SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

M.Tech. in Chemical Engineering

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY

ICHHANATH, SURAT – 395007, GUJARAT.

VISION & MISSION

INSTITUTE VISION

To be one of the leading Technical Institutes disseminating globally acceptable education, effective industrial training and relevant research output.

DEPARTMENT VISION

In-line with the vision of the institute, to be a well reputed department with global acceptance and to produce highly skilled and knowledgeable chemical engineering graduates, post graduates and doctorates capable of delivering the best output to the society.

INSTITUTE MISSION

To be a globally accepted centre of excellence in technical education catalyzing absorption, innovation, diffusion and transfer of high technologies resulting in enhanced quality for all the stake holders.

DEPARTMENT MISSION

To be one of the top engineering departments with excellent research work in the fields related to Chemical Engineering and offering technical knowhow to the stake holders.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Have successful career in the diversified areas of chemical engineering (Research & Development, Academic and Industry) by acquiring knowledge in various advances of chemical engineering at global Level.

PEO 2: Analyze and design contemporary chemical engineering issues with socio-economic and environmental awareness and responsibility.

PEO 3: Exhibit professional approach, communication skills, team work in their profession and adapt to modern trends by engaging in lifelong learning.

PROGRAM OUTCOMES (POs)

PO 1: An ability to independently carry out research / investigation and development work to solve practical problems.

PO 2: An ability to write and present a substantial technical report / document.

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO 1: Recognize global challenges for solving engineering prolems related to chemical and allied fields through design and development of chemical processes.

PSO 2: Propose, investigate and evaluate sustainable solutions for chemical processes/products with socio-economical and environmental awareness alongwith professional ethics.

TEACHING SCHEME

M.Tech - I (SEMESTER – I)

S.No.	Course	Code	Credits	Teaching scheme			Examination scheme			Total
				L	T	P	L	T	P	
1	Optimization Techniques (Core - 1)	CHCH101	4	3	1	0	100	25		125
2	Advanced Chemical Engineering Thermodynamics (Core – 2)	CHCH102	4	3	1	0	100	25		125
3	Advanced Transport Phenomena (Core – 3)	CHCH103	4	3	1	0	100	25		125
4	Department Elective-1	CHCH1XX	3	3	0	0	100			100
5	Department Elective-2	CHCH1YY	3	3	0	0	100			100
6	Modelling/ Simulation/ Software Tools Laboratory - 1	CHCH104	2	0	0	4			100	100
7	Laboratory Practice - 1	CHCH105	2	0	0	4			100	100
	TOTAL		22	15	3	8	500	75	200	775
Total contact hours per week = 26										

Department Elective - 1 (CHCH1XX)		
S.No.	Code	Elective course
1	CHCH110	Nanotechnology
2	CHCH111	Smart Polymers
3	CHCH112	Nanomaterials Synthesis and Applications
4	CHCH113	Interfacial Science and Engineering

Department Elective - 2 (CHCH1YY)		
S.No.	Code	Elective course
1	CHCH120	Polymer Engineering
2	CHCH121	Process Intensification
3	CHCH122	Multiphase Flow

M.Tech - I (SEMESTER – II)

S.No.	Course	Code	Credits	Teaching scheme			Examination scheme			Total
				L	T	P	L	T	P	
1	Advanced Chemical Reaction Engineering (Core - 4)	CHCH201	4	3	1	0	100	25		125
2	Advanced Separation Methods (Core - 5)	CHCH202	4	3	1	0	100	25		125
3	Department Elective-3	CHCH2XX	3	3	0	0	100			100
4	Department Elective-4	CHCH2YY	3	3	0	0	100			100
5	Institute Elective - 1	CHCH2ZZ	3	3	0	0	100			100
6	Modelling/ Simulation/ Software Tools Laboratory - 2	CHCH203	2	0	0	4			100	100
7	Laboratory Practice - 2	CHCH204	2	0	0	4			100	100
8	Seminar	CHCH205	2	0	0	4			100	100
	TOTAL		23	15	2	12	500	50	300	850
Total contact hours per week = 29										

Department Elective - 3 (CHCH2XX)		
S.No.	**Code**	**Elective course**
1	CHCH210	Complex Fluids
2	CHCH211	Industrial Biotechnology
3	CHCH212	Environment, Health and Safety
4	CHCH213	Computational Fluid Dynamics

Department Elective - 4 (CHCH2YY)		
S.No.	**Code**	**Elective course**
1	CHCH221	Design of Experiments
2	CHCH222	Advanced Process Control
3	CHCH223	Catalyst Science and Technology
4	CHCH224	Sustainable Development Goals

Institute Elective - 1 (CHCH2ZZ)		
S.No.	**Code**	**Elective course**
1	CHCH230	Corrosion and Electrochemical Engineering
2	CHCH231	Non Conventional Energy
3	CHCH232	Environment Management System

M.Tech - II (SEMESTER – III)

S.No.	Course	Code	Credits	Teaching scheme			Examination scheme			Total
				L	T	P	L	T	P	
1	Dissertation Preliminaries	CHCH301	10	0	0	20	--	--	300	300
	TOTAL		10	0	0	20	--	--	300	300

M.Tech - II (SEMESTER – IV)

S.No.	Course	Code	Credits	Teaching scheme			Examination scheme			Total
				L	T	P	L	T	P	
1	Dissertation	CHCH401	12	0	0	24	--	--	400	400
	TOTAL		12	0	0	24	--	--	400	400

Total Credits: 67

Core 1: Optimization Techniques

L	T	P	Credit
3	1	0	04

CHCH101 **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** **(4 Hours)**
  Scope and Hierarchy of Optimization, The essential Features of Optimization Problems, Maximization and minimization problems- examples, Basic concepts of optimization – Convex and concave functions, Necessary and sufficient conditions for stationary points, Degrees of freedom.

- **MODELS FOR OPTIMIZATION** **(4 Hours)**
  Classifications of Models, How to build a Model fitting.

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

- **UNCONSTRAINED AND CONSTRAINED SEARCH** **(8 Hours)**
  Optimizing a function of one-variable, Unconstrained multivariable optimization, direct search methods, Indirect first order and second order methods, Constrained multivariable optimization - necessary and sufficient conditions for constrained optimum.

- **LINEAR PROGRAMMING AND APPLICATIONS** **(7 Hours)**
  Geometry of linear programs, Basic solution methods, Simplex algorithm and its applications. Sensitivi Analysis

- **NON-LINEAR PROGRAMMING WITH CONSTRAINTS** **(5 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.

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

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

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

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.

Core 2:
Advanced Chemical Engineering Thermodynamics

L	T	P	Credit
3	1	0	04

CHCH102 **Scheme**

1. Course Outcomes (COs):

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

CO1	Describe intermolecular forces and relate to macroscopic thermodynamic properties.
CO2	Differentiate between ideal and non-ideal thermodynamic behaviour in both pure substances and mixtures.
CO3	Explain phase equilibria for multicomponent systems.
CO4	Estimate the thermodynamics properties of mixtures and solutions.
CO5	Evaluate and apply different methods/assumptions for performing phase equilibrium calculations,
CO6	Explain multi-reaction equilibria and solve problems.

2. Syllabus:

- **REVIEW OF CLASSICAL THERMODYNAMICS** **(3 Hours)**

- **PROPERTIES OF PURE FLUIDS** **(4 Hours)**
  Thermo Properties from Volumetric Data, Equations of State, Generalized correlations.

