digital control system

2. Syllabus:

- **INTRODUCTION AND MOTIVATION** **(4 Hours)**
  Introduction, Application; Plant wide control

- **DIGITAL SAMPLING, FILTERING AND CONTROL** **(5 Hours)**
  Sampling and signal reconstruction, Signal processing and data filtering

- **DEVELOPMENT OF CONTROL RELEVANT LINEAR PERTURBATION MODELS** **(6 Hours)**
  Development of Control Relevant Linear Perturbation Models; Linearization of Mechanistic Models; Introduction to z-transforms and Development of Grey-box models

- **DEVELOPMENT OF LINEAR BLACK-BOX DYNAMIC MODELS** **(10 Hours)**
  Introduction to Stochastic Processes; Development of ARX models; Statistical Properties of ARX models and Development of ARMAX models; Issues in Model Development; Model Structure Selection and Issues in Model Development; Issues in Model Development and State Realizations of Transfer Function Models

- **STABILITY ANALYSIS, INTERACTION ANALYSIS AND MULTI-LOOP CONTROL** **(6 Hours)**
  Stability Analysis of Discrete Time Systems; Lyapunov Functions; Jury's Stability Test.

- **MULTILOOP AND MULTIVARIABLE CONTROL** **(6 Hours)**
  Interaction Analysis and Multi-loop Control; Pairing of controlled and Manipulated Variables; RGA and Singular Value Analysis; Decoupling and Multivariable Control Stratigies

- **STATE ESTIMATION AND KALMAN FILTERING** **(5 Hours)**
  Soft Sensing and State Estimation, Development of Luenberger Observer; Introduction to Kalman Filtering

(Total Lecture Hours: 42)

3. Books Recommended:

1. Astrom, K.J., and B. Wittenmark, “Computer Controlled Systems”, Prentice Hall India, 3rd Edition, 1997.
2. Franklin, G.F., Powell, J.D., and M.L. Workman, “Digital Control Systems”, Addison Wesley, 3rd Edition, 1997.
3. Seborg, D.E., Edgar, T.F., and Mellichamp, D.A., “Process Dynamics and Control”, Wiley, 3rd Edition, 2010.
4. Goodwin, G.C., S.F. Graebe, M.E. Salgado, “Control System Design”, Prentice Hall, 2000.
5. Stephanopoulos, G., “Chemical Process Control: An Introduction to Theory and Practice”, Prentice Hall India, 2008

Elective: Computational Fluid Dynamics

L	T	P	Credit
3	0	0	03

CH426 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Explain fundamentals of computational methods in fluid flow applications
CO2	Analyze Initial Boundary Value problems and determine various quantities of interest
CO3	Apply appropriate solution strategy and estimate the accuracy of the results for a given flow case
CO4	Select and formulate various CFD problems by considering appropriate boundary conditions
CO5	Adapt to various commercial software for solving numerical problems
CO6	Interpret computational results

2. Syllabus:

- **INTRODUCTION AND GOVERNING EQUATIONS** **(5 Hours)**
  Introduction, Classification of partial differential equations, Navier-Stokes system of equations, Boundary conditions.

- **FINITE DIFFERENCE METHODS** **(5 Hours)**
  Basic aspects of finite difference equations, Derivation of finite difference equations, Accuracy of finite difference solutions,

- **SOLUTION METHODS OF FINITE DIFFERENCE EQUATIONS** **(6 Hours)**
  Methods for Elliptic, Parabolic and Hyperbolic equations, Implicit and explicit schemes, Von Neumann stability analysis, Example problems.

- **INCOMPRESSIBLE VISCOUS FLOWS** **(6 Hours)**
  General, Artificial compressibility method, Pressure correction methods, Vortex methods.

- **COMPRESSIBLE FLOWS** **(6 Hours)**
  Potential equation, Euler equations, Navier-Stokes system of equations, Preconditioning process for compressible and incompressible flows.

- **INTRODUCTION TO FINITE VOLUME METHOD** **(4 Hours)**
  Integral approach, discretisation & higher order schemes.

