B.TECH FOURTH YEAR SYLLABUS CHEMICAL ENGINEERING

7th SEMESTER

Sl. No.	Course Name	L	T	P	Credits
1	Elective II	3	0	0	3
2	Data Analytics and AI for Process Industry	3	0	0	3
3	Project Engineering and Management	3	0	0	3
4	Process Safety	1	0	0	1
5	Industrial Training	0	0	0	2
6	Mass Transfer Lab	0	0	3	2
7	Project I	0	0	6	4
	Total	**10**	**0**	**9**	**18**

8th SEMESTER

Sl. No.	Course Name	L	T	P	Credits
1	Process Integration and System Design	3	1	0	4
2	Elective III	3	0	0	3
3	Elective IV	3	0	0	3
4	Elective V	3	0	0	3
5	Project II	0	0	9	6
6	Comprehensive Viva-Voce	0	0	0	2
	Total	**12**	**1**	**9**	**21**

7^{th} SEMESTER

Course Type	Course Code	Name of Course	L	T	P	Credit
Core	BS40002	Data Analytics and AI for Process Industry	3	0	0	3

Course Objective

1. To introduce students to basic applications, concepts, and techniques of data mining.
2. To understand various key paradigms for machine learning approaches.
3. To understand and differentiate among various machine learning techniques.

Learning Outcomes

Student will be able to:

1. Understand the need for data analysis, basic techniques used in data mining and machine learning.
2. Design a data mart or data warehouse for any organization and extract knowledge using data mining techniques.
3. Design and implement machine learning solutions to classification, regression, and clustering problems; and be able to evaluate and interpret the results of various machine learning algorithms.
4. Understand the importance of big data analytics, a Big Data Platform and its uses.

Unit No.	Topics to be Covered	Learning Outcome
1.	**Introduction:** Introduction to Data Analytics and Artificial Intelligence-Some illustrations of AI problems-Data-Information-Knowledge-Applications of Data Analytics-Introduction to the Languages of Data Science: R, SQL, and Python.	Student will understand the need for this course and also learn the basics (SQL, Python libraries) needed for the rest of the course.
2.	Data warehousing: Introduction to Data warehousing, Concepts of Data warehousing-OLAP-Data Preparation and Visualization.	Students will understand a data mart or a data warehouse and extract knowledge from them using data mining techniques.

3.	Descriptive Statistics: Central Tendency and Variability, Inferential Statistics-Probability-Central Limit Theorem-Exploratory Data Analysis-Hypothesis Testing.	Student will learn to calculate and interpret the various measures of central tendency, dispersion skewness. Analyse and compare different sets of data. Making an inference about a population from a sample.
4.	Linear Regression, Classification and Clustering Techniques: KNN, Naïve Bayes and Logistic Regression-K-means and Hierarchical Clustering-Decision Trees-Support Vector Machines-Neural Networks-Association Rule Mining.	Design and implement machine learning solutions to classification, regression, and clustering problems; and be able to evaluate and interpret the results of various machine learning algorithms.
5.	Introduction to Big Data And Hadoop; Managing Big Data: Hadoop Ecosystem tools (Sqoop and Hive).	Understand the importance of big data analytics, a Big Data Platform and its uses.

Text Books:

1. Thomas A. Runkler, Data Analytics: Models and Algorithms for Intelligent Data Analysis, Springer, 2012.
2. Data Mining: Concepts and Techniques (The Data Mining: Concepts and Techniques (The Morgan Kaufmann Series in Data Management Systems) by Jiawei Han (Author), Micheline Kamber (Author), Jian Pei.
3. Big Data and Hadoop by V. K. Jain.

References:

Wes McKinney, Python for Data Analysis, O' Relley, 2013.

1. Keith R. Holdaway, Harness Oil and Gas Big Data with Analytics: Optimize exploration and Production with Data Driven Models, Weily, 2014.
2. Robert Haining, Spatial Data Analysis, Theory and Practice, Cambridge University Press, 2003.

Course Type	Course Code	Name of Course	L	T	P	Credit
	CH 40001	Project Engineering and Management	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	Stages of Project Implementation; Project Milestone: Planning, Analysis, Selection, Implementation; Generation and Screening of project ideas. Feasibility studies. Project Analysis and introduction to various component of Project cost and their estimation; Elements of Coat of Project, Cost of Production; Financing of projects: Debt-Equity ratio etc.. Depreciation concept, Capital cost estimation, Working capital estimation, Project Evaluation, break-even analysis, ROI, IRR, Discounted cash flow analysis. Project Management and Scheduling, Network Technique for project management: CPM and PERT, Project Risk Assessment, Social Cost benefit analysis, Venture capital and Private Equity.	

Text Books:

1. Projects: Planning, Analysis, Selection, Financing, Implementation, and Review by P. Chandra.
2. Plant Design and Economics for Chemical Engineers by M. S. Peters and K. D. Timmerhaus.
3. Project Engineering of Process Plants by H.F. Rase.

Course Type	Course Code	Name of Course	L	T	P	Credit
Core	BS40003	Process Safety	1	0	0	1

Course Objective

1. Understand the unsafe situations that can arise in process plants.
2. To take action to make the plant safer.
3. Prevent the accident.
4. Mitigate the consequences should an accident occur.

