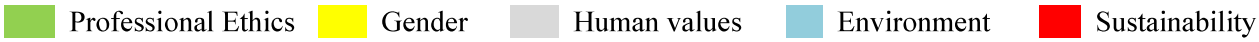
Bachelor of Technology in Chemical Engineering

Program Outcomes (POs)

PO1	**Engineering knowledge:** Apply the knowledge of basic science, mathematics and fundamentals of engineering with specialization to solve the complex problems of chemical engineering.
PO2	**Problem analysis:** Attain the capability to identify, formulate and analyze chemical engineering problems considering the knowledge of engineering mathematics, natural, and engineering sciences and review of the research articles
PO3	**Design/Development of solutions:** Demonstrate and develop the appropriate solutions to chemical engineering design based problems to meet the specified needs of the nation and overall sustainability of the processes, considering the necessary approaches of safety, health hazards, societal and environmental factors.
PO4	**Conduct investigations of complex problems:** Investigate, demonstrate and conduct the design based complex problems using research based knowledge and methodologies, experimental studies, subsequent analysis and interpretation of data to prepare the valid technical reports as per national and global standards
PO5	**Modern tool usage:** Select and apply appropriate available resources, and modern chemical engineering tools such as optimization techniques, simulations, including predictions and modelling to complex process engineering problems with an understanding of their limitations
PO6	**Engineer and society:** Able to carry out their professional practice in chemical engineering by appropriately considering and weighing the issues related to society, health and culture and the consequent responsibilities
PO7	**Environment and sustainability:** Understand and demonstrate the impact of chemical engineering solutions in societal and environmental contexts, and understand the need for global sustainable development
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the chemical engineering practice.
PO9	**Individual and team work:** Work effectively as an individual or in diverse and multidisciplinary global environments showing team solidarity.
PO10	**Communication:** Ability to communicate efficiently with the engineering community, society and able to represent and explain the design documentation effectively with clear instructions, following standard national and international codes

Professional Ethics Gender Human values Environment Sustainability

PO11	**Project management and Finance:** Demonstrate the knowledge and principles of chemical engineering, management, cost and feasibility studies for the desired projects as an individual, or a member or leader in a team of multidisciplinary settings
PO12	**Life-long learning:** Possess the attitude of lifelong independent learning as per the need of wider context of technological changes and can pursue higher education for careers in academics, research and development



Program Specific Outcomes (PSOs)

PSO-1	Impart education and training of Chemical Engineering to the students and to make them competent and well qualified Chemical Engineers who can meet global challenges
PSO-2	Provide best knowledge of the Chemical Engineering to the students and nurture their creative talent by motivating them to work on various challenging problems facing the nation
PSO-3	Acquire high end industry centric skills in the field of Chemical Engineering to solve local, regional and national problems
PSO-4	Knowledge of the software used in the field of Chemical Engineering
PSO-5	To prepare Professional Engineer with ethical, social and moral values

Program Educational Outcomes (PEOs)

1. To make the students ready for successful career leading to global higher education and /or in national industry related domains of design, regional research and development, testing, and local manufacturing.
2. To solve diverse real-life national and global engineering problems equipped with a solid foundation in global mathematical, scientific, and chemical engineering principles.
3. To motivate and encourage the students to adopt global professionalism, teamwork, leadership, communication skills, ethical approach.
4. To provide global learning opportunity in a broad spectrum of multidisciplinary field.