  INTRODUCTION TO FINITE ELEMENT METHOD **(4 Hours)**
  Finite element formulations, definition of errors, Finite element interpolation functions.

- **APPLICATIONS** **(6 Hours)**
  Chemically reactive flows, Heat transfer and Multiphase flow.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Anderson J.D., "Computational Fluid Dynamics", McGraw-Hill International Editions, 1995.
2. Patankar S.V., "Numerical Heat Transfer and Flow" , McGraw Hill, New York, 2002.
3. Ferziger J. H. and Peric M., "Computational Methods in Fluid Dynamics ", Springer, New York, 2003.
4. Muralidhar K. and Sunderrarajan T., "Computational Fluid Flow and Heat Transfer ", Narosa Publishing House, New Delhi, 2nd Edition, 2003.
5. Chung T. J., "Computational Fluid Dynamics", Cambridge University Press, London, 2nd Edition, 2014.

Elective: Design of Experiments

L	T	P	Credit
3	0	0	03

CH428 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Explain the importance of statistical approach in research and experimental planning.
CO2	Select suitable data set for analysis of the results.
CO3	Devise effective ways to conduct experiments and obtain optimum conditions.
CO4	Analyze effect of various factors using analysis of variance.
CO5	Apply various methods of factorial designs (2^K method, Response surface method, Taguchi method) for a given set of parameters.
CO6	Interpret experimental results with softwares.

2. Syllabus:

- **REVIEW OF BASIC STATISTICAL CONCEPTS** **(2 Hours)**
  t-Distribution, F-distribution, Confidence intervals, Hypotheses testing

- **FUNDAMENTALS OF EXPERIMENTAL DESIGN** **(4 Hours)**
  Experimentation, Basic principles of Design, Steps in experimentation, Choice of sample size, Normal probability plot, Rejection of data, Linear regression

- **INTRODUCTION TO THE ANALYSIS OF VARIANCE (ANOVA)** **(6 Hours)**
  Understanding variation, No-way ANOVA, One-way ANOVA, Two-way ANOVA, Three-way ANOVA, Use of relevant software

- **SINGLE, MULTI-FACTORIAL EXPERIMENTS** **(4 Hours)**
  Completely randomized design, Block Design, Latin and Graeco-latin square design, Two-factor experiments, Three-factor experiments, Degree of freedom and sum of squares.

- **2^K FACTORIAL EXPERIMENTS AND DESIGNS** **(5 Hours)**
  2^2 Factorial design, 2^3 Factorial design, 2^k Factorial design, Blocking and confounding

- **RESPONSE SURFACE METHODS** **(5 Hours)**
  Response surface designs (Central composite design; Box-behnken design), Use of relevant software

- **QUALITY LOSS FUNCTIONS** **(2 Hours)**
  Nominal-the better case, Smaller-the better case, Larger-the better case, Estimation of quality loss.

- **TAGUCHI METHOD** **(14 Hours)**
  Development of orthogonal designs, Robust design; Data analysis, Multi-level factor designs, Multi-response optimization, Use of relevant software

(Total Lecture Hours: 42)

3. Books Recommended:

1. Ross P. J., "Taguchi Techniques for Quality Engineering", McGraw-Hill Book Co, New York, U.S.A., 1989.
2. Krishnaiah K., Shahabudeen P., "Applied Design of Experiments and Taguchi Methods", PHI Learning, India, 2012.
3. Taguchi G., Chowdhury S., Wu Y., "Taguchi's Quality Engineering Handbook", John Wiley and Sons, New York, U.S.A., 2005.
4. Montgomery D. C., "Design and Analysis of Experiments", 5th edition, John Wiley and Sons, New York, U.S.A., 2001.
5. Lazic Z. R., "Design of Experiments in Chemical Engineering", Wiley-VCH Verlag GmbH & Co., Germany, 2004.