Learning Outcomes

1. Understand the different unsafe situations that can arise in a chemical plant.
2. Forewarn their subordinates and inform their seniors about unsafe situations.
3. Suggest/ take actions to prevent such situations and mitigate the consequences.

Unit No.	Topics to be Covered	Learning Outcome
1.	Safety in chemical industry; Setting & layout of chemical plant. Forms of hazards: chemical, toxic, explosion, electrical, mechanical, radiation, noise hazards. Control and prevention of hazards.	Understand basic terminologies of process safety. Will be able to read and appreciate documents related to process safety. Case studies.
2.	Asphyxiation, respiratory and skin effect of petroleum hydrocarbons, sour gases. Thresh-hold limits. Analysis of documented accidents: emission from Leaks, free jets, Pool formation and vaporization, dispersion in atmosphere, fires and explosions, boiling liquid expanding vapour explosion (BLEVE), dust explosion.	Will understand the entry, metabolism and effect of toxicants in the body. Will understand specific toxicant effects from case studies. Will understand source and dispersion models of emissions. Case studies.

3.	Characteristics of chemical with special reference to safe storage & handling. Layout of storage, modes of transport, associated hazards control and prevention. Offshore safety. Onshore and Offshore Emergency Management Plans.	Will appreciate risks and hazards associated with storage and handling of flammable materials. Will understand offshore safety challenges. Case studies.
4.	Risk Analysis: hazard and operability (HAZOP) studies. Hazard analysis (HAZAN), fault tree analysis, consequence analysis, scenario and probabilistic assessment. Safety audit: objective, procedure, engineering standards, Factories Act and Regulation, regulating agencies. Safety and Environmental Management Systems, SEMS.	Will be able to do risk assessment. Will be familiarize with the safety audit and standards.

Text Book:

1. Crowl, D.A., Louvar, J. F., "Chemical Process Safety – Fundamentals with Applications". Prentice-Hall, Pearson, 2011.

Reference:

1. CCPS," Guidelines for Engineering Design for Process Safety", AIChE

Course Type	Course Code	Name of Course	L	T	P	Credit
Core	BS 48001	Industrial Training	0	0	0	2

Course Objective

1. The objective of this course is to provide hands-on industrial training to students which helps them to gain practical knowledge on various industrial operations and introduce them to professional work environment.

Learning Outcomes

Upon successful completion of industrial training, students will:

1. Gain working knowledge on various industrial operations.
2. Have acquired hands-on practical training to perform different industrial operations.
3. Be introduced to latest technologies and advancements adopted in the industry.
4. Understand the technological challenges and constraints currently faced by the industry.
5. Understand the professional work culture practised in the industry.

Course Type	Course Code	Name of Course	L	T	P	Credit
Lab	CH 40003	Mass Transfer Laboratory	0	0	3	2

Course Objective

To provide hands-on experience and practical knowledge of various mass transfer operations through lab scale experiments.

Learning Outcomes

At the end of the course, the student will be able to

1. Determine diffusion coefficient and interpret adsorption data.
2. Understand and operate different types of lab scale distillation apparatus.
3. Compute drying calculations and estimate drying time.

Unit No.	Topics to be Covered	Learning Outcome
1.	Determination of Diffusion Coefficient of Air-Acetone by Stefan's method.	Hands on experience on mass transfer equipment and property estimation.
2.	T-X-Y equilibrium diagram for binary mixture	
3.	Batch Distillation,	
4.	Sieve Plate Distillation,	
5.	Packed Bed Distillation Column, Flooding and Loading in Packed Tower,	
6.	Water Cooling Tower,	
7.	Liquid-Liquid Extraction,	
8.	Rotating Disk Contactor,	

9.	Liquid-Liquid Extraction in Sieve Plate Column,	
10.	Drying Characteristics of Wet Solids in Flowing Air, Rotary Drier (Hold-Up), Rotary Drier (Drying Characteristics of Wet Solids), Gas-Solid Adsorption	

Text Book:

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill Education, 2017.

Reference:

2. W. L. McCabe, J. C. Smith and P. Harriott, Unit Operations of Chemical Engineering, McGraw Hill Education, 2017.

8th SEMESTER

Course Type	Course Code	Name of Course	L	T	P	Credit
Core	CH 40005	Process Integration and system Design	3	1	0	4

Course Objective

1. This course is intended to provide basics of chemical process design, use of pinch technology in Heat, and Mass integration of process plants.

Learning Outcomes

1. Understand pinch technology as it applied to heat and mass integration of chemical process plants.
2. Understand both graphical and numerical procedures for finding minimum energy, minimum area, and minimum units, minimum cost targets in heat integration.
3. Basics of optimization, Components of an optimization problems and types of optimization problems.
4. Use Aspen Plus for simulating process flow sheets.
5. Use Aspen Plus energy analyzer and other software to develop targets for heat integration and design of heat exchanger networks.

Unit No.	Topics to be Covered	Learning Outcome
1.	Process Flow Sheet in Aspen plus and Aspen HYSYS. Pinch technology and its application; Heat exchanger networks: analysis and design for maximum energy recovery, Loop Breaking & Path Relaxation, targeting of energy, area, number of units and cost, Trading off energy against capital.	Students will have understanding of basic concepts of conceptual process design, technology selection, and integration. Students are introduced to the basics of optimization.
2.	Network Integration: Super targeting, maximum energy recovery, multiple utilities and multiple pinches, Grand Composite curve.	Learn how to do simulations in aspen plus. Learn basics of process integration and Pinch technology. Understand steps in chemical process integration.