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Semester-wise Course Structure

1st Year - Semester 1

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	HSS-S101	Professional Communication	3	0	0	4
2.	MTH-S101	Mathematics-I	3	1	0	4
3.	PHY-S101	Physics-I	3	1	3	5
4.	TCA-S102	Workshop Concepts &Practice	1	1	6	5
5.	ISC-S101	Programming & Computing	3	0	3	5
6.	UHV-S101	Universal Human Values –I (SIP)				-
		Total	**13**	**3**	**12**	**23**

1st Year - Semester 1I

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MTH-S102	Mathematics-II	3	1	0	4
2.	PHY-S102	Physics-II	3	1	3	5
3.	CHM-S101	Chemistry-I	3	1	3	5
4.	ESC-S101	Basic Electrical & Electronics Engg.	3	1	3	5
5.	TCA-S101	Engineering Drawing	2	1	3	5
		Total	**14**	**5**	**12**	**24**

2ndYear - Semester II1

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MTH-S201	Mathematics-III	3	1	0	4
2.	ESC-S201	Engineering Mechanics	3	1	0	4
3.	ESC-S202	Basic Thermodynamics	3	1	0	4
4.	CHE-S201	Process Calculations	3	1	0	4
5.	CHE-S202	Fluid Mechanics	3	1	0	4
6.	CHM-S301	Chemistry-II	3	0	3	4
7.	SST-S201	Summer Internship	0	0	0	2
		Total	**18**	**5**	**3**	**26**

2nd Year - Semester IV

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHE-S203	Chemical Engineering Thermodynamics	3	1	0	4
2.	CHE-S204	Heat Transfer	3	1	0	4
3.	CHE-S205	Chemical Process Industries	4	0	0	4
4.	CHE-S206	Mechanical Operations	3	1	0	4
5.	HSS-S401	Engineering Economics	3	0	0	4
6.	EVS-S101	Environmental Science	2	0	0	2
7.	UHV-S201	Universal Human Values -II	2	1	0	3
		Total	**20**	**4**	**0**	**25**

3rd Year - Semester V

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHE-S301	Mass Transfer-I	3	1	0	4
2.	CHE-S303	Unit Operations Laboratory -I	0	0	4	4
3.	CHE-S304	Chemical Reaction Engineering-I	3	1	0	4
4.	CHE-S309	Numerical Methods for Chemical Engineers	3	1	0	4
5.	HSS-S301	Communication Practicum	1	0	2	2
6.	CHE-S5**	Departmental Elective	3	1	0	4
7.	SST-S301	Summer Internship	0	0	2	2
		Total	**13**	**4**	**8**	**24**

3rd Year - Semester VI

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	CHE-S305	Mass Transfer-II	3	1	0	4
2.	CHE-S306	Instrumentation & Process Control	3	1	0	4
3.	CHE-S307	Chemical Engineering Design-I	3	1	0	4
4.	CHE-S308	Unit Operations Laboratory-II	0	0	4	4
5.	CHE-S5**	Departmental Elective	3	1	0	4
6.	SSM-S301	Student Seminar	0	0	2	2
		Total	**12**	**4**	**6**	**22**

Course Code: CHM-S301 **Breakup: 3 –0 – 3 –4**
Course Name: Chemistry II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the theory based ideas in solid state chemistry, phase rule, composites and its importance in engineering
CO2	Understand the basic concepts of polymer chemistry and its importance in engineering chemistry
CO3	Understand the chemistry behind water pollution, its causes and perform experiments related to water pollution
CO4	Understand the concepts related to corrosion and its prevention, fuels, lubricants and its importance in engineering
CO5	Understand the introductory concepts related to nano science, superconductivity, cause of pollution and its prevention benefiting the society

Course Details: (Theory)

UNIT-1
Solid state: Crystal lattices, space lattices and unit cells, crystal systems, Miller indices, Imperfection in crystals: Point defects- Schottky and Frankel defects, Liquid crystals, conducting properties of solids.
Phase Rule- Gibbs's phase rule, phase diagrams of one-component system (water), two component system (lead-silver)
Electronic materials- Composites, Materials related to nanotechnology.

UNIT-II
Polymers: Introduction, Classification of Polymers, Intermolecular forces in Polymers, Structure of Organic and Inorganic polymers of industrial importance, Specialty Polymers: Liquid crystalline polymer, Conducting & electroluminescent polymers.