Elective: Fluidization Engineering

L	T	P	Credit
3	0	0	03

CH432 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Recognize the capability of fluidized bed system to conduct different types of chemical engineering operations (e.g. fluid-particle mechanics, bubble mechanics, mass transfer, heat transfer, chemical reaction engineering, drying, mixing, granulation)
CO2	Calculate operating parameters of fluidized bed system (e.g., Pressure drop, minimum fluidization velocity, voidage of bed, voidage and height of fluidized bed at different velocity)
CO3	Identify fluidization regime using process variables.
CO4	Classify different types of fluidized bed system.
CO5	Predict behaviour of gas solid and liquid solid fluidized bed system.
CO6	Design and develop gas-solid contacting system based on different fluidized bed models.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Introduction to phenomenon of fluidization; Types of fluidization operations; Typical industrial applications of fluidized beds.

- **PARTICLE CHARACTERIZATION AND DYNAMICS** **(2 Hours)**
  Overview of advanced particle measurement techniques, size measurement by Dynamic light scattering, size measurement by sedimentation techniques, Introduction to imaging techniques and surface area measurement, XRD Line broadening analysis to determine crystallite size and strain.

- **FLUIDIZED BED HYDRODYNAMICS** **(6 Hours)**
  Estimation of minimum fluidization velocity; Mapping of Fluidization regimes, Gas distributor types; Fluidity and power consumption

- **BUBBLING BED BEHAVIOUR AND BUBBLE DYNAMICS** **(9 Hours)**
  Bubbles in liquid and fluidized bed, jet penetration and bubble formation, bubble shape, size and stability, models of bubbling beds, Davidson’s isolated bubble model, two phase theory of fluidization, coalescence and splitting of bubbles, slugging conditions in fludized bed, Kuni-levenspiel model.

- **ELUTRIATION IN FLUIDIZED BED** **(3 Hours)**
  Basics of elutriation, Estimation of transport disengaging height (TDH), Empirical correlations for estimation of elutriation rate. Estimation of TDH for Geldart’s A group powder.

- **FLUIDIZATION OF MICRONIC POWDERS AND NANOPARTICULATE ASSEMBLIES (3 Hours)**
  Modified Richardson zaki equation for nanoparticles fluidization, Nanoparticle fluidization and Geldart's classification.

- **HEAT AND MASS TRANSFER IN FLUIDIZED BED (4 Hours)**
  General characteristics and correlations of heat transfer in fluidized bed, Heat transfer between gas-particle and bed surfaces, Effects of parameters on rate of heat transfer, General characteristics and correlations of mass transfer in fluidized bed, Mass transfer between different phases of fluidized bed.

- **FLUIDIZED BED REACTOR DESIGN (7 Hours)**
  Basics of reactor design, Different approaches of reactor design, Reactor design using Kuni-levenspiel model

- **SCALE UP OF FLUIDIZED BED (3 Hours)**
  Generalized scaling laws for fluidized bed system

- **CASE STUDIES ON TYPICAL APPLICATIONS OF FLUIDIZED BED SYSTEMS (3 Hours)**
  Coating and granulation, FCC, Gasification.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Kunii, D. and Levenspiel, O., "Fluidization Engineering", 2nd ed., Elsevier, New Delhi, 2005.
2. Wen-Ching Yang, "Handbook of Fluidization and Fluid-Particle Systems", Marcel Dekker.
3. Davidson, J.F. and Harrison, D., "Fluidized Particle", Book Chapter Cambridge University Press.
4. Gibilaro, L. G., "Fluidization Dynamics, The formulations & applications of predictive",1st Edition, Butterworth-Heinemann (2001).
5. Howard, J.R. Fluidized Bed Technology: Principles and Applications. 1st ed., CRC press (1989)

Elective: Heterogeneous Catalysis

L	T	P	Credit
3	0	0	03

CH434 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Demonstrate concepts of physical adsorption and chemisorption of gases on metals and oxides
CO2	Evaluate catalyst deactivation and determine structure of catalyst
CO3	Analyze and evaluate performance of catalyst based on characterization techniques (e.g., Surface area, pore size distribution, pore volume; XRD; IR; DTG-TGA)
CO4	Analyze and compare catalysis in different industries (e.g., Petrochemicals, Refining, Fertilizers, etc. Processes)
CO5	Illustrate advance concepts in heterogeneous catalysis
CO6	Identify appropriate catalysts and corresponding operating conditions for a given process

2. Syllabus:

- **ADSORPTION IN CATALYSIS** **(7 Hours)**
  Physical adsorption of gases, chemisorption of gases on metals and oxides, theoretical aspects of catalysis.