3.	Mass integration: Distillation sequences. Graphical and numerical targeting methods of mass exchanger network.	Learn the interconnection between the targets and the optimal. Concepts of Grand composite curves and how it can help in selection of multiple utilities. Total annual cost estimation of a HEN.
4.	Water integration, targeting and network design. Property integration.	Understand the steps in the design of HEN using Pinch technology and its optimization.
5.	Introduction to optimization; Separation scheme synthesis and residue curve theory; Non-linear programming, mixed integer and disjunctive programming, flow sheet optimization; scheduling of batch and continuous multistage plants. Case Studies: Refinery scheduling and blending, multisite production-planning. Supply chain optimization.	Understand the application of pinch technology to Mass integration.

Text Books:

1. Smith, R., Chemical Process Design and Integration, John Wiley & Sons (2005).
2. W. D. Seider, J. D. Seader, D. R. Levin and S. Widagdo, Product and Process Design Principles: Synthesis, Analysis and Design, 3rd Ed.; Wiley, New York, 2009.
3. Kamal I.M. Al-Malah, Aspen Plus: Chemical Engineering Applications Wiley (2016).
4. Linnhoff, D.W., User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers (1994).

References:

1. T. F. Edgar, D. M. Himmelblau and L. S. Lasdon, Optimization of Chemical Processes, 2nd Ed., McGraw Hill, New York, 2001.
2. G. Towler and R. K. Sinnot, Chemical Engineering Design, Elsevier, Oxford, UK.
3. S. Thakore and B. Bhatt, Introduction to Process Engineering Design, Tata McGraw Hill, New Delhi, India, 2008.
4. B. V. Babu, Process Plant Simulation, Oxford University Press, New Delhi, 2004.
5. Shenoy, V. U., Heat Exchanger network synthesis, Gulf Publishing (1995).
6. Kumar, A., Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1977).

7. Michael E. Hanyak Jr, Chemical Process Simulation and the Aspen HYSYS v8.3 Software Cretespace (2013).
8. A.K. Jana, Process Simulation and Control using Aspen. Prentice Hall India (2012).

ELECTIVES	
Elective - II	1. Unconventional Hydrocarbon Resources 2. Enhanced Oil Recovery 3. Solar Energy, Photovoltaic Energy 4. Advanced Separation 5. Advanced Material Design 6. Waste to Energy Conversion
Elective - III	1. Petroleum Engineering System Design 2. Nuclear Wind and Geothermal Energy 3. Hazardous Waste Treatment and Safety Devices 4. Analytical Techniques 5. Offshore and Deep sea technology
Elective - IV	1. Natural Gas Engineering 2. Advanced Reservoir Modelling 3. Petroleum Refinery Engineering 4. Air Pollution Control 5. Tribology & Introduction to the Lubricants 6. Energy Storage System
Elective - V	1. Prospecting, Field Development and Asset Management 2. Petrochemical Technology 3. Nano Materials for Hydrocarbon Industry 4. Process Modelling and Simulation 5. Hydrogen Energy

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective II	PE30010	Unconventional Hydrocarbon Resources	3	0	0	3

Course Objective

1. This course is designed to give the students an overview of exploration, development and production from unconventional hydrocarbon energy resources such as Shale gas/oil, CBM, Gas hydrates, Heavy oil and Tar sand. The course also highlights technological advancement in exploration, drilling, completion and production for these unconventional hydrocarbon reservoirs.

Learning Outcomes

1. Potential of Unconventional Hydrocarbon Energy resources to meet the rising energy demand.
2. Production technique and technological advancement for efficient and economical extraction from these reservoirs.
3. Challenges associated with production and development of Unconventional Hydrocarbon Energy resources.

Unit No.	Topics to be Covered	Learning Outcome
1.	CBM: Introduction, formation and properties, exploration, isotherm studies, reserve estimation, drilling and production. system, artificial lift, hydraulic fracturing of coal seam, produced water separation and disposal, surface facilities, well testing.	• CBM reservoir characteristics. • Drilling, Completion and Production methods. • from CBM reservoir. • Hydraulic fracturing. • and fluid for CBM reservoir. • Water treatment and • disposal for CBM wells.
2.	Natural Gas Hydrates: Introduction, formation and properties, thermodynamics, kinetics and phase behavior, gas extraction methodologies.	• Thermodynamic and kinetic conditions of hydrate formation. • Gas hydrate reservoir characteristics and method of production.
3.	Shale Gas/ Oil: Introduction, geology, important occurrences, petro physical properties, hydro fracturing, horizontal wells, production profiles.	• Shale gas reservoir occurrence & characteristics. • Production optimization from shale reservoir.

4.	Non-Conventional Oil: Introduction to Heavy oil, extra heavy oil, Tar Sand and bituminous, oil shales; origin and occurrence worldwide, resources, reservoir characteristics, new production technologies.	• Production methodology from Heavy Oil reservoir, Tar sand and Oil shale. • Reservoir characteristics.