UNIT-III
Chemistry of cells: Proteins, Nucleic acids, Enzymes, Lipids, Genome.

UNIT-IV
Corrosion: Causes and types of corrosion, Measurement of corrosion, Corrosion prevention methods(electrochemical, inhibitor and coating methods)

UNIT-V
Water Treatment: Hardness of water, softening of water, Reverse osmosis, Treatment of boiler feed water by Calgon process, Ion- exchange resins and Zeolites.

UNIT-VI
Fuels: Coal, Biomass, Biogas, Determination of net calorific values of Bomb calorimeter.

UNIT-VII
Environmental Pollution: Types of pollution and pollutants, Air pollution, Formation and depletion of ozone, Smog and acid rain.

UNIT-VIII
Clusters: Introduction, Types of clusters- Vander Waals clusters, Molecular clusters, Nanoclusters, Macroscopic clusters.

Course Code: EVS-S101 **Breakup: 2 –0 – 0 – 2**
Course Name: Environmental Science

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the concepts and definitions associated with ecosystems, environmental pollution and its causes
CO2	Gain knowledge to analyse problems and suggest alternatives and new methods to manage natural resources
CO3	Understand how to Redesign, Recreate & Restore the ecosystems
CO4	Understand the legal aspects and the role of government in environment protection

Course Details:

UNIT-I
Global scope and importance of environmental studies, Need for public awareness, Segments of environment, biodiversities: Genetic diversity, Species diversity, Ecosystem diversity, Landscape diversity, Causes of pollution and detrimental effects.

UNIT-II
Eco systems- Types of systems, energy flow in an ecosystem, Balanced ecosystem,Human activities- Food, shelter, economic and social security, Effects of human activities on environment-Agriculture, housing, Industry, mining and transportation activities, Basics of Environmental Impact Assessment, Sustainable Development.

UNIT-III
Types of natural resources: Water resources-Availability and quality aspects, Water borne diseases, Fluoride problems in portable water, Mineral resources, Food resources, Land resources, Forest Wealth, Material cycles- Carbon, Nitrogen and Sulphur cycle.

UNIT-IV
Energy- Different types of energy (Renewable and Non-renewable), Convectional and non-conventional energy-sources Electromagnetic radiation, Hydro Electric, Fossil fuel based, Nuclear, Solar, Biomass and Bio-gas, Hydrogen as an alternative future source of energyat local and regional level

UNIT-V
Environmental pollution and their effects, Water pollution, Land pollution, Noise pollution, public Health aspects, Air pollution. Current environmental issues of importance and their impact on environmentat local and regional level: Population Growth, Climate change and global warming effect, Urbanization, Automobile pollution, Acid rain, Ozone layer depletion.

UNIT-VI
Preventive measures and control of pollution, Air and Water pollution control, Sold waste management, Case studies at local and regional level.

UNIT-VII
Role of Government in environment protection, Legal Aspects, Initiatives and protection Acts, public awareness, Initiatives by Non-governmental Organizations (NGOs), Role of IT services, Disaster management at local and regional level .

UNIT-VIII
Field work/ Activities/ Visit

Text and Reference Books:

1. Benny Joseph, Environmental Studies, Tata McGraw Hill Publication (2017)
   D.L. Manjunath, Environmental Studies, Pearson Education.
2. R. Rajgopalan, Environmental Studies, Oxford Publication (2015)
3. M. Anji Reddy, Textbook of Environmental Science and Technology, BS Publication (2010)
4. P. Venugopala Rao, Principles of Environmental Science and Engineering, Prentice Hall of India (2006)
5. Meenakshi, Environmental Science and Engineering, Prentice Hall of India (2012)

Course Code: UHV-S201 **Breakup: 2 –1 – 0 – 3**
Course Name: Universal Human Values - II

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the significance of value inputs in a classroom and start applying them in their life and profession
CO2	Distinguish between values and skills, happiness and accumulation of physical facilities, the Self and the Body, Intention and Competence of an individual, etc
CO3	Understand the role of a human being in ensuring harmony in society and nature
CO4	Distinguish between ethical and unethical practices, and start working out the strategy to actualize a harmonious environment wherever they work