- **CHARACTERIZATION OF CATALYTIC MATERIALS** **(10 Hours)**
  Surface area, pore size distribution, pore volume, pore volume, XRD, IR, DTG-TGA, NMR, UV-visible, NH_3 TPD. Catalyst structure: Nature of active site

- **SYNTHESIS OF POROUS SOLIDS** **(2 Hours)**
  Oxides and zeolites.

- **HETEROGENEOUSLY CATALYZED CATALYTIC REACTIONS** **(12 Hours)**
  Catalytic oxidation reactions, catalysis by solid acids, catalysis in production of petrochemicals, catalysis in refining processes, catalyst deactivation and regeneration protocol.

- **CATALYTIC PROCESS ENGINEERING** **(3 Hours)**
  Kinetics, catalytic reactor engineering.

- **NEW DEVELOPMENTS** **(8 Hours)**
  New understanding in catalysis, catalysis in motion, nanoalloy catalysis.

(Total Lecture Hours: 42)

3. <u>Books Recommended:</u>

1. Catalysis: Principles and Applications, B. Viswanathan, S. Sivasankar, A.V. Ramaswamy (Eds.) Narosa Publishing House, New Delhi, 2002.
2. J.M. Thomas, W.J. Thomas, Principles and Practice of Heterogeneous Catalysis, 2nd Ed., Wiley-VCH, Weinheim, 2015.
3. Green Chemistry and Catalysis, Roger A. Sheldon, Isabel Arands, Ulf Hanfeld, Wiley-VCH, 2007.
4. Chemical Reaction Engineering, Octave Levenspiel, John Wiley & Sons, 3rd Edition, 2008
5. Chemical Reaction Engineering – II, K. A. Gavhane, Nirali Publications, 5th Edition, 2009.

Elective: Interfacial Science and Engineering

L	T	P	Credit
3	**0**	**0**	**03**

CH436 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Explain about interfaces and methods to measure them
CO2	Summarize various types of colloidal dispersions and their stability
CO3	Describe about the surface forces
CO4	Discuss various transport processes at interface
CO5	Describe the criteria for stability of thin films between interfaces
CO6	Solve the problems of stability of thin films based on given conditions

2. Syllabus:

- **INTRODUCTION TO INTERFACIAL SCIENCE AND ENGINEERING (2 Hours)**
  Introduction of colloids and interfacial science, applications and scope of interfacial science and engineering.

- **INTERFACIAL TENSION (3 Hours)**
  Thermodynamic approach of interfacial tension, mechanical approach of interfacial tension, equilibrium shape of fluid interfaces, methods of measuring interfacial tension.

- **INTERFACES (6 Hours)**
  Energy and stress based characterization, Young-Laplace and Kelvin equations for curved interfaces, flux and momentum balances for interfaces, solid-fluid interfaces, free interfaces, interfaces in motion, rheology of interfaces.

- **COLLOIDAL DISPERSIONS (7 Hours)**
  Forces in colloidal systems, stability of emulsions and foam, DLVO theory, surfactants, self-assembly, thermodynamics of monolayers, micelles, reverse micelles, vesicles, critical miceller concentration, creaming, flocculation, coalescence, Ostwald ripening, zeta potential, electrophoresis, electro-osmosis, micro-emulsions.

- **PARTICLES AT INTERFACES (6 Hours)**
  Pickering emulsions, effects of particles at interfaces, pattern formation, contact angle hysteresis, wetting and spreading, work of adhesion and cohesion.

- **TRANSPORT PHENOMENA AT INTERFACES (5 Hours)**
  Interfacial mass transfer, interfacial instability during mass transfer, transport theorem for body containing intersection dividing surfaces, Marangoni flow, stability of moving interfaces with chemical reactions, dynamic interfaces.