- **INTERMOLECULAR INTERACTIONS AND CORRESPONDING STATE THEORY** **(5 Hours)**
  Origin of interactions (Permanent, induced and instantaneous dipoles), Intermolecular forces and potential energy functions, Corresponding states theory

- **THERMODYNAMIC PROPERTIES OF MIXTURES** **(15 Hours)**
  Mixtures, partial molar properties, Chemical potential, Gibbs Duhems equations, Property changes on mixing, Fugacity in gas mixtures-Virial and Cubic EOS, corresponding states, fugacities in liquid mixures, fugacities in liquid mixures(electrolyte solution) Excess Functions in Liquid Mixtures, Models for Excess Gibbs energy

- **PHASE EQUILIBRIA** **(8 Hours)**
  Multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Solubility of gases in liquids, solubility of solids in liquids.

- **CHEMICAL EQUILIBRIUM** **(5 Hours)**
  Combined phase and Reaction equilibrium

- **INTRODUCTION TO MOLECULAR SIMULATION** **(2 Hours)**

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

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

1. J.M. Prausnitz, R.M. Lichtenthaler and E.G. Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria,3rd edition, Prentice Hall Inc., New Jersey,1999.
2. J.M. Smith. H.C. Van Ness and M.M.Abott, Introduction to Chemical Engineering Thermodynamics, 8th edition, McGraw Hill International edition, 2018.
3. S. I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, 5th Edition, John Wiley & Sons, Inc.,2017. ISBN: 978-1-119-32128-6
4. B. E. Poling, J. M., Prausnitz, J. P. O'Connell, The Properties of Gases and Liquids, 5th edition, McGraw Hill, 2001.
5. J.W. Tester and M. Modell, Thermodynamics and Its Applications, 3rd ed.,Prentice Hall, NJ, 1997.

Core 3: Advanced Transport Phenomena

L	T	P	Credit
3	1	0	04

CHCH103 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand the chemical and physical transport processes and their mechanism
CO2	Perform heat, mass and momentum transfer analysis
CO3	Analyze industrial problems along with appropriate approximations and boundary conditions
CO4	Develop steady and time dependent solutions along with their limitations
CO5	Analyze various transport processes with understanding of solution approximation methods and their limitations.
CO6	Solve mass balance for steady and unsteady-state problems.

2. Syllabus:

- **INTRODUCTION** **(1 Hour)**
  .
- **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)** **(14 Hours)**
  Shell momentum balances and velocity distributions. Shell energy balances and temperature distributions. Shell mass balances and concentration distributions.
- **USE OF GENERAL TRANSPORT EQUATIONS** **(5 Hours)**
  Equations of change and their use in momentum transport (isothermal). Equations of change and their use in energy transport (nonisothermal). Equations of change and their use in mass transport (mixtures).
- **TRANSPORT WITH TWO INDEPENDENT VARIABLES** **(2 Hours)**
- **VELOCITY DISTRIBUTION IN TURBULENT FLOW** **(2 Hours)**
- **INTERPHASE TRANSPORT IN ISOTHERMAL SYSTEMS** **(4 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.

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

3. Books Recommended:

1. Bird R.B., Stewart W.E. and Lightfoot E.N., “Transport Phenomena” 2nd Ed., John Wiley & Sons, Singapore, 2002.
2. Thomson, W.J. “Introduction to Transport Phenomena” Pearson Education Asia, Singapore, 2000.
3. Brodkey R.S. and Hershey H.C., “Transport Phenomena: A Unified Approach” McGraw-Hill, 1989.
4. Plawsky J.L., “Tranport Phenomena Fundamentals”, Marcel Dekker, New York, 2001.
5. Slattery J.C., Sagis L. and Oh E-S., “Interfacial Transport Phenomena”, 2nd Ed., Springer, 2007

Core 4: Advanced Chemical Reaction Engineering

L	T	P	Credit
3	1	0	04

CHCH201 **Scheme**

1. Course Outcomes (COs):

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

CO1	Analyse the non ideal behaviour of reactors by tracer experiments and suitable models.
CO2	Understand heterogeneous catalysed reactions.
CO3	Design reactors for catalytic reactions.
CO4	Discuss about the applications of supported catalysts.
CO5	Apply the knowledge gained for the environmental impact.
CO6	Distinguish between laboratory and structured reactors.

2. Syllabus:

- **NON-IDEAL REACTORS AND RTD STUDIES** **(6 Hours)**
  Non ideal flow in reactors, RTD of fluid in reactors, E and F curves, Washout and Intensity Functions, Effects of RTD on performance of Chemical Process Equipment, Two-parameter models for analyses of flow through reactors

- **KINETICS OF HETEROGENEOUSLY CATALYSED REACTIONS** **(6 Hours)**
  Adsorption kinetics, External and internal diffusional and thermal resistances, Diffusion disguised kinetic observations, Effects of heat generation/absorption, Nonisothermal effectiveness factors, LHHW and Eley-Rideal rate expressions, Method of initial rates

- **CATALYSIS** **(6 Hours)**
  Typical catalysts used in chemical processes, Catalyst characterizations, Design of catalysts, Mechanistic aspects of catalysis

- **CATALYST DEACTIVATION AND REGENERATION PROTOCOL** **(2 Hours)**
  Modelling catalyst deactivation by coking, sintering, etc., Concept of conversion capacity, Circumventing catalyst deactivation during operation, Catalyst regeneration protocols

- **MULTIPHASE REACTORS** **(6 Hours)**
  Kinetic analyses of slurry- and trickle bed- reactors, Bubble column slurry reactors, Loop slurry reactors, Hydrodynamics in reactors

- **REACTOR DESIGN** **(5 Hours)**
  Fixed bed-, Fluid bed-, Trickle bed-, Slurry- reactors

- **ZEOLITE CATALYSIS** **(4 Hours)**
  Rise of Acidity, Modifications, Shape Selectivity, Inverse shape selectivity, Applications in refining and petrochemicals processes

- **ENVIRONMENTAL CATALYSIS** **(2 Hours)**

Importance, Applications

- **LABORATORY REACTORS** **(3 Hours)**
  Experiments for absence of Intra-particle and extra-particle transport gradients, Criteria for kinetic regime of experiments, Experimental measures of catalyst performance, Guidelines for catalyst testing, Types of laboratory reactors

- **STRUCTURED REACTORS** **(2 Hours)**
  Configurations, Preparation, Hydrodynamics and Applications, Accelerated Deactivation of catalysts, Laboratory reactors, Oscillatory motion of reactants in catalyst pores, Microreactors, Single pellet string reactors.

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

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3. Books Recommended:

1. Fogler H.S., Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall, NJ, 2006
2. Doraiswamy L.K., Uner D., Chemical Reaction Engineering Beyond the Fundamentals, CRC Press, Ney York, 2014
3. Smith J. M., Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, N Y, 1981.
4. Levenspiel O., Chemical Reaction Engineering, 3rd Edition, John Wiley & Sons, Singapore, 1998.
5. Aida T. and Silverstone PL, Cyclic Separating Reactors, Blanchwell publications Ltd. 2005.

4. Additional Reading:

1. Silverston P. L., Composition Modulation of Catalytic Reactors, CRC Press, 1998
2. Hand-outs from recent publications.

Core 5: Advanced Separation Methods

L	T	P	Credit
3	**1**	**0**	**04**

CHCH202 **Scheme**

1. Course Outcomes (COs):

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

CO1	Describe fundamental concepts of separation processes
CO2	Discuss the principles and process of crystallization
CO3	Identify various membrane-based separation processes and its applications
CO4	Summarize the properties of colloidal separation
CO5	Explain surfactant-based separation
CO6	Discuss supercritical fluid extraction

2. Syllabus:

- **MEMBRANE SEPARATION PROCESSES** **(25 Hours)**
  Reverse Osmosis, Nanofiltration, Ultrafiltration, Microfiltration, Dialysis, Electrodialysis, Gas Permeation, Pervaporation, Liquid Membranes, Membrane Preparation Methods, Membrane Properties and Characterization, Membrane Transport Models, etc.