Course Details:

UNIT I: Introduction to Value Education
Value Education, Definition, Concept and Need for Value Education.
The Content and Process of Value Education
Basic Guidelines for Value Education
Self exploration as a means of Value Education
Happiness and Prosperity as parts of Value Education

UNIT II: Harmony in the Human Being
Human Being is more than just the Body
Harmony of the Self ('I') with the Body
Understanding Myself as Co-existence of the Self and the Body
Understanding Needs of the Self and the needs of the Body
Understanding the activities in the Self and the activities in the Body

UNIT III: Harmony in the Family and Society and Harmony in the Nature
Family as a basic unit of Human Interaction and Values in Relationships
The Basics for Respect and today's Crisis: Affection, e, Guidance, Reverence, Glory, Gratitude and Love
Comprehensive Human Goal: The Five Dimensions of Human Endeavour.
Harmony in Nature: The Four Orders in Nature.
The Holistic Perception of Harmony in Existence

UNIT IV: Social Ethics
The Basics for Ethical Human Conduct
Defects in Ethical Human Conduct
Holistic Alternative and Universal Order
Universal Human Order and Ethical Conduct
Human Rights violation and Social Disparities

UNIT V: Professional Ethics
Value based Life and Profession.
Professional Ethics and Right Understanding
Competence in Professional Ethics
Issues in Professional Ethics – The Current Scenario
Vision for Holistic Technologies, Production System and Management Models

Text and Reference Books:

1. R.R. Gaur., R, Sangal. G.P Bagaria., A Foundation Course in Value Education, Excel Books, (2009).
2. R.R. Gaur., R, Sangal. G.P Bagaria, Teachers Manual for A Foundation Course in Human Values and Professional Ethics Excel Books, (2009).
3. A.N. Tripathy, Human Values, New Age International Publishers, (2003)
4. A. Nagaraj, JeevanVidya: EkParichaya, JeevanVidyaPrakashan, Amarkantak, (1999)
5. M.K. Gandhi, My Experiemnts with Truth, Maple Classics (2011)
6. I.C. Sharma, Ethical Philosophy of India, Nagin & Co Julundhar
7. Cecile Andrews, – Slow is Beautiful (2006)

Course Code: HSS-S301 **Breakup: 1 –0 – 1 – 2**
Course Name: Communication Practicum

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the nuances of English language for enhancing presentation skills
CO2	Speak in standard English with clarity and fluency and to write business messages professionally
CO3	Speak and communicate clearly in different professional contexts which would improve their chances of employability
CO4	Understand the importance of ethical practices in their professional life

Course Details:

Unit 1- Presentation techniques
Meaning and importance of presentation technique
Presentation skills required for business organization: Negotiation, Persuasion & Time management
Types of business presentations- meetings, seminars, conferences

Unit 2- Oral presentations
Effective oral delivery- Phonetics
Interviews, Group discussions, debates, speeches
Listening skills, Reading skills

Unit 3- Written communication
Style and tone of writing business messages and documents
Persuasive, sales and goodwill messages, delivering bad news
Writing e-mails and short messages, Resume writing

Unit 4 – Non Verbal communication
Nonverbal communication techniques
Business manners, ethics and personality development
Power point presentations

Text and Reference Books:

1. Bove`e, Thill and Schatzman, Business Communication Today, Pearson Education (Singapore), (2003)
2. H. Dan O'Hair, James S. O'Rourke and Mary John O'Hair, Business Communication-a framework of success", South Western College Publishing, (2001)
3. Raymond V. Lesikar, Marie E. Flatley, Basic Business Communication, Tata McGraw Hill Publishing Company Ltd., (2002)

Course Code: CHE-S307 **Breakup: 3 –1 – 0 – 4**
Course Name: Chemical Engineering Design-I