- **BUBBLES, DROPS AND THIN FILMS (7 Hours)**
  Interactions of bubbles or drops in dispersed systems, interaction forces in interfacial systems, stability of thin films

- **SELECTED TOPICS FROM CURRENT LITERATURE** **(6 Hours)**
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(Total Lecture Hours: 42)

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3. <u>Books Recommended:</u>

1. Slattery J.C., Sagis L., and Oh E.-S., "Interfacial Transport Phenomena", 2nd Ed., Springer, New York, 2007.
2. Rosen M.J., "Surfactants and Interfacial Phenomena", 4th Ed., John Wiley & Sons, New Jersey, 2012.
3. Stokes R.J., Evans D.F., "Fundamentals of Interfacial Engineering", Wiley – VCH, New York, 1997.
4. Miller C.A., Neogi P., "Interfacial Phenomena: Equilibrium and Dynamic Effects", 2nd Edition, CRC Press, N.Y., 2019.
5. Israelachvili J.N., "Intermolecular and Surface Forces", 3rd Ed., Academic Press, New York, 2015.

Elective: New Separation Techniques

L	T	P	Credit
3	0	0	03

CH438 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Analyze the fundamental concepts of separation processes
CO2	Understand the principles and process of crystallization
CO3	Classify various membrane based separation processes and its applications
CO4	Explain the properties of colloidal separation
CO5	Interpret the surfactant-based separation
CO6	Understand the supercritical fluid extraction

2. Syllabus:

- **FUNDAMENTALS OF SEPARATION PROCESSES** **(4 Hours)**
  Basic definitions of relevant terms, classification, separation processes in chemical process industries, categorization of separation processes, equilibrium and rate governed processes.

- **CRYSTALLIZATION AND REACTIVE SEPARATIONS** **(7 Hours)**
  Concept, Different types of crystallization, phase equilibrium, different techniques, commercial applications, Cavitations and its application in crystallization, Reactive crystallization.

- **MEMBRANE BASED SEPARATION PROCESSES** **(15 Hours)**
  Historical background, physical and chemical properties of membranes, techniques of membrane preparation, membrane characterization, various types of membranes and modules. Details and applications of various membrane separation processes.

- **EXTERNAL FIELD INDUCED MEMBRANE SEPARATION PROCESSES FOR COLLOIDAL PARTICLES** **(6 Hours)**
  Fundamentals of various colloid separations. Derivation of profile of electric field strength. Coupling with membrane separation and electrophoresis.

- **SURFACTANT BASED SEPARATION PROCESSES** **(8 Hours)**
  Cloud point extraction, Micellar enhanced separation processes.

- **SUPERCRITICAL FLUID EXTRACTION** **(2 Hours)**
  Working Principle, Advantages & Disadvantages of supercritical solvents over conventional liquid solvents, commercial applications of supercritical extraction, Applications under research

(Total Lecture Hours: 42)

3. Books Recommended:

1. Wankat P. C., "Rate-Controlled Separations", Elsevier Applied Science, New York, 1990.
2. Bungay P.M., Lonsdale H.K. & de Pinho M.N. (Eds.), "Synthetic Membranes: Science, Engineering and Applications", NATO ASI Series, Vol.181, D.Reidel Publishing Company, Dordrecht, Holland, 1986
3. Kaushik Nath, "Membrane Separation Processes" , 1st Edition, PHI pvt.Ltd., New Delhi, 2008.
4. Seader J.D., Henley E.J. & Roper D.K., "Separation Process Principles",4th Edition, John Wiley & Sons, Inc. Hoboken, New Jersey,2016
5. Kulprathipanja S. "Reactive Separation Processes" , Taylor and Francis, New York, 2002.

Elective: Chemical Engineering Plant Design and Economics

L	T	P	Credit
3	0	0	03

CH442 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Appraise criteria for selection of a process and explain the importance of plant location and plant layout, cost estimation and profitability analysis of process plants
CO2	Construct flow diagrams for a given reaction with known conditions.
CO3	Recognize the importance of process utilities and auxiliaries for better plant operations.
CO4	Prepare the control strategies for a given process flow diagram with known conditions.
CO5	Compare various equipment's for the same activity based on economy.
CO6	Appraise the concept of optimization in plant operation and importance of project management tools (PERT and CPM) in process industries.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Basic consideration in chem. Engg. plant design, project identification, preliminary techno-economic feasibility.