Text Books:

1. Natural gas Hydrates: A guide for engineers by John Carroll.
2. Coal Bed Methane: From Prospects to Pipeline by P Thakur, K Aminian and S. Schatzel.
3. Unconventional Gas Reservoirs: Evaluation, Appraisal, and Development by MR Islam.
4. Class Notes.

Reference:

1. Clathrate hydrates of Natural Gases by ED Sloan and Carolyn A Koh.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective II	PE40003	Enhanced Oil Recovery	3	0	0	3

Course Objective

1. The objective of this course is to impart knowledge about different EOR techniques and its underlying mechanism on enhancing the oil recovery. This course also aims to provide knowledge on how to field implement and evaluate the performance of different EOR techniques.

Learning Outcomes

Upon successful completion of this course, students will:

1. Understand the importance of EOR, learn when to apply EOR, learn about different EOR types and its functions and learn about the different indicators/measures used to evaluate the EOR performance.
2. Learn about chemicals/agents used for different EOR techniques and its functions in enhancing oil recovery.
3. Learn about the underlying mechanisms that causes oil recovery in different EOR techniques.
4. Learn about the field implementation and performance evaluation of different EOR techniques.

Unit No.	Topics to be Covered	Learning Outcome
1.	**Fundamentals of EOR:** Global and domestic necessity for EOR; India's EOR policy; microscopic and macroscopic displacement of fluids in reservoir; mobilization of trapped oil; mobility control; EOR performance indicators - Capillary Number, mobility ratio, breakthrough from fractional flow curves, wettability alteration from relative permeability curves; recovery factor – volumetric displacement and microscopic displacement efficiency; overview of waterflooding process; different EOR methods and its functions; EOR screening.	Students will understand why EOR is required & India's effort to promote EOR. Students will learn on: when to apply EOR in the field; what different EOR techniques are applied; what different indicators/measures are used to evaluate the EOR performance; and how EOR screening is performed.

2.	**Chemical EOR Methods – I:** ***Surfactant flooding EOR***: Oil recovery mechanism by surfactants, surfactant types & its functions; CMC; microemulsion – types & its phase behavior; field implementation of surfactant flooding EOR; performance evaluation and screening of surfactants. ***Polymer flooding EOR***: Oil recovery mechanism by polymers; mobility control; polymer types & its behavior under reservoir conditions; field implementation of polymer flooding EOR; performance evaluation and screening of polymers for EOR. ***Alkaline-Surfactant-Polymer (ASP) flooding EOR***: Role of alkaline in oil recovery; oil recovery mechanism and field implementation of ASP flooding EOR; performance evaluation of ASP EOR.	Students will learn in detail about the underlying oil recovery mechanisms involved in surfactant, polymer and ASP flooding EOR techniques. Students will have understanding on different surfactants, polymers and alkali used in respective EOR techniques and its function in enhancing the oil recovery. Students will also learn about how EOR techniques such as surfactant, polymer and ASP flooding EOR are implemented in the field and how its performance are evaluated.
3.	**Chemical EOR Methods – II:** ***Low salinity water flooding (LSWF) EOR*:** Oil recovery mechanisms – Double layer expansion, MIE process, pH alteration, fines migration, etc.; evaluation of wettability alteration from rel. permeability curves; field implementation; challenges in LSWF EOR. ***Microbial EOR (MEOR):*** Different types of microbes and bioproducts and its role in oil recovery; MEOR types and its oil recovery mechanism; field implementation and performance evaluation of MEOR; Merits and challenges in implementing MEOR. ***Hybrid EOR techniques***: Oil recovery mechanism of Low salinity surfactant flooding, Low salinity polymer flooding.	About low salinity water flooding (LSWF), microbial and hybrid EOR techniques, students will learn: Underlying concepts and mechanisms that causes the enhancement in oil recovery. How those EOR techniques are implemented in field and how its recovery performance is evaluated. Current merits and challenges of those EOR techniques, which helps them to identify solutions for those challenges in the future.

4.	**Gas EOR Methods & CO_2 Sequestration:** Gases used for EOR; Gas EOR types; MMP; immiscible gas flooding EOR; miscible flooding EOR – first contact miscibility and multiple contact miscibility – vaporization, condensation and combined drive mechanism; ternary phase diagrams for immiscible and miscible gas flooding EOR mechanisms. Field implementation and oil recovery mechanism of: continuous gas injection, CO2 flooding, WAG, SWAG, SSWAG EOR process. Necessity for CO_2 sequestration; CO_2 sequestration in aquifers and oil reservoirs; CO_2 trapping mechanisms – Structural, hydrodynamic, residual, dissolution and mineral trappings. Challenges in CO_2 sequestration.	Students will learn about: Different gases that are conventionally used for EOR; How gases enhance the oil recovery by miscibilization and immiscibilization process; how miscibilization of injected gas with the reservoir oil happens in first and during multiple contacts between gas and oil; how oil composition ternary phase diagram evolves during first and multiple contact miscibility. Different gas EOR methods implemented in the field and its governing mechanism on enhancing the oil recovery. CO_2 sequestration and different geo-trapping mechanisms by which CO_2 is sequestrated in the subsurface.
5.	**Thermal EOR Methods:** Types of thermal EOR and its oil recovery mechanism, advantages and constraints – Hot water flooding, steam flooding, cyclic steam flooding or huff & puff steam flooding, steam assisted gravity drainage, in-situ combustion oil recovery technique.	Students will learn about the field implementation, merits and constraints of different thermal EOR methods such as Hot water flooding, steam flooding, cyclic steam flooding or huff & puff steam flooding, steam assisted gravity drainage, in-situ combustion oil recovery technique.

Text Books:

1. Enhanced Oil Recovery. SPE (2018): Don W. Green and G. Paul Willhite.
2. Fundamentals of Enhanced Oil Recovery. SPE (2015): Larry W. Lake, Russell Johns, Bill Rossen, Gary Pope.
3. Fundamental of enhanced oil and gas recovery from conventional and unconventional reservoirs (2018): Alireza Bahadori.

Reference:

1. Enhanced oil recovery, I: Fundamentals and analysis: E.C. Donaldson, G.V. Chilingarian, T.F. Yen.
2. Enhanced oil recovery, II: Processes and operations : E.C. Donaldson, G.V. Chilingarian, T.F. Yen.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective II		Solar Energy, Photovoltaic Energy	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction; Nature and availability of solar energy; Principle of operation of solar cells – materials and processing, thin film, unconventional materials and systems; Concentrators; Cells and system characteristics; Power conditioning, energy storage, and grid connection; Maximum power point tracking, PV to grid – single and three phases; Economy and Life cycle costing. Solar thermal energy. Water pumping: dc and ac pump drive; Peltier refrigeration.	

Text Books:

1. Hans S. Rauschenbach, Solar Cell Array Design Handbook: The Principles and Technology of Photovoltaic Energy Conversion. Springer (2013).
2. C. Hu and R.M. White, Solar Cells: From Basic to Advanced Systems. McGraw Hill (1983).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-II	CH 40004	Advanced Separation	3	0	0	3

Course Objective

1. To impart understanding of various aspects of novel separation systems considering application, theory and design. Learn to develop design equations for various filtration processes.

Learning Outcomes

At the end of the course, the student will be able to

1. Evaluate the design parameters for multicomponent distillation process.
2. Identify and model suitable membrane process for treatment of target contaminants.
3. Understand specific applications of novel separation process.

Unit No.	Topics to be Covered	Learning Outcome
1.	Thermodynamics: Phase equilibria, non-ideal thermodynamic property models, activity coefficient models for the liquid phase; Single equilibrium stages: Multicomponent Liquid-Liquid, Solid- Liquid, Gas-Liquid, Vapor-Liquid-Liquid systems.	Modeling and design of multi-component distillation system.
2.	Multicomponent multistage separations: Approximate methods, Equation tearing procedures.	Advanced knowledge about Novel Separation processes.
3.	Enhanced distillation; Supercritical extraction. Vapor-liquid flow pattern and rate based models for distillation.	Advanced knowledge about membrane based gas separation processes and design expertise.
4.	Membrane separations; Adsorption, ion exchange, and chromatography.	Advanced knowledge about membrane based liquid separation processes and design expertise.

Text Books:

1. J. D. Seader and E.J. Henley, Separation Process Principles, Wiley (2006).
2. R.W. Baker, Membrane Technology and Applications, Second Edition, Wiley (2004).

Reference Books:

1. Charles Holland, Fundamentals of Multicomponent Distillation, McGraw Hill (1997).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective II	PE 40009	Advanced Material Design	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	Materials characterization using optical and neutron spectroscopies; Multiscale atomistic modeling; Use of density functional theory to predict temperature dependent thermodynamic properties of new materials e.g., complex hydrides, and kinetic processes in diffusion; Introduction to molecular simulations; Semiconductor and oxide nanostructure for optoelectronic devices, high energy solar cells; Quantum dots; Thermoelectric materials.	

Text Books:

1. Edward L. Wolf, Nanophysics and Nanotechnology. Wiley Verlag (2006).
2. Peter Würfel, Physics of Solar Cells: From Basic Principles to Advanced Concepts. Wiley (2009).
3. Charles Kittel, Introduction to Solid State Physics. Wiley (2012).
4. D. C. Rapaport, The Art of Molecular Dynamics Simulation. Cambridge University Press (1995).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective: II	-	Waste to Energy Conversion	3	0	0	3

Pre-Requisites:

Basic of heat, thermodynamics, and chemical reaction engineering; Biochemical processes.

Objectives:

1. The course provides a thorough understanding of waste to energy resources, technologies and systems to convert the waste into energy (e.g., anaerobic digestion, fermentation, pyrolysis, gasification, incineration, etc.).
2. It also provides a basic understanding of the principles underlying the modern design and operation of systems based on recent research.

Learning Outcomes

1. Understand and learn the fundamental aspects involved during the conversion of waste into energy (e.g., anaerobic digestion, fermentation, pyrolysis, gasification, incineration, etc.)
2. Familiar with the current research scenario associated with biochemical and thermal treatment of wastes & biomass.
3. Acquired skills will be useful in the preparation, planning, and implementation of energy projects.

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction to energy from waste: Characterizations and classification of waste as fuel- agro-based, forest residues, industrial waste, municipal solid waste, & E-waste.	Understand energy, energy balance, and acquainted with various source and characterization of wastes
2.	Global and Indian scenario: Environmental aspects, Waste Management; 3R Principle of Reduce, Reuse and Recycle.	Familiar with the Global and Indian scenario and 3R principle.
3.	Waste to energy options: Biochemical and Thermochemical routes; Biochemical Options – Anaerobic Digestion, Fermentation; Thermochemical Options – Pyrolysis, Gasification, and Incineration; Other options – Biodiesel synthesis, Briquetting, Torrefaction, and Hazardous waste management.	Learn the energy options and fundamental aspects involved during the conversion of waste into energy.

4.	Properties of fuels derived from waste to energy technology: Producer gas, Biogas, Ethanol, and Briquettes, Comparison of properties with conventional fuels.	Understand the properties of fuels derived from waste.
5.	Energy production from waste plastics and E-waste, Cultivation of algal biomass from wastewater and its application in energy production. Calculations: heat & mass balances.	Familiar with the Energy production from plastics wastes & algal biomass with Heat & Mass balance.
6.	Landfills: Gas generation and collection in landfills, Introduction to transfer stations, Case studies related to waste to energy conversion.	Learn the collection and transportation of fuel and case studies.

Books:

1. D.O. Hall and R.P. Overeed, Biomass-Renewable Energy, John Willy and Sons, New York. 1987.
2. M.M. EL-Halwagi, Biogas Technology, transfer and diffusion, Elsevier Applied science Publisher, New York, 1984.

References:

1. M. J. Rogoff and F. Screve, Waste-to-energy: technologies and project implementation. Academic Press., 2019.
2. N. B. Klinghoffer and M. J. Castaldi, Waste to energy conversion technology. Elsevier., 2013.
3. J.H. Harker, and J.R. Backhusrt, Fuel and Energy, Academic Press Inc.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective III	PE 40010	Petroleum Engineering System Design	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	• Rig selection and design: Drilling rig, Work-over rig, Loading and stability of rig. • Casing and Drill string design. • Crude oil treatment: Heater treater, Electrostatic Heater treater, Design of Heater treater. • Design Gas lift system: Continuous and Intermittent system. • Design of SRP, ESP and PCP system. • Design of Pump and Compressor, Coil tubing unit.	

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective III	PE40011	Nuclear Wind and Geothermal Energy	3	0	0	3

Course Objective

1. The course aims to give students a basic understanding of nuclear energy concepts such as nuclear fission, fusion, nuclear reactors, nuclear fuel, and their management.
2. To facilitate the students to achieve a clear conceptual understanding of technical and commercial aspects of wind energy generation.
3. To be familiar with fundamental concepts of geothermal energy generation.

Learning Outcomes

1. At the end of the course, students will learn and understand fundamental concepts of nuclear energy generation which include nuclear fission, fusion, nuclear reactors, nuclear fuel, and their management.
2. On completion of this course, the students will be able to exhibit conceptual knowledge of the technology, economics, and viability of wind energy generation.
3. Students will get to know about basic concepts of geothermal energy.

UnitNo.	Topics to be Covered	LearningOutcome
1	Nuclear Energy: Basic nuclear models, radioactivity, nuclear reactions – energy systems based on fission & fusion reactions.	The course aims to give students a basic understanding of nuclear energy concepts such as nuclear fission, fusion, nuclear reactors, nuclear fuel, and their management.
	Reactor heat generations and removal; Nuclear Fuel cycle from Uranium / Thorium supply, enrichment.	
	Fuel management and waste disposal.	
	Interaction of ionizing radiation with matter, radiation detection, shielding, and effects on human health.	
2	Wind Energy: Introduction to wind resources: wind speed and terrain properties, power density; Measurement of wind speed and turbulence.	On completion of this course, the students will be able to exhibit conceptual

	Wind turbine / rotor design: Thrust, torque, speed, and power; Turbine material design and structural analysis.	knowledge of the technology, economics, and viability of wind energy generation.
	Integration of variable power production into electrical systems: Control of rotor speed, maximum power in low wind speeds, constant power in high wind speeds.	
	Offshore wind farm:Dynamic wind and wave loadings, grid integration, operational and maintenance strategies.	
	Cost of energyfrom wind turbine during lifetime.	
3	Nature, occurrence, types and classification of geothermal fields;	Students will get to know about basic concepts of geothermal energy.
	Resource Exploration and Characterization.	
	Geothermal Energy Recovery.	
	Analysis of energy system proposals with reference to engineering, economic, socio-political, and environmental objectives.	

References

1. Murray, R. and Holbert, K.E., 2014. Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes. Elsevier.
2. Manwell, J.F., McGowan, J.G. and Rogers, A.L., 2010. Wind energy explained: theory, design and application. John Wiley & Sons.
3. Grant, M.A. and Bixley, P.F. Geothermal Reservoir Engineering. Second Edition. Elsevier. 2011.
4. Glassley, W.E. Geothermal Energy. Second Edition. CRC Press. 20.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective III	CH 40011	Hazardous Waste Treatment and Safety Devices	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	• Fundamental knowledge of hazardous waste, their sources, generation, identification, classification and characterization. • Health and safety related problems of hazardous waste, routes of migration. • Minimization Technologies of hazardous waste. • Hazardous waste treatment and its disposal. • Regulatory aspects of hazardous wastes: regulation on storage handling and transportation of hazardous waste. • Clean-up of hazardous waste contaminated sites. • Risk assessment and hazardous waste management. • Management of hazardous waste case studies: pesticides and containers. • Management of hazardous nuclear waste.	

Text Books:

1. Michael D. Lagrega, Phillip L. Buckingham, Jeffrey C. Evans, Hazardous Waste Management.
2. Waveland Pr Inc. (2010).
3. S. Bhatia, Solid and Hazardous Waste Management. Atlantic (2007).
4. Mackenzie Davis, David Cornwell, Introduction to Environmental Engineering. McGraw Hill Indian Edition (2017)

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-III	CH 40006	Analytical Techniques	3			3

Course Objective
The objective of the course is to provide technical prospectus and overview of different analytical techniques for spectroscopic, spectrometric, microscopic, thermal and chromatographic characterization of materials.

Learning Outcomes
By the end of the course, the students will be able to, 1. Understand the basics and application of different analytical techniques and instrumentation used in different analytical laboratories for material characterization. 2. Categorically interpret the fundamental properties of the material using spectroscopic, spectrometric,microscopic, thermal and chromatographic characterization instruments.

Unit No.	Topics to be Covered	Learning Outcome
1.	**Spectroscopy:** Introduction, Spectroscopy methods: Infrared, UV-Visible, Fluorescence, Nuclear Magnetic Resonance, Atomic Absorption.	Learn Fundamentals, Working and Instrumentation of Spectroscopy.
2.	**Spectrometry:** Mass, Matrix-assisted laser desorption/ionization (MALDI).	Learn Fundamentals, Working and Instrumentation of Spectrometry.
3.	**Microscopy:** Introduction, Atomic Force Microscopy, Field Emission Scanning Electron Microscope with EDXS (Energy-dispersive X-ray spectroscopy), Transmission Electron Microscopy, Laser Scanning Confocal Microscopy, Confocal Raman.	Learn Fundamentals, Working and Instrumentation of Microscopy.

4.	**Thermal analysis:** Differential Scanning Calorimetry, Thermal Gravimetric Analysis.	Learn Fundamentals, Working and Instrumentation of Thermal Analysis techniques.
5.	**Chromatography:** Introduction, Thin-Layer Chromatography, Types of Column Chromatography: Affinity and Ion Exchange, Gel Permeation and HPLC, Gas Chromatography–Mass Spectrometry.	Learn Fundamentals, Working and Instrumentation of Chromatography.

Text Book:

1. Keith Wilson and John Walker, Principles and Techniques of Biochemistry and Molecular Biology, Cambridge University Press; 8th Edition,Cambridge University Press, (2018).
2. D. A. Skoog and D. M. West, Fundamentals of analytical chemistry, Cengage Publishers; 9th Edition. Cengage Publishers, (2014)R. M. Silverstein, F. X. Webster, D. J. Kiemle and D. L. Bryce, Spectrometric Identification of Organic Compounds, Wiley Publishers; 8th Edition, Wiley, (2014).
3. D. B. Williams and C. B. Carter, Transmission electron microscopy-a text book for material science, Springer Publishers; 2nd Edition ,Springer, (2009).

Reference:

1. G. D. Christian, P. K. Dasgupta and K. A. Schug, Analytical Chemistry, Wiley Publishers; 7th Edition , Wiley, (2013)
2. Introduction to Polymer Science. Charles E. Carreher. Jr.,4th Edition,CRC Press, (2017).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective III	PE 40005	Offshore and Deep Sea Technology	3	0	0	3

Course Objective
1. The objective of the course is to introduce the students to the challenging area of petroleum industry and make them understand different offshore platforms used for drilling and production; their stability criteria and station keeping methods. The aim of this course is also to provide a clear understanding of the difference between offshore and onshore operations w.r.t. drilling, completion and production operations with the help of case studies.
Learning Outcomes
On successful completion of the course, the student shall be able to: 1. Explain the offshore sea environment and stability of offshore structures, 2. Explain applications and limitations of the various fixed and floating offshore drilling/production structures, 3. Explain offshore drilling, challenges and technologies, 4. Explain offshore production processing, transportation and storage and deep sea technologies, 5. Explain well abandonment methods and environmental concerns and emerging technologies, 6. Solve practical case studies.

Unit No.	Topics to be Covered	Learning Outcome
1	**Introduction:** Offshore oil and gas operations and ocean environment. Sea floor marine soils, Geotechnical aspects. Various forces acting on offshore structure; Stability of offshore structure.	Explain the offshore sea environment and stability of offshore structures.
2	**Offshore Platforms:** Offshore fixed platforms, mobile units, Station keeping methods like mooring & dynamic positioning system.	Explain applications and limitations of the various fixed and floating offshore drilling/production structures.
3	**Offshore Drilling and Well Completion:** Difference in drilling from land, from fixed platform,	Explain offshore drilling, challenges and technologies.

	Jackup, ships and semi submersibles. Use of conductors and risers. Deep sea drilling. Well completion. Deep water applications of subsea technology: drilling rig, well construction issues, cementations, casing and mud design, mud window for vertical / horizontal drilling, gas hydrates.	
4	**Offshore Production and sub-sea technologies** Offshore production: Oil processing platforms, water injection platforms, storage, SPM and SBM transportation and utilities. Deep water production system: Subsea transducers / sensors, control module, Wellheads and manifolds phase separators.	Explain offshore production processing, transportation and storage and deep sea technologies
5	Well abandonment, environmental concerns, Emerging deep water technologies, equipment and systems, remote operation vessels, safety of divers.	Explain well abandonment methods and environmental concerns and emerging technologies.
6	**Case studies** Selection of offshore platform, mooring system, production facilities based on given conditions.	Solve practical case studies.

Text Books:

1. S. Laik "Offshore Petroleum Drilling and Production" CRC Press, Taylor and Francis.
2. Yong Bai, Qiang Bai, Subsea Engineering Handbook. Gulf Professional Publishing (2012).
3. James Speight, Handbook of Offshore Oil and Gas Operations. Gulf Professional Publishing (2014).
4. Yong Bai, Qiang Bai, Subsea Pipelines and Risers. Elsevier Science (2005).
5. Andrew Clennel Palmer, Roger A. King, Subsea Pipeline Engineering. PennWell Books (2008).
6. Subrata Chakrabarti, Handbook of Offshore Engineering, Volume I and II. Elsevier Science (2005).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective - IV	PE 40003	Natural Gas Engineering	3	0	0	3

Course Objective

The objective of the course is to provide the basic knowledge of natural gas production, natural gas processing and gas transportation. This course also covers both upstream and refining process related to natural gas and along with highlighting the current status of production of natural gas through unconventional sources/technics and the utilization of natural gas in various forms and their value chains.

Learning Outcomes

Upon successful completion of this course, students should be able to:

(a) Explain Natural Gas Significance in Global energy scenario, its composition and utilization.

(b) Explain the Phase behavior of Natural gas and Calculate Natural Gas Properties based on its composition.

(c) Explain the subsurface well completion methods and wellbore performance.

(d) Design surface compression, dehydration, sweeting units required for natural gas processing.

(e) Explain transportation, storage and metering process of natural gas and conversion of natural gas to CNG and LPG.

(f) Explain LNG and CNG value chains.

Unit No.	Topics to be Covered	Learning Outcome
1	**Introduction:** Composition of Natural Gas, Utilization of Natural Gas, Natural Gas Industry, Natural Gas Reserves, Types of Natural Gas Resources, Future of the Natural Gas Industry.	Explain Natural Gas Significance in Global energy scenario, its composition and utilization.
2	**Properties of Natural Gas:** Phase Behaviour, properties of Natural Gas, Formation Volume Factor, etc., Determination of natural gas properties such as specific gravity, pseudocritical properties, viscosity, compressibility factor, gas density, formation and expansion volume, and compressibility.	Explain the Phase behavior of Natural gas and Calculate Natural Gas Properties based on its composition.

3	**Production of Natural Gas:** Overview of well Completion and wellbore Performance.	Explain the subsurface well completion methods and wellbore performance.
4	**Gas Gathering system, transportation and Storage:** Gas Gathering system, Transmission of Natural gas, Transportation and Measurement, Pipeline Design. Flow through pipeline, issues and solutions. Underground storage. Natural Gas Metering.	Explain transportation, storage and metering process of natural gas and conversion of natural gas to CNG and LPG.
5	**Natural Gas Processing & surface facilities:** Gas Compressor, Compressor design, Gas Flow Measurement, Principle of Separator, Design of Separator. Dehydration of Natural Gas, Design of Dehydration, Sweeting processes and sulphur recovery, Processing of LPG, CNG system, Conversion of gas to liquid.	Design surface compression, dehydration, sweeting units required for natural gas processing.
6	**Gas Supply/Distribution:** City Gas/CNG development, CNG stations, Design aspects for City Gas Network and CNG Stations, Maintenance and safety of City Gas Networks and CNG equipment. • LNG: Import of LNG, LNG liquefaction plant and shipping, LNG regasification, LNG Plant.	Explain LNG and CNG value chains.

Text Books:

(a) B. Guo and A. Ghalambor, Natural Gas Engineering Handbook, Gulf Publishing Company, 2005.

(b) T. Ahmed and P. D. McKinney, Advanced Reservoir Engineering, Elseveir, 2005.

(c) D.L. Katz and R.L. Lee, Natural Gas Engineering, M

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective IV	PE 40012	Advanced Reservoir Modelling	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	Geostatistical modeling, quantification of connectivity, lithofacies, porosity, permeability using variogram, krigging techniques; Construction of heterogeneous reservoir models, constrained to well and seismic data; Upscaling and ranking; Stochastic simulation and modeling; Overview of uncertainty analysis and integrated studies; Case studies.	

Text Books:

1. M.J. Pyrez and C.V. Deutsch, Geostatistical Reservoir Modeling. Oxford University Press.
2. J. Caers, Modeling Uncertainty in Earth Sciences. Wiley Blackwell.
3. Matlab Reservoir Simulation Toolbox. SINTEF.
4. S. Cannon, Reservoir Modeling: A Practical Guide. Wiley

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-IV	PE 40003	Petroleum Refinery Engineering	3	0	0	3

Course Objective

The objective of the course is to provide technical prospectus and overview of different processes and unit operations in petroleum refineries to the students.

Learning Outcomes

At the end of the course, the student will be able to

1. Characterize the crude based on the assay data and interpret different parameters associated with the crude characterization and petroleum products to different unit operations in the refinery.
2. Obtain technical information and overview of various unit operations in petroleum refinery with respective feed, products and process parameters of each unit operation in the refinery.

Unit No.	Topics to be Covered	Learning Outcome