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the General overall design considerations, design steps for chemical processes; types of projects
CO2	Have an understanding of development of design database; process creation; types of process design; Feasibility survey; flow sheet presentation – PFD, PID, utility and safety diagrams
CO3	Carry out cost estimation by cash flow for industrial operations, understand factors affecting investment and production costs, capital investment – fixed capital and working capital investment, cost indices
CO4	Understand Taxes and Insurance: cost of capital, corporate tax, insurance Depreciation: depreciable investments
CO5	Find out the optimum solution methodologies – one variable and two variable, optimum production rates in plant operation

Course Details:

Introduction to Chemical Engineering Plant design: Global design considerations, design steps for chemical processes; types of projects; optimum design – optimum economic design, optimum operation design, practical considerations in design; engineering ethics in design at local and regional level

Process design development: development of design global standard database; process creation; types of process design; feasibility survey; flow sheet presentation – PFD, PID, utility and safety diagrams; vessel and piping layout isometrics; flowsheet symbols; utility streams; equipment design and specifications, equipment specification sheet, scale-up of equipment in design, safety factors at local and regional level

Flowsheet synthesis and development: fundamentals of material balance and energy balance for manual flowsheet calculations, general procedure for flowsheet development – hierarchical and algorithmic methods; conceptual design of a chemical process - hierarchy of decisions; computer-aided flow sheeting

General design considerations: Health and safety hazards; Loss prevention; Environmental consideration; Plant location; Plant layout, Plant operation and control
Cost estimation: cash flow for industrial operations, factors affecting investment and production costs, capital investment – fixed capital and working capital investment, cost indices, cost components and methods for estimating capital investment, estimation of revenue, estimation of total product cost, gross and net profit at local and regional level

Interest and investments costs: simple, compound and continuous interest rates, nominal and effective interest rates, time value of money, annuity, cash flow patterns, capitalized cost;
Taxes and Insurance: cost of capital, corporate tax, insurance
Depreciation: depreciable investments, depreciation and taxes, current value, salvage value, methods for calculating depreciation at local and regional level
Profitability, Alternative investments and Replacements: methods of calculating profitability, alternate investment, replacements, practical factors in alternative investment and replacement analysis

Optimum design and Design strategy: optimum solution methodologies – one variable and two

Course Code: CHE-S504 **Breakup: 3-1-0-4**
Course Name: Environmental Pollution and Control

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Assess and understand the sources, causes and effects of air, water and land pollution
CO2	Understanding the metrological aspects of air pollutant dispersion, and the dispersion and control of air pollutants at local regional and global level
CO3	Ability to design air pollutant abatement systems for particulate matter and gaseous pollutants at local regional and global level
CO4	Understanding the types of water pollutants and their effect on human and animal life
CO5	Understanding the physical, chemical and biological methods for wastewater treatment and the different unit operations involved in them
CO6	Ability to design wastewater and industrial treatment units at local regional and global level
CO7	Understanding the processes for sludge treatment and solid-waste disposal
CO8	Understanding the process and modelling of treatment wastewater disposal in water bodies

Course Details:

Introduction and importance of Environmental Pollution, case studies;

Air Pollution – Global sources, causes, effects; meteorological and natural purification processes; control of air pollutants – particulates and gases –design aspects ; automobile pollution;

Water Pollution – classification and characterization of water pollutants, Global sources, causes, effects of water pollution; control processes : physical- design of equalization tanks, sedimentation tanks clarifiers etc., chemical- coagulation, disinfection, adsorption etc.,
biological – introduction to bacterial growth and kinetics, BOD estimation, aerobic and anaerobic treatment methods, activated sludge process, trickling filters- design aspects, sludge disposal, clarified water disposal at local and regional level

Solid-waste management, Noise Pollution, Radioactive Pollution at Global local and regional level

Text and Reference Books:

1. Metcalf & Eddy, Waste Water Engineering- Treatment Disposal and Reuse, Tata McGraw Hill (2017)
2. Noel De Nevers, Air Pollution Control Engineering, McGraw Hill (2010)
3. Wark & Werner, Air Pollution
4. C. S. Rao, Environmental Pollution Control Engineering, CBS Publishers (2018)
5. H. S. Peavy & D. R. Rowe, Environmental Engineering, McGraw Hill (2017)

Course Code: CHE-S505 **Breakup: 3-1-0-4**
Course Name: Non-conventional Energy Sources

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understand the principles of electricity generation from various non-Conventional sources of energy
CO2	Understand the concept of Solar energy, it's collection and utilization at domestic and industrial level
CO3	Understand the concepts involved in Wind energy, Biomass energy and Geothermal energy
CO4	Understand the concepts of Ocean thermal energy conversion, Tidal energy, and Wave energy
CO5	Understand the concepts of Fuel cells, Batteries, and Hydrogen energy

Course Details:

Introduction: Energy and development; Types of energy resources – Conventional and nonconventional; Indian energy scenario at Global, local and regional level.

Solar energy: Introduction; Fundamentals of solar radiation - Structure of Sun, Solar constant, Extraterrestrial solar radiation, Spectral nature of solar radiation, Terrestrial solar radiation, Solar radiation geometry, Solar radiation measurement at Global, local and regional level.

Solar collectors: Flat plate collectors, Liquid-heating and air-heating flat plate collectors; Solar concentrators - Operating principle, Difference between flat plate collector and concentrating collector, Concentrator parameters, Types of concentrators, Concentrating solar power plants.

Solar thermal energy storage: Introduction, Sensible heat storage, Latent heat storage, Thermo-chemical energy storage, Storage material containers, Solar thermal energy storage for buildings, Solar pond – Non-convecting solar pond, Physics of solar ponds, Design considerations of a solar pond at local and regional level.

Solar photovoltaic power generation: Introduction, Basic structure of a photovoltaic cell, Semiconductor materials, Semiconductor junctions, Photovoltaic cell operation, Types of solar cells.

Wind energy: Introduction, Wind resources, Local winds, Global wind patterns, Jet streams, Theoretical power of the wind, Types of wind turbines - Horizontal axis wind turbines, Vertical axis wind turbines, Offshore wind turbines, Near-shore wind turbines, Selection of wind site, Design of a wind turbine rotor blade, Major components of wind electric system - Wind turbine blades or rotor, Transmission System (Hub, Main shaft, Main bearings, Clamping unit, Gear box, Coupling), Generator, Controller, Towers, Advantages and disadvantages of wind energy, Environmental concerns of wind energy.

Bioenergy: Introduction, Feedstock properties, Chemistry of biomass, Biomass conversion processes - Direct combustion, Thermal conversion, Biochemical conversion; Gasification process - Types of Gasifiers, Properties of Producer gas, Advantages of gasification, Difference between gasification and combustion; Anaerobic digestion process - Types of microorganisms, Anaerobic digestion process, Anaerobic digestion operation modes, Feedstock propertiesat Globallocal and regional level; Biogas plants, Design of biogas plants, Benefits of biogas technology to rural economy; Fuels from biomass – Biogas, Alcohols, Biodiesel, Charcoal.

Geothermal energy: Introduction, Geothermal resources – Hydrothermal, Geopressure, Hot Dry Rock, Magma; Technology and resource type - High temperature resources, Medium temperature

resources, Low temperature resources, Advantages and disadvantages of geothermal energy.

Ocean Thermal Energy Conversion: Introduction, Solar energy absorption by water, Cycle types - Closed cycle OTEC, Open cycle OTEC, Hybrid; Selection of working fluids, Potential sites and plant design - Land-based and near-shore facilities, Shelf-mounted facilities, Floating facilities; Advantages and disadvantages of OTEC systems.