- **PROCESS DESIGN ASPECTS** **(4 Hours)**
  Selection of process, factors affecting process selection, types of flow diagrams.

- **SELECTION OF PROCESS EQUIPMENT** **(2 Hours)**
  Standard versus special equipment, materials of construction, selection criteria etc.

- **PROCESS AUXILIARIES** **(3 Hours)**
  Piping design, layout, support for piping insulation, types of valves, process control & instrumentation control system design.

- **PROCESS UTILITIES** **(4 Hours)**
  Process water, boiler feed water, water treatment & disposal, steam, oil heating system, chilling plant, compressed air and vacuum system.

- **PLANT LOCATION AND LAYOUT** **(4 Hours)**
  Factors affecting plant location, use of scale models.

- **COST ESTIMATION** **(6 Hours)**
  Factors involved in project cost estimation, total fixed & working capital, types & methods of estimation of total capital investment, estimation of total product cost, factors involved.

- **DEPRECIATION** **(3 Hours)**
  Types and methods of determination, evaluation.

- **PROFITABILITY** **(4 Hours)**
  Alternative investment & replacement methods for profitability evaluation, economic consideration in process and equipment design, inventory control.

- **OPTIMUM DESIGN** **(2 Hours)**
  General products rates in plant operation, optimum conditions etc.

- **PRODUCTION, PLANNING, SCHEDULING AND CONTROL** **(8 Hours)**
  Introduction, PERTS & CPM

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Peters M.S., Timmerhaus, K.D., "Plant Design and Economics for Chemical Engineers", 4th Ed., McGraw-Hill, Singapore, 1991.
2. Vilbrant F.C., Dryden, C.E., "Chemical Engineering and Plant Design", 4th Ed., McGraw-Hill, New York, 1959.
3. Pant J.C. "CPM and PERT with Linear Programming", Jain Brothers, New Delhi, 1986.
4. Davis, G.S, "Chemical Engineering Economics and Decision Analysis", CENDC, I.I.T., Madras, 1981.
5. Holland, F.A., Watson, F.A and Wilkinson, J.K., "Introduction to Process Economics", Wiley, New York, 1974.

Elective: Safety and Pollution Control in Chemical Process Industries

L	T	P	Credit
3	0	0	03

CH440 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Express knowledge about types of pollution, its sources, effects and control
CO2	Classify Industrial Laws and Act.
CO3	Describe different methods of hazard analysis and control of hazards.
CO4	analyze different types of fire and explosions and its control
CO5	Explain about the quantification and analysis of wastewater and treatment.
CO6	Propose various analysis and quantification of hazardous and nonhazardous solid waste, treatment and disposal

2. Syllabus:

- **ENVIRONMENTAL AND POLLUTION IN CHEMICAL INDUSTRIES (2 Hours)**
  Definitions, scope and importance, need for public awareness, sources of pollution from Chemical industries

- **ENVIRONMENTAL LAWS AND STANDARDS (3 Hours)**
  Laws related to solid, liquid and gases effluents, standards and legislations, Health and environmental effects, case studies for specific industries like petrochemicals, fertilizers, desalination, petroleum refining.

- **POLLUTION PREVENTION THROUGH PROCESS MODIFICATION (9 Hours)**
  Recovery of by-products, Energy recovery, Waste utilization and recycle and reuse and waste generation minimization

- **AIR POLLUTION CONTROL (5 Hours)**
  Air pollution control through mechanical separation, adsorption, etc

- **WATER POLLUTION CONTROL (5 Hours)**
  Water pollution control by physical, chemical and biochemical methods

- **DESIGN OF CONTROL EQUIPMENT AND SYSTEMS (6 Hours)**
  Designs to prevent fires and explosions, fire triangles, fault tree analysis, case studies

- **SOLID WASTE TREATMENT AND DISPOSAL (4 Hours)**
  Types of solid waste, generation, onsite handling, storage & processing, Disposal techniques, recovery of resources, conversion products and energy

- **SAFETY IN CHEMICAL PROCESS INDUSTRIES** **(8 Hours)**
  Safety and loss prevention, safety systems, Hazardus properties of chemicals, characterization of chemical processes, the nature and impact of chemical plant accidents, occupational safety and industrial hygiene, Toxicology, toxic release, case studies

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Crowl D. A., Louvar J. F., "Chemical Process Safety", Prantice-Hall, 2nd Ed., New York, 2002.
2. Metcalf & Eddy, "Waste Water Engineering: Treatment, Disposal and Reuse", Tata-McGraw-Hill, New Delhi, 2002.
3. MaCarty S., "Chemistry for Environmental Engineering", Tata-McGraw-Hill, New Delhi, 2004.
4. Rao C.S., Environmental Engineering, Wiley Eastern Limited, New Delhi, 1995.
5. Sanders R E., "Chemical Process Safety", Butterworth-Heinemann, New Delhi, 2005.

Elective: SAFETY, HAZARD AND RISK ANALYSIS

L	T	P	Credit
3	0	0	03

CH446 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Recognize the importance of safety in any chemical process industries.
CO2	Adapt the basic fundamentals of chemical process safety, laws of safety.
CO3	Apply various the methods of hazard identification for any chemical process.
CO4	Perform the risk analysis and risk assessment for any system to minimize the hazards.
CO5	Adapt the important learnings from the Case Histories.
CO6	Summarize the characteristics of various causes of incidents like toxic release, fire and explosion etc.

2. Syllabus:

- **SAFETY** **(10 Hours)**
  Safety Programs, Engineering Ethics, Accident Loss Statistics- FAR, OSHA, Fatality rate, Acceptable risk, Public Perceptions, Inherent safety, Nature of the accident process and their steps, Case Studies: Flixborough, England, Bhopal Gas Tragedy, A massive explosion in Pasadena, Leakage of 2,3,7,8-tetrachlorodibenzoparadioxin in Seveso, Related to Static Electricity, Chemical Reactivity, System Designs, Procedures.

- **HAZARDS AND ITS IDENTIFICATION** **(10 Hours)**
  Toxicology: Entry of toxicants in Biological organism (BO), Elimination of Toxicant from BO, Effect of Toxicants in BO, Dose Versus Response, TLVs; **Fire And Explosion**: The fire triangle, Distinction between Fire and explosion, estimation of flammability characteristics of vapor and liquids, Limiting oxygen characteristics and inerting, Detonation and deflagration, BLEVE, Vapor-cloud explosion, Fire extinguisher. **Methods of Hazard Identification**: Process hazard checklists, HAZOP study, Safety Reviews, Other methods, Problem solving.

- **RISK ANALYSIS** **(10 Hours)**
  Review of Probability theory, Probability of Coincidence, Revealed & Unrevealed failures, Fault tree analysis, Cut Sets, Path sets, Reliability diagram, Event tree analysis, Quantitative risk analysis, Layer of Protection analysis, Consequence, Frequency, Problems solving.

- **CASE HISTORIES** **(12 Hours)**
  Static Static Electricity:Tank Car Loading Explosion, Explosion in a Centrifuge, Duct System Explosion; Chemical Reactivity: Bottle of Isopropyl Ether, etc; System Designs: Ethylene Oxide Explosion, Ethylene Explosion, Butadiene Explosion, Pump Failure etc ; Procedures: Leak Testing a Vessel, Man Working in Vessel, Vinyl Chloride Explosion

etc , Dangerous Water Expansion, Phenol-Formaldehyde Runaway Reaction, Conditions and Secondary Reaction Cause Explosion etc

(Total Lecture Hours: 42 Hours)

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3. Books Recommended:

1. Crowl D. A., Louvar J. F., "Chemical Process Safety", Prentice-Hall, 2nd Ed., New York, 2002.
2. Sanders R E., "Chemical Process Safety", Butterworth-Heinemann, New Delhi, 2005.
3. Perry's Chemical Engineers' Handbook, 8^{th} Edition
4. "Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control", Butterworth-Heinemann, 2012.
5. Raju, K.S.N., "Chemical Process Industry Safety", McGraw Hill Education Pvt Ltd. (India), 2014.

B. Tech. IV (Chemical Engineering), Semester - VIII

Innovation, Incubation and Entrepreneurship

L	T	P	Credit
3	0	0	04

HU 402 **Scheme**

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Explain the concepts of Entrepreneurship
CO2	Develop skills related to various functional areas of management (Marketing Management, Financial Management, Operations Management, Personnel Management etc.)
CO3	Develop skills related to Project Planning and Business Plan development
CO4	Demonstrate the concept of Innovation, Intellectual Property Rights (IPR) and Technology Business incubation
CO5	Build knowledge about Sources of Information and Support for Entrepreneurship
CO6	Develop Entrepreneurial Culture

2. Syllabus:

- **CONCEPTS OF ENTREPRENEURSHIP** **(10 Hours)**

  Scope of Entrepreneurship, Definitions of Entrepreneurship and Entrepreneur, Characteristics of an Entrepreneur, Entrepreneurial Development models and Theories, Entrepreneurs Vs Managers Classification of Entrepreneurs; Major types of Entrepreneurship – Techno Entrepreneurship, Women Entrepreneurship, Social Entrepreneurship, Intrapreneurship (Corporate entrepreneurship), Rural Entrepreneurship, Family Business etc.; Problems for Small Scale Enterprises and Industrial Sickness; Entrepreneurial Trait Tests; Entrepreneurial Environment – Political, Legal, Technological, Natural, Economic, Socio – Cultural etc. ; Motivation; Business Opportunity Identification

- **FUNCTIONAL MANAGEMENT AREA IN ENTREPRENEURSHIP** **(12 Hours)**

  Marketing Management: Basic concepts of Marketing, Development of Marketing Strategy and Marketing plan, Online Marketing, New Product Development Strategy

  Operations Management: Basic concepts of Operations management, Location problem, Development of Operations strategy and plan

  Personnel Management: Main operative functions of a Personnel Manager, Development of H R strategy and plan

  Financial Management: Basics of Financial Management, Ratio Analysis, Capital Budgeting, Working Capital Management, Cash Flow Statement, Break Even Analysis

- **PROJECT PLANNING** **(6 Hours)**

  Product Development – Stages in Product Development; Feasibility analysis – Technical, Market, Economic, Financial etc.; Project report; Project appraisal; Setting up an Industrial unit – procedure and formalities in setting up an Industrial unit; Business Plan Development

- **PROTECTION OF INNOVATION THROUGH IPR** **(4 Hours)**

  Introduction to Intellectual Property Rights – IPR, Patents, Trademarks, Copy Rights

- **INNOVATION AND INCUBATION** **(6 Hours)**

  Innovation and Entrepreneurship, Creativity, Green Technology Innovations, Grassroots Innovations, Issues and Challenges in Commercialization of Technology Innovations, Introduction to Technology Business Incubations, Process of Technology Business Incubation

- **SOURCES OF INFORMATION AND SUPPORT FOR ENTREPRENEURSHIP** **(4 Hours)**

  State level Institutions, Central Level institutions and other agencies

Tutorial: Case Study Discussion, Group Discussion, Management games and Assignments / Mini projects & presentation on related Topics

(**Total Lecture Hours: 42 + Tutorial Hours: 14)**

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3. <u>Books Recommended:</u>

1. Desai Vasant, "Dynamics of Entrepreneurial Development and Management", Himalaya Publishing House, India, 6th Revised Edition, 2011
2. Charantimath P. M., "Entrepreneurial Development and Small Business Enterprises", Pearson Education, 3rd Edition, 2018
3. Holt David H., Entrepreneurship: New Venture Creation, Pearson Education, 2016
4. Chandra P., Projects: Planning, Analysis, Selection, Financing, Implementation and Review, Tata McGraw Hill, 9th Edition, 2019
5. Banga T. R. &Shrama S.C., Industrial Organisation& Engineering Economics, Khanna Publishers, 25th Edition, 2015