- **BASICS OF EMERGING MEMBRANE SEPARATION PROCESSES** **(7 Hours)**
  Membrane Distillation, Membrane Distillation-Crystallization, Membrane Bioreactor, Forward Osmosis, Pressure Retarded Osmosis, Reverse Electrodialysis, Membrane Dryer, etc.

- **OTHER SEPARATION METHODS** **(10 Hours)**
  Supercritical Fluid Extraction, Reactive Separations, Chromatography, Sublimation, Foam Separation, Ion Exchange, Zone Melting, etc.

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

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3. Books Recommended:

1. Wankat P. C., "Rate-Controlled Separations", Elsevier Applied Science, New York, 1990.
2. Baker R.W., "Membrane Technology and Applications", 3rd Ed., John Wiley and Sons, Chichester (UK), 2012.
3. Rajindar Singh, "Membrane Technology and Engineering for Water Purification", 2nd Ed., Elsevier Inc., Oxford (UK), (2015)
4. 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.
5. Kaushik Nath, "Membrane Separation Processes", 2nd Ed., PHI, New Delhi, 2017.
6. Recent literature from Journals on related topics.

L	T	P	Credit
3	0	0	03

Department Elective - 1: Nanotechnology

CHCH110 **Scheme**

1. Course Outcomes (COs):

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

CO1	To describe about the origin of Nanotechnology and its scope.
CO2	To explain the nanomaterials and their synthesis processes.
CO3	To explain about basics of characterization techniques of nanomaterials.
CO4	To estimate various types of applications and performance.
CO5	To analyse the potential of nanotechnology and new opportunity for future.
CO6	To explain the risk associated with nanoparticles and their remediation.

2. Syllabus:

- **INTRODUCTION TO NANOTECHNOLOGY** **(5 Hours)**
  Global issues, what is nanotechnology, its overview and need, History, nano-scale, its need or significance, scope utilization, applications, importance, properties at nanoscale, applications, Theoretical concepts from Classical Physics and Quantum Mechanics, hazards associated at nanoscale, etc.

- **NANOMATERIALS** **(6 Hours)**
  Nanoparticles, carbon nanotubes, nanowires, nanofilms, nanostructured bulk materials, magnetic nanoparticles, biological nanoparticles, Applications, etc. Zero-D, One-D, Two-D, Three-Dimensional materials

- **SYNTHESIS OF NANOMATERIALS** **(8 Hours)**
  Top-down and bottom approach for nano-material synthesis, Sol-Gel process, Microwave heating, Gas phase condensation, Sputtering Techniques, High energy attrition milling, electro depositions, plasama enhanced vapour deposition, physical and chemical vapor deposition, benefits and limitations of each and applications, nanomaterials fabrications by modeling and simulations.

- **CHARACTERIZATION TECHNIQUES** **(8 Hours)**
  Atomic Force Microscope (AFM), Scanning electron microbiology (SEM), Transmission electron microscopy (TEM), Scanning Tunneling microscopy (STM), Scanning Probe microscopy (SPM), Thermogravemetric analysis (TGA), X-ray diffraction technique (XRD)
  Particle Size: Nano particle sizer, Plasama emission spectrophotometer
  Film thickness: Nano film thickness

- **APPLICATION OF NANOTECHNOLOGY** **(10 Hours)**
  Environmental Engineering, wastewater treatment, nanocoatings, nanocomposites, nano catalyst, paint industry, glass industry, textile industries, medical, drug delivery, energy sector, nanomembranes, nanosensors, zerovalent iron nanoparticle, nanosized photo catalyst, nano-probs/sensors, FISH, Waste to energy systems, Fuel cell systems, Energy storage devices.

- **RISK OF NANOTECHNOLOGY** **(5 Hours)**
  Toxic effects, phytotoxicity, limits and guidelines for air, water, soil and future threat, health aspects, Life cycle assessment.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Pradeep T. "A text book of Nanoscience and Nanotechnology" 2017, 2nd Edition
2. Guozhong C. "Nanostructure and nanomaterials, synthesis, properties and applications" (Imperial College Press), 2nd Edition, 2019
3. Wilson M. "Nanotechnology, basic science and emerging Technology" (Chapman & Hall/CRC), 1st Edition, 2002.
4. Harald F. K. "Nanotechnology, Environmental Aspects" Vol. 2 (Wiley) 1st Edition, 2008
5. Chattopadhyay K. K. and Banarjee A. N. "Introduction to Nanoscience and nanotechnology", 1st Edition, 2009.

Department Elective -1: Smart Polymers

L	T	P	Credit
3	0	0	03

CHCH111 **Scheme**

1. Course Outcomes (COs):

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

CO1	Summarize knowledge of basic concepts of polymer and its characterization
CO2	Identify various rheological properties for polymer
CO3	Evaluate polymer properties from different polymerization data
CO4	Understand various properties of smart polymers
CO5	Explain huge potential role of smart polymers in the future technology development
CO6	Describe degradation behavior of polymer and its impact on environment

2. Syllabus:

- **POLYMERIZATION** **(4 Hours)**
  Mechanism of different polymerization, Newer methods of synthesis of polymers, Special purpose polymers.

- **CHARACTERIZATION METHODS** **(3 Hours)**
  Polymer Characterization i.e., Gel Permeation chromatography (GPC), Concept of different average molecular weight Fourier Transform Infrared Spectroscopy (FTIR), Thermal Analysis, X-ray Diffraction, Electrical Properties, Optical Properties.

- **RHEOLOGICAL PROPERTIES OF POLYMERS** **(3 Hours)**
  Simple shear flows, elongation flows. Polymer solutions. Relation between properties and structure, crystallinity and orientation. Crosslinking of polymers and elastomers,

- **NEWER METHODS FOR SYNTHESIS OF POLYMERS** **(7 hours)**
  Classification of nanocomposites & their comparison with normal composites & blends, Different methods of preparation of polymer nanocomposite and blend

- **SPECIAL PURPOSE POLYMER** **(8 Hours)**
  Polymers responding to various stimuli such as heat, light, pressure, fluids/chemicals etc. Conducting polymers classification/ requirements for conductivity, doping of polymers, light emitting polymers, liquid crystal polymers their classification (LCPs).

- **SMART POLYMERS** **(10 Hours)**
  Microgels, Protein-based smart polymers, pH-responsive and photo-responsive polymers, Self-assembly, Shape-memory polymers (SMPs), Biodegradable polymers, self-cleaning polymer, Other newer type of polymers.

- **SMART HYDROGELS** **(4 Hours)**

Synthesis, Fast responsive hydrogels, Molecular recognition, Smart hydrogels as actuators, Controlled drug release, artificial muscles, Hydrogels in microfluidics

- **BIO- POLYMER AND DEGRADATION** **(3Hours)**
  Bio-polymer, Recycling of polymers & environment and Polymer coding, various latest methods of polymer degradation and its impact on Environment.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. N. Yui, R. J. Mrsny, K. Park (Eds.), Reflexive Polymers and Hydrogels: Understanding and Designing Fast Responsive Polymeric Systems, CRC Press, 2004.
2. Galaev, B. Mattiasson (Eds.), Smart Polymers: Applications in Biotechnology and Biomedicine, 2nd ed., CRC Press, 2008.
3. Gowariker, V.R., Viswanathan, N.V., and Sreedhar, J., “Polymer Science”, Halsted Press
4. B. R. Gupta, Applied Rheology in Polymer Processing, Asian Books Private Limited, New Delhi, 2005
5. M. M. Schwartz, Composite Material Handbook, , McGraw-Hill company, 1984.
6. Recent literature from Journals on smart polymer.

Department Elective -1: Nanomaterials Synthesis and Applications

L	T	P	Credit
3	0	0	03

CHCH112 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand the importance of nanomaterials, and types of synthesis methods and their applications
CO2	Learn advantages of chemical synthesis methods of nanomaterials and aspects involved in chemical methods of nanomaterial synthesis
CO3	Learn aspects involved in Colloidal synthesis of various nanostructures and phase behavior
CO4	Learn features involved in Nano catalyst preparation methods and applications
CO5	Learn aspects involved in Nanomaterial synthesis and thin film preparation methods for energy sectors and aspects and controlling operating parameter involved
CO6	Optimization and finding the best optimum parameters using DOE

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.

- **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 NANO CATALYSIS** **(8 Hours)**
  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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3. Books Recommended:

1. Hornyak G.L., Tibbals, H.F., Dutta, J., "Introduction to Nanoscience and Nanotechnology", CRC Press, Taylor and Francis, US, 2009.
2. Singh N.(Editor), "Encyclopedia of Nanoscience and Nanotechnology", Volume 10, American Scientific Publishers,USA, 2004.
3. Brechignac, C., Houdy, P., Lahmani, M. (Editors), "Nanomaterials and Nanochemistry, Springer-Verlag Berlin Heidelberg, 2007
4. Ozin G.A, Arsenault A.C., "Nanochemistry: A chemical approach to nanomaterials", Royal society of chemistry, UK,2005.
5. Philips J. Ross,"Taguchi Techniques for Quality Engineering", Magraw-Hill, 1996.

4. Additional Reading:

1. Ratner M., Ratner D., "Nanotechnology: A gentle introduction to the next big idea", Prentice-Hall, New Jersey, 2002.
2. Chatopadhyay K. K., Banerjee A. N., 2009, PHI Learning Pvt. Ltd., New Delhi, India

Department Elective -1: Interfacial Science and Engineering

L	T	P	Credit
3	0	0	03

CHCH113 **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. Books Recommended:

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.

4. Additional Reading:

1. Adamson A. W. Gast A., "Physical Chemistry of Surfaces", 6th edition, John Wiley and Sons, New Jersey, 1997.
2. Edwards D. A. Brenner H., Wasan D.T., "Interfacial Transport Processes and Rheology", Butterworth Heinmen, Oxford, 2013.
3. Masliyah J.H., Bhattacharjee S., "Electrokinetic and Colloid Transport Phenomena" John Wiley & Sons, New Jersey, 2008.

Department Elective -2: Polymer Engineering

L	T	P	Credit
3	0	0	03

CHCH120 **Scheme**

1. Course Outcomes (COs):

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

CO1	Estimate the basic concept of monomer, polymer and polymer blend/composite.
CO2	Classify different polymerization reactions and their mechanisms/kinetics.
CO3	Analyze polymerization data and calculate the conversion and molecular weight.
CO4	Describe the thermal, mechanical and viscoelastic behavior of polymers with respect to their chemical structures and molecular weights.
CO5	Demonstrate an ability to predict polymer degradation.
CO6	Express the knowledge of smart polymer and its uses.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Monomers, Polymers, Classification of polymers

- **POLYMER CHEMISTRY** **(9 Hours)**
  Polymerization methods: addition and condensation; their kinetics, Copolymerization, Monomer reactivity ratios and its significance, Kinetics, Different copolymers, random, alternating, azeotropic copolymerization, block and graft copolymers, Techniques for copolymerization-bulk, solution, suspension, emulsion

- **POLYMER CHARACTERIZATION** **(10 Hours)**
  Concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, Gel Permeation Chromatography (GPC), Membrane osmometry, Dilute solution viscosity method, Ultracentrifugation, Analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques.

- **POLYMER BLANDS AND COMPOSITES** **(4 Hours)**
  Difference between blends and composites, their significance, Choice of polymers for blending, Fiber-reinforced plastic, long and short fibre reinforced composites, Nanocomposites

- **POLYMER TECHNOLOGY** **(3 Hours)**
  Polymer compounding, Need and significance of polymer compounding, Different compounding ingredients for polymer, Crosslinking and vulcanization, Smart polymer

- **POLYMER PROCESSING** **(6 Hours)**
  Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer. Commodity and general-purpose thermoplastics

and thermosetting polymers: PE, PP, PS, PVC, PF, MF, UF, Epoxy, Unsaturated polyester etc.

- **SMART POLYMER** **(5 Hours)**
  Special purpose polymers, Stimuli response polymers, Self-healing polymer, Conductive polymers, Superabsorbent polymers

- **POLYMER DEGRADATION** **(3 Hours)**
  Definition, Types of degradation, Nanoplastic, Recent trend polymer degradation.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Gowariker, V.R., Viswanathan, N.V., and Sreedhar, J., "Polymer Science" 1st Edition, Halsted Press (John Wiley & Sons), New York, 1986.
2. Billmeyer, F.W., "Text Book of Polymer Science, 3rd edition, John Wiley & Sons, New York, 1984.
3. Ghosh, P. "Polymer Science & Technology of Plastic, Rubber, Blends and Composites" 2nd Edition, Tata McGraw-Hill, New delhi, 2008.
4. Morton-jones, D.H., Chapman and Hall, "Polymer Processing", Springer, London, 1989,1st Edition.
5. McCrum, N.G., Buckley, C.P. and Bucknall, C.B., "Principles of Polymer Engineering", 2nd Edition, Oxford Science Publication, 1997.

Department Elective - 2: Process Intensification

L	T	P	Credit
3	0	0	03

CHCH121 **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", 2^{nd} 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.

Department Elective - 2: Multiphase Flow

L	T	P	Credit
3	0	0	03

CHCH122 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand multiphase flow and its principles
CO2	Analysing the theoretical principles for potential applications of multiphase flow
CO3	Integrating interfacial transport phenomena in the multiphase flow systems
CO4	Illustrating the multiphase flow in process industries
CO5	Solving multiphase flow problems
CO6	Assessing the physical understandings of the multiphase flow through interdisciplinary studies

2. Syllabus:

- **INTRODUCTION TO MULTIPHASE FLOW** **(5 Hours)**
  Gas/liquid, liquid/liquid and liquid/solid particle flow systems. Multiphase flows in pipes, flow regime maps, pressure drop.

- **GENERAL CONSERVATION LAWS** **(4 Hours)**
  Equation of motion for a small spherical particle, Stokes flow around a spherical particle, interfacial flow and constitutive relations.

- **ONE DIMENSIONAL STEADY SEPARATED FLOW** **(5 Hours)**
  One dimensional steady separated flow model.
  Phases are considered together but their velocities differ.
  Phases are considered separately, flow with phase change.

- **SOLID-LIQUID AND GAS-SOLID FLOW** **(5 Hours)**
  Hydrodynamics of solid-liquid and gas-solid flow.
  Particle Dynamics: Inertial effects, Two Fluid Models, Turbulence modulation by particles.

- **THREE PHASE FLOW** **(4 Hours)**
  Introduction to three phase flow

- **MEASUREMENT TECHNIQUES** **(5 Hours)**
  Measurement techniques for multiphase flow, Flow regime identification, pressure drop, void fraction and flow rate measurement.

- **FLOW IN MICROCHANNELS** **(6 Hours)**
  Flow in minichannels/microchannels, their principles and applications. Bubble dynamics, Droplet deformation and breakup, Droplet collisions and coalescence.

- **CASE STUDIES-APPLICATION AREAS** **(8 Hours)**

Case studies of the multiphase flow. Modeling and simulations using CFD software's.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Yadigaroglu G., and Hewitt Geoffrey F., "Introduction to Multiphase Flow", Springer International Publishing, 2018
2. Brennen, C.E. "Fundamentals of Multiphase Flow", Cambridge University Press, New York, 2005.
3. Crowe, C.T. "Multiphase Flow Handbook". Taylor & Francis, Boca Raton, Fl. 2006.
4. V. P. Carey, Liquid-Vapor Phase-Change Phenomena, 2nd ed., Taylor & Francis, New York, 2008.
5. Michaelides E. E., Crowe C. T., Schwarzkopf J. D.", Multiphase Flow Handbook", CRC Press, 2016.

4. Additional Reading:

1. Fries D. M., "Multiphase Flow in Microchannels: Hydrodynamics and Implementation in Process Engineering", ETH, 2008.

Department Elective - 3: Complex Fluids

L	T	P	Credit
3	0	0	03

CHCH210 **Scheme**

1. Course Outcomes (COs):

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

CO1	Classify types of different types of complex fluids.
CO2	Evaluate the rheological characteristics of the complex fluids.
CO3	Identify the rheological property responsible for the deformation characteristics.
CO4	Select appropriate test for evaluating rheological properties of complex fluids.
CO5	Apply the knowledge of rheology to test the rheology of complex fluids.
CO6	Apply the concepts to design new complex fluids with improved rheology.

2. Syllabus:

- **INTRODUCTION COMPLEX FLUIDS** **(3 Hours)**
  Types of fluids, 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

- **DEFORMATION OF COMPLEX FLUIDS** **(6 Hours)**
  Deformation characteristics, Rheology, Viscoelasticity, 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

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

- **COMPUTATIONAL RHEOLOGY** **(6 Hours)**
  Micro-macro approach, methods of computational rheology,

- **POLYMERIC COMPLEX FLUIDS** **(6 Hours)**
  Structure of polymeric complex fluids, 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** **(6 Hours)**
  Flow properties of suspensions, emulsions, filled systems, gels, yield stresses of particulate gels, their measurements and applications

- **RHEOMETRY** **(3 Hours)**

Testing methods, 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** **(6 Hours)**

(Total lecture hours: 42)

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3. Books Recommended:

1. Chhabra R.P., Richardson, J.F., Non-Newtonian Flow and Applied Rheology: Engineering Applications", 2nd Ed., Butterworth Heinemann, Oxford, 2008.
2. Pal R., "Rheology of Particulate Dispersions and Composites", CRC Press, New York, 2007.
3. Larson R.G., "The Structure and Rheology of Complex Fluids", Oxford University Press, New York, 1999.
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.

Department Elective - 3: Industrial Biotechnology

L	T	P	Credit
3	0	0	03

CHCH211 **Scheme**

1. Course Outcomes (COs):

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

CO1	Comprehend the principles behind Industrial biotechnology
CO2	Solve problems related to kinetics of enzymes and interpret actions
CO3	Design the concepts related to Bioreactor design
CO4	Describe broad understanding of concepts and applications of microorganism
CO5	Develop mathematical models in biotechnology
CO6	Impart the knowledge to apply in sustainable biotechnology, environmental biotechnology and nano-biotechnology

2. Syllabus:

- **INTRODUCTION** **(3 Hours)**
  Key factor for development of Biotechnology processes. Classification and Nomenclature of Microorganism, Staining Method, Method of Determination of cell no and mass, genetically engineering Cell.

- **ENZYMES** **(8 Hours)**
  Enzyme kinetics introduction, Mechanistic models for simple enzyme kinetics, models for more complex enzyme kinetics, Models for pH and temperature effect on enzymes and deactivation kinetics. Immobilized enzyme systems, Applied enzyme catalysis.

- **BIOREACTORS** **(5 Hours)**
  Different types of bioreactors and bioreactor design, application of artificial intelligence in bioprocess control.

- **MICROBIAL GROWTH** **(6 Hours)**
  Microbial growth, substrate degradation and product formation kinetics, stoichiometric microbial growth and product formation

- **SUSTAINABLE BIOTECHNOLOGY** **(6 Hours)**
  Plants as source of chemicals, Microbial production of chemicals, Microbial polymers, Microbial plastics, Industrial processes and clean technology

- **NANOBIOTECHNOLOGY** **(4 Hours)**
  Biosensor, Biomaterials, nano-medicine.

- **MATHEMATICAL METHODS IN BIOTECHNOLOGY** **(6 Hours)**
  Classification of mathematical models applicable in biotechnology with applications examples.

Statistical analysis, Testing mathematical models.

- **ENVIRONMENTAL BIOTECHNOLOGY** **(4 Hours)**
  Bioremediation, Biofuels, Biofouling, Natural resource recovery.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Michael L. Shuler and Fikret Kargi, "Bioprocess Engineering: Basic Concepts: International edition", 3rd Ed., Prentice Hall International series, 2017.
2. James E. Bailey, David F. Ollis, "Biochemical Engineering Fundamentals", 2 nd Ed., McGraw hill, 1986.
3. Debabrata Das and Soumya Pandit, "Industrial Biotechnology", 1st Ed., CRC Press, Boca Raton, FL, USA, 2021.
4. Binay K. Dutta, "Mathematical Methods in Chemical and Biological Engineering", 1st Ed., CRC Press, Boca Raton, FL, USA, 2017
5. Alan Scragg, "Environmental Biotechnology", 2nd Ed., Oxford University Press, 2005.

Department Elective - 3: Environment, Health and Safety

L	T	P	Credit
3	0	0	03

CHCH212 **Scheme**

1. Course Outcomes (COs):

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

CO1	To describe the environmental ecosystem and its significance.
CO2	To analyze the effects of pollutants on the environment and health.
CO3	To estimate and decide the treatment technologies for waste effluents.
CO4	To justify the significance of safety for industries and available laws.
CO5	To estimate the hygiene and occupational health in industrial environment.
CO6	To design and illustrate the treatment methodologies for resource generation.

2. Syllabus:

- **INTRODUCTION** **(5 Hours)**
  Importance of Environment, its components, ecology, biosphere, interaction, impact of development, pollution and its effects, reversibility of environment. Safety, Health and safe practices in industries and its importance, sources of pollution from Chemical Industries, public awareness, and sustainability.

- **IMPACT ON BIOLOGICAL ENVIRONMENT** **(8 Hours)**
  Discharge of various effluents (water, air, and solid) and their impacts on environmental and human health, characterization, identification, different treatment processes (chemical, biological, and advanced), Mix first and separate later (MFSL) approach and its disadvantages, decentralization, tertiary treatment, and disinfection.

- **SOLID WASTE TREATMENT AND DISPOSAL** **(9 Hours)**
  Definition, Types of solid waste, generation, onsite handling, storage & processing, Different types of disposal techniques, recovery of resources, reuse of solid waste, electronic waste, policies, and current practices.

- **SAFETY PRACTICES IN INDUSTRIES** **(5 Hours)**
  Safety, loss prevention, safe practice, codes of safety, and integrity for various types of processes, safety and morals, accidents, accident reporting and investigation, personal protective equipments', releases mitigation procedures, financial aspects of safety, case histories, release of toxic effluents

- **INDUSTRIAL HYGIENE AND OCCUPATIONAL HEALTH** **(5 Hours)**
  Industrial hygiene, health and environmental effects, safety and health training, stress safety, radiations and industrial hazards, industrial noise, vibration, electric hazards, Disposal of scrap and other trade wastes, spillage prevention, housekeeping and its advantages, First aid,

causalities and injuries.

- **LEGISLATIVE MEASURES** **(5 Hours)**
  Different laws related to liquid, solid, and gases effluents, Different standards and legislations, Factories Act, Workman's Compensation Act, Air Water Pollution Act, Bureau of Indian Standards on safety and health, OSHA, etc.

- **RESOURCE GENERATION** **(5 Hours)**
  Minimizing waste generation, reduce, reuse and recycling of by-products, Waste utilization, waste to energy concept, Sustainability, various advanced techniques like UASB, MFC, OMFC etc.

(Total Lecture Hours: 42)

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3. Books Recommended:

6. Masters G.M., "Introduction to Environmental Engineering and Science", Prentice-Hall, New Delhi, 3rd Edition, 2008.
7. MaCarty S., "Chemistry for Environmental Engineering", Tata-McGraw-Hill, New Delhi, 5th Edition
8. Metcalf & Eddy, "Waste Water Engineering: Treatment, Disposal and Reuse", Tata-McGraw-Hill, New Delhi, 4th Edition, 2002.
9. Crowl D. A., Louvar J. F., "Chemical Process Safety", Prantice-Hall, 2nd Ed., New York, 2002.
10. Grady, C.P.L, Daigger, G, and Lim, H, C, "Biological Waste Water Treatment", 2nd Edition, Marcel Dekker, 1999.

4. Additional Reading:

1. Lees, F.P., "Loss Prevention in Process Industries", Butterworths, NewDelhi, 4thEdn., Aug 2012
2. Rao, C. S., "Environmental Engineering", Wiley Eastern Limited, New Delhi, 1995.
3. Droste R. L., "Theory and Practice of Water and Wastewater Treatment", Wiley India, 1996.

Department Elective - 3: Computational Fluid Dynamics

L	T	P	Credit
3	0	0	03

CHCH213 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understanding the fundamentals of computational methods in fluid flow operations
CO2	Analysing the initial and boundary value problems
CO3	Integrating the appropriate solution methodology and estimating the accuracy of the results for a given flow case
CO4	Solving CFD problems using appropriate boundary conditions
CO5	Adapting to various CFD software for solving interdisciplinary problems
CO6	Illustrating the computational results for the given case

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)

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3. **Books Recommended:**

1. Anderson J.D., "Computational Fluid Dynamics", McGraw-Hill International Editions, 1st Ed., 1995.
2. Patankar S.V., "Numerical Heat Transfer and Flow", Taylor & Francis, Reprinted 1st Ed., 2004.
3. Ferziger J. H. and Peric M., "Computational Methods in Fluid Dynamics", Springer, 1st Ed., 2003.
4. Muralidhar K. and Sunderrarajan T., "Computational Fluid Flow and Heat Transfer", Alpha Science International, 2nd Ed., 2003
5. Chung T. J., "Computational Fluid Dynamics", Cambridge University Press, 2nd Ed., 2014.

Department Elective - 4: Design of Experiments

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

CHCH221 **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	Perform analysis of variance for analysing effect of various factors studied.
CO5	Apply various methods of factorial designs (2^K method, Response surface method, Taguchi method) for a given set of parameters.
CO6	Able to use software for analysis of the experimental results.

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)

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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.

Department Elective - 4: Advanced Process Control

L	T	P	Credit
3	0	0	03

CHCH222 **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	Elaborate 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)

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3. Books Recommended:

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

Department Elective - 4: Catalyst Science and Technology

L	T	P	Credit
3	0	0	03

CHCH223 **Scheme**

1. Course Outcomes (COs):

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

CO1	Describe concepts and significance related to heterogeneous and homogeneous catalysts
CO2	Explain steps and methods in catalyst preparation
CO3	Describe and apply selected catalyst characterization methods (identify anayltical tools for specific catalytic applications)
CO4	Explain why and how catalysts deactivate and how catalyst deactivation can be postponed or prevented
CO5	Outline dis-/advantages of supported and full-catalysts with respect to their application
CO6	Explain industrial catalytic processes

2. Syllabus:

- **INTRODUCTION TO CATALYSIS** **(2 Hours)**
  Significance of catalysis, Heterogeneous Catalysis: Examples, Case Histories and Current Trends.

- **SOLID CATALYSIS** **(4 Hours)**
  Types of catalysts, Preparation methods of Solid Heterogeneous Catalysts, Catalyst supports, Activation.

- **CATALYSTS CHARACTERIZATION METHODS** **(8 Hours)**
  Adsorption methods, Physicochemical Properties, Spectroscopic Methods.

- **CATALYST PERFORMANCE** **(3 Hours)**
  Testing of catalysts, activity and selectivity studies.

- **EFFECT OF TRANSPORT PROCESSES** **(4 Hours)**
  External transport processes, internal transport processes for reaction and diffusion in porous catalysts.

- **MECHANISM OF CATALYTIC REACTIONS** **(4 Hours)**
  Rates of adsorption, desorption, surface reactions, rate determining steps.

- **KINETIC MODELLING AND PARAMETER ESTIMATIONS.** **(4 Hours)**
  Kinetic study and parametric evaluation.

- **CATALYSTS DEACTIVATION** **(2 Hours)**
  Promoters, inhibitors, catalyst deactivations, kinetics of catalyst deactivations.

- **INDUSTRIAL CATALYSIS APPLICATION** **(6 Hours)**
  Green Chemistry, Biomass to biofuels and chemicals, CO_2 utilization etc.

- **NEW DEVELOPMENT IN SOLID CATALYSIS** **(2 Hours)**
  Monolith catalysts, Nanocatalysts, etc.

- **INTRODUCTION TO HOMOGENEOUS CATALYSIS** **(3 Hours)**

(Total Lecture Hours: 42)

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3. Books Recommended:

1. J. M. Thomas and W. J. Thomas, "Principles and Practice of Heterogeneous Catalysis", Wiley- VCH. ISBN: 978-3-527-31458-4 February 2015
2. C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes", Wiley- VCH. ISBN: 978-0-471-73007-1 August 2010
3. Julian Ross: Heterogeneous Catalysis - Fundamentals and Applications, © Elsevier 2012.
4. S. Lowell, Joan E. Shields, Martin A. Thomas, Matthias Thommes. Characterization of Porous Solids and Powders: Surface Area, Pore Size and Density. 2004, Springer Science, New York
5. Fogler H.S., “Elements of Chemical Reaction Engineering”, 4th Edition, Prentice Hall, NJ, 2006
6. Articles from Peer Reviewed Journals

Department Elective - 4: Sustainable Development Goals

L	T	P	Credit
3	0	0	03

CHCH224 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand critically emergence and development of the Sustainable Development Goals (SDGs)
CO2	Identify and apply different methods for assessing clean water
CO3	Evaluate sustainabable solutions for SDGs using different approach and calculation
CO4	Describe various potentials ways to get affordable and clean energy
CO5	Explain current challenges i.e., social, environmental and econmic in achieving the SDGs
CO6	Examine how the different SDGs are implemented and interrelated

2. Syllabus:

- **THE ORIGIN, DEVELOPMENT AND IDEA OF THE SDGs** **(11 Hours)**
  History and origins of the Sustainable Development Goals. What are the SDGs? What are their aims, methodology and perspectives? How are they related to the Millennium Development Goals?

- **CLEAN WATER** **(13 Hours)**
  Overview of conventional wastewater treatment plant, Biological treatment: Principles of biological treatment, kinetics of biological growth, aerobic (ASP) and anaerobic treatment (UASB) of sewage. Activated sludge, Trickling filters, biological disc, packed bed and fluidized bed treatment, stabilization ponds, Advanced waste water treatment: Principles of tertiary treatment (membrane based treatment i.e., MF, UF, NF and RO), reuse and resource recovery, and recent developments i.e., forward osmosis (FO), membrane bio reactor (MBR), Pressure retarded osmosis (PRO) and Pressure assisted FO (PAFO), Seawater Desalination

- **SANITATION** **(7 Hours)**
  Concept of environment and scope of sanitation in rural areas. Magnitude of problem of water supply and sanitation. National policy. On site sanitation system i.e., septic tanks, soakage pits etc., Composting, land filling, Biogas plants.

- **AFFORDABLE CLEAN ENERGY** **(11 Hours)**
  Examples of future Clean Technology, Biodiesel, Natural Compost, Eco-Friendly Plastic, Alternate Energy, Hydrogen, Bio-fuels. Solar Energy, Wind, Hydroelectric Power, Biotransformation of biomass/organic waste into value added chemicals energy, Bio-fertilizers,

Microbial fuel cell (MFC), Osmotic microbial fuel cell (OMFC), Benthic microbial fuel cell (BMFC), Hybrid OMFC etc.

(Total Lecture Hours: 42)

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

1. R.W. Baker, Membrane Technology and Application, John Wiley and Sons Ltd. ,2004.
2. Dalby, Simon, et al. Achieving the Sustainable Development Goals: Global Governance Challenges. Routledge, 2019.
3. C.S. Rao, Environmental Engineering, Wiley Eastern Limited, New Delhi, 1995.
4. APHA, "Standard Methods for Examination of Water and Wastewater"; 21st Edition, 2002.
5. Metcalf and Eddy. Wastewater Engineering, Treatment, Disposal and Reuse, Inc. Third Edition Mograw hill 1991.

Institute Elective - 1: Corrosion and Electrochemical Engineering

L	T	P	Credit
3	0	0	03

CHCH230 **Scheme**

1. Course Outcomes (COs):

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

CO1	Apply laws of electrochemistry to understand mechanism of corrosion
CO2	Estimate the rate of corrosion.
CO3	Differentiate between different types of corrosion.
CO4	Identify the factors causing corrosion and solve problems involving various types of corrosion.
CO5	Assessment of damage caused by corrosion.
CO6	Select suitable technique for corrosion prevention.

2. Syllabus:

- **ELECTROCHEMISTRY OF CORROSION** **(6 Hours)**
  Corrosion – introduction and definitions; Electrochemical cells - definitions and principles; Potential measurements - galvanic cells, concentration cells; EMF and Galvanic series - bimetallic couples; Eh-pH diagrams – fundamental aspects; Construction of Eh – pH diagrams; FeH2O-O2 diagram; Copper, Aluminium and general corrosion diagrams

- **CORROSION KINETICS AND APPLICATION OF ELECTROCHEMISTRY** **(10 Hours)**
  Overpotential; Activation Polarization; Concentration Polarization; Ohmic Drop; Graphical Presentation of Kinetic Data (Evans Diagrams); Activation Controlled Processes; Concentration Controlled Processes; Examples of Applied Electrochemistry to Corrosion; Electrochemical Polarization Corrosion Testing; Corrosion Monitoring;Cathodic Protection; Anodic Protection; Aluminum Anodizing; Chloride Extraction.

- **FORMS OF CORROSION** **(6 Hours)**
  Recognizing Corrosion; Localized Corrosion (Pitting Corrosion, Crevice Corrosion, Galvanic Corrosion, Intergranular Corrosion, Dealloying, Hydrogen-Induced Cracking, Hydrogen Blistering, etc.); Velocity Induced Corrosion (Erosion–Corrosion, Cavitation, etc.); Mechanically Assisted Corrosion (Stress Corrosion Cracking, Corrosion Fatigue, Fretting Corrosion, etc.).

- **FACTORS AFFECTING CORROSION AND ITS MONITORING** **(8 Hours)**
  Effect of ambient conditions;Corrosion by fresh water and other types of water; Corrosion by atmosphere;corrosion in soil; Microbiologically affected corrosion; Corrosion in concrete; corrosion in petroleum industries; Corrosion Test Methods and Testing Procedure; Electrochemical Testing; Corrosion Monitoring and Inspection; Monitoring of Cathodic Protection; Inspection and Monitoring of Process Plants; Monitoring and Testing in Other Environments.

- **RISK ASSESSMENT OF COROSION AND ITS MITIGATION** **(12 Hours)**

Risk Assessment and Analysis; Risk Assessment Methods; Cost of Corrosion;Hazard and Operability; Failure Modes – Effects and Criticality Analysis; Risk Matrix Methods; Fault Tree Analysis; Event Tree Analysis; Industrial Example of corrosion assessment and Damage Assessment; Cathodic Protection; Sacrificial Cathodic Protection; Impressed Current Cathodic Protection; Protective Coatings; Types of Coatings; Coatings Failure; Economic Aspects of Coating Selection and Maintenance; Organic Coatings; Inorganic (Nonmetallic) Coatings; Metallic Coatings; Coating Inspection and Testing; Surface Preparation.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Roberge, P.R., 'Corrosion engineering: principles and practice' 1st Edition, New York: McGraw-Hill, 2008.
2. Kelly, R.G., Scully, J.R., Shoesmith, D. and Buchheit, R.G., 'Electrochemical techniques in corrosion science and engineering' 1st Edition, CRC Press, 2002.
3. Bardal, E., 'Corrosion and protection' 1st Edition, Springer Science &Business Media, 2004.
4. Landolt, D., 'Corrosion and surface chemistry of metals' 1st Edition, EPFL press, 2007.
5. Ahmad, Z., 'Principles of corrosion engineering and corrosion control' 1st Edition, Elsevier Science and Technology Books, 2006.

Institute Elective - 1: Non-Conventional Energy

L	T	P	Credit
3	0	0	03

CHCH231 **Scheme**

1. Course Outcomes (COs):

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

CO1	Identify energy demand and relate with available energy resources
CO2	Understand the basics of various nonconventional energy systems
CO3	Demonstrate the generation of electricity/energy from various Non-Conventional sources, have a working knowledge on types of fuel cells
CO4	Analyze harnessing of various nonconventional techniques like solar, biomass, wind, hydrogen, Ocean, fuel cells, etc.
CO5	Evaluate the hydrogen and other various fuel cell for the conversion of chemical energy to electrical energy
CO6	Design and illustrate the nonconventional energy conversion systems for real applications

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Overview of World Energy and India's Energy Scenario, Scale of quantities, Impact of current energy usage, Conventional sources of energy, Overview of non-conventional energy resources, environmental aspects of energy utilization, conventional and non-conventional sources of energy, merits and challenges, Introduction to various renewable energy sources.

- **SOLAR ENERGY** **(8 Hours)**
  Solar energy incident on earth, solar spectrum, overview of solar energy technologies, performance and durability of solar devices. Solar thermal energy conversion: Solar radiation on the earth surface, measurement of solar radiations, concentrating and non-concentrating types of solar collectors, various solar thermal applications, examples of systems. Solar electrical energy conversion: Construction and working of solar cells, materials and PV modules, different PV technologies, photovoltaic system components and different applications, power plants, case studies.

- **WIND ENERGY** **(6 Hours)**
  Principle of wind energy conversion; Basic components of wind energy conversion systems; wind mill components, various types and their constructional features; design considerations of horizontal and vertical axis wind machines: analysis of aerodynamic forces acting on wind mill blades and estimation of power output; wind data and site selection considerations.

- **BIOMASS ENERGY** **(8 Hours)**
  Biomass conversion technologies, Biogas generation plants, Classification, advantages and disadvantages, constructional details, site selection, digester design

consideration, filling a digester for starting, maintaining biogas production, Fuel properties of bio gas, utilization of biogas. Waste as liquid fuels and utilization of Bio-electrochemical systems for conversion of chemical to electrical energy, principles, application and potentials.

- **OCEAN ENERGY** **(5 Hours)**
  Ocean thermal electric conversion, open and closed cycle of OTEC, basic principles of tidal power & components of tidal power plants, single & double basin arrangements, Energy from ocean waves, wave energy conversion devices. Tidal Energy-Principle of working, performance and limitations. Wave Energy-Principle of working, performance and limitations. Ocean Thermal Energy-Availability, theory and working principle, performance and limitations.

- **GEOTHERMAL ENERGY** **(5 Hours)**
  Estimation and nature of geothermal energy, geothermal sources and resources like hydrothermal, geo-pressured hot dry rock, magma. advantages, disadvantages and application of geothermal energy, prospects of geothermal energy in India.

- **HYDROGEN ENERGY** **(4 Hours)**
  Hydrogen Production methods, Hydrogen storage, hydrogen transportation, utilization of hydrogen gas, hydrogen as alternative fuel for vehicles, limitations and future. Principle of working of various types of fuel cells and their working, performance and limitations.

- **BIOGAS ENERGY** **(4 Hours)**
  Principle of bio gas generation, constructional details of various biogas plants, factors affecting generation of biogas and methods of maintaining biogas, Bio Mass: Introduction, methods of obtaining energy from biomass, thermal gasification.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Rai G. D. "Non-Conventional Energy Sources", 4th Edition, Khanna Publishers, 2000.
2. Sukhatme, S. P. "Solar Energy", 3rd Edition, Tata Mc Graw Hill Education Pvt Ltd, 2008.
3. Khan, B. H. "Non-Conventional Energy Resources", 2nd Edition, Tata Mc Graw Hill Education Pvt Ltd, 2011.
4. Hasan, S and Sharma,D. K. "Non-Conventional Energy Resources",3rd Edition, S. K. Kataria & Sons, 2012.
5. Tiwari, G.N. and Ghosal, M.K. "Renewable Energy Resource: Basic Principles and Applications", Narosa Publishing House,2004.

4. Additional Reading:

1. Twidell, J. and Weir, T. "Renewable Energy Resources", Taylor & Francis; 2nd edition, 2005.
2. Logan B. E., "Microbial Fuel Cells", First Edition, Wiley (2007).

Institute Elective - 1: Environment Management System

L	T	P	Credit
3	0	0	03

CHCH232 **Scheme**

1. Course Outcomes (COs):

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

CO1	Describe, develop and interpret methods of the Environmental Management Systems.
CO2	Justify the need for the knowledge of various environmental protection rules, standards, and EIA guidelines.
CO3	Apply the applications of environmental management systems on different chemical industries.
CO4	Understand the concept of environmental impact assessment
CO5	Implement the Environmental Auditing in various Industries/Projects
CO6	Prepare the post-project monitoring activities

2. Syllabus:

- **INTRODUCTION TO ENVIRONMENT MANAGEMENT SYSTEM** **(5 Hours)**
  Introduction to environment, basic Definitions and terms of environmental management system, framework for environmental management system

- **RESOURCE MANAGEMENT AND SUSTAINABLE DEVELOPMENT** **(4 Hours)**

- **ENVIRONMENTAL PROTECTION ACTS, RULES AND STANDARDS, EIA GUIDELINES** **(6 Hours)**
  The Water (Prevention and Control of Pollution) Act, Air (Prevention and Control of Pollution) Act, Environmental Protection Act

- **ENVIRONMENT IMPACT ASSESSMENT** **(6 Hours)**
  Definition and scope, preliminary screening requiring EIA of projects. Impact identification, Assessment of Impact; Impact Evaluation. Types of EIA, rapid and comprehensive, Methods of environment impact assessment

- **ENVIRONMENT MANAGEMENT** **(6 Hours)**
  Natural Resources Conservation, Conservation of Energy, Pollution prevention, Disposal of Treated effluents, Solid Waste Disposal, Concept of green cities

- **INTRODUCTION TO ENVIRONMENTAL AUDITING** **(7 Hours)**
  Introduction to Environmental Auditing, Category "A" & "B" types of projects. Procedures and Guidelines to conduct Environmental Audit.

- **APPLICATIONS OF ENVIRONMENTAL MANAGEMENT SYSTEM** **(6 Hours)**

  Applications EMS in terms of Process flow chart, effluent Generation, composition and treatment of effluents from different chemical industries.
- **POST PROJECT MONITORING** **(6 Hours)**

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Environmental Management Systems: An Implementation Guide for Small and Medium-Sized Organizations, Second Edition, NSF International, Ann Arbor, Michigan, January 2001.
2. M. N Rao, "Waste Water Treatment" Oxford and IBH publishing Co. Pvt Ltd, 2007.
3. Peavy, H.S, D.R. Rowe & T.George, "Environmental Engineering", New York: McGraw Hill, 1987.
4. Christopher Sheldon and Mark Yoxon, "Installing Environmental management Systems – a step by step guide" Earthscan Publications Ltd, London, 1999.
5. Uberoi, N. K. (2004) Environmental Management. Excel Book, New Delhi.

4. Additional Reading:

1. Recent literature from Journals on Separations.

Modelling/Simulation/Software Tools-1

L	T	P	Credit
0	0	04	02

CHCH104 **Scheme**

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

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

CO1	Understand the basics of simulation software
CO2	Simulate cubic and partial differential equations using computational software
CO3	Adapt simulation software to solve chemical engineering thermodynamics problems
CO4	Validate the analysis of heat transfer and fluid flow operations problems using computational software
CO5	Solve chemical engineering case studies using CFD software

2. <u>Syllabus:</u>

Introduction to the different simulation softwares (MATLAB, ASPEN PLUS) and their applications to solve the problems arising in chemical engineering systems. Solving different case studies from chemical engineering thermodynamics, heat transfer and fluid flow, mass transfer, and chemical reaction engineering using simulations softwares.

Modelling/Simulation/Software Tools-2

L	T	P	Credit
0	0	04	02

CHCH203 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand the basics of CFD software such as ANSYS, COMSOL, ASPEN Plus, etc.
CO2	Analyse the laminar and turbulent flows using CFD software
CO3	Adapt CFD software to analyse the heat transfer devices
CO4	Validate the analysis of chemical reactors using CFD software
CO5	Solve chemical engineering case studies using CFD software

2. Syllabus:

Introduction to the different CFD softwares (ANSYS, COMSOL, and ASPEN PLUS) and their application to solve the problems arising in chemical engineering systems. Solving different case studies from chemical engineering thermodynamics, heat transfer and fluid flow, mass transfer and chemical reaction engineering using CFD softwares.

Laboratory Practice-1

L	T	P	Credit
0	0	04	02

CHCH105 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand, explain and select instrumental techniques for analysis
CO2	Prepare the plan for the experiments in chemical engineering
CO3	Illustrate working of several specific instruments
CO4	Analyse and interpret the experimental data
CO5	Predict and analyse results of the case studies in chemical engineering

2. Syllabus:

Introduction to analytical experimental methods and sophisticated instruments. Experiments using sonication, microwave radiation, membrane separation, reactors, etc. and analysis using GC, HPLC, UV, TURBISCAN, DLS, Contact Angle measuring instruments.

Laboratory Practice-2

L	T	P	Credit
0	0	04	02

CHCH204 **Scheme**

1. Course Outcomes (COs):

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

CO1	Understand, explain and select instrumental techniques for analysis
CO2	Prepare the plan for the experiments in chemical engineering
CO3	Illustrate working of several specific instruments
CO4	Analyse and interpret the experimental data
CO5	Predict and analyse results of the case studies in chemical engineering

2. Syllabus:

Introduction to analytical experimental methods and sophisticated instruments. Experiments using sonication, microwave radiation, membrane separation, reactors, etc. and analysis using GC, HPLC, UV, TURBISCAN, DLS, Contact Angle measuring instruments.