Tidal energy: Introduction, Fundamental principles of tides, Creation of tides, Effect of gravity and inertia on tidal bulges, variations in tides due to position and distance of Sun, Moon and Earth, Other factors affecting tidal characteristics, Coriolis forces, Energy of tides, Tidal current velocity, Extraction of tidal energy, Advantages and disadvantages of tidal energy.

Wave energy: Introduction; Formation of waves; Power in waves; Ocean wave energy technologies - Terminator, Attenuator, Point absorber, Overtopping Device; Advantages and disadvantages of wave energy at Global, local and regional level.

Fuel cells: Introduction, Thermodynamics of a fuel cell, Types of fuel cells - Polymer electrolyte membrane fuel cell, Direct methanol fuel cell, Alkaline fuel cell, Phosphoric acid fuel cell, Molten carbonate fuel cell, Solid oxide fuel cell.

Batteries: Introduction; Generation of electricity by a battery; Basic parameters - Free energy, Theoretical voltage, Theoretical capacity (Coulombic), Theoretical energy; Types of batteries - Primary (non-rechargeable) batteries, Secondary (rechargeable) batteries, Reserve batteries; Discussion on some examples of different battery types; Major considerations in selecting a battery; Advantages and limitations of batteries.

Hydrogen energy: Introduction; Production of hydrogen from fossil fuels, water splitting, biomass, and chemical hydrides; Storage of hydrogen in gaseous, liquid, and solid form; Technical issues in hydrogen storage; Pipeline transport of compressed hydrogen gas; Road delivery of hydrogen; Liquid hydrogen transport; Hydrogen fueled vehicular transport.

Energy from waste: Introduction, Definitions of waste, Characteristics of municipal solid wastes, Energy from waste, Incineration of municipal solid waste, Advantages and disadvantages of incineration, Pyrolysis, Other methods.

Text and Reference Books:

1. U C Sharma, Non-conventional Sources of Energy, Studium Press, Texas (2014).
2. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 1: Fundamentals and Non-Renewable Resources, Springer (2009).
3. T K Ghosh, M A Prelas, Energy Resources and Systems, Vol. 2: Renewable Resources, Springer (2011).
4. E E Michaelides, Alternative Energy Sources, Springer (2012).
5. J Twidell, T Weir, Renewable Energy Sources, Second edition, Taylor & Francis (2006).
6. V V N Kishore, Renewable Energy Engineering and Technology: Principles and Practice, Fundamentals of Renewable Energy Processes, Earth scan (2009).
7. A V da Rosa, Fundamentals of Renewable Energy Processes, Elsevier (2009).

Course Code: CHE-S509 **Breakup: 3-1-0-4**
Course Name: Biochemical Engineering

Course outcomes (CO): At the end of the course, the student will be able to:

CO1	Understanding of biological basics and bioprocessing for cell Structure and Cell Types
CO2	Understanding the Kinetics of Enzyme Reactions, Applied Enzyme Catalysis,
CO3	Define the transport Phenomena in Biosystems and Analysis of Biological Reactors
CO4	Design the downstream Product Recovery and Purification system
CO5	Interaction of Mixed Microbial Populations, biological wastewater treatment

Course Details:

Cell Structure and Cell Types, Chemicals of Life (RNA, DNA, enzymes etc.),

Kinetics of Enzyme Reactions, Applied Enzyme Catalysis, Metabolic Stoichiometric and Energetics, Molecular Genetics and Control, Biomass Production,

Transport Phenomena in Biosystems, Design and Analysis of Biological Reactors, Fermentors, Downstream Product Recovery and Purification, Interaction of Mixed Microbial Populations, Biological Wastewater Treatment at Global, local and regional level.

Text and Reference Books:

1. M.L. Shular, F. Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall (2015)
2. J.E. Bailey and D.F. Ollis, Biochemical Engineering Fundamentals, Mc Graw Hill (2017)
3. P.M. Doran, Bioprocess Engineering Principles, Academic Press Limited (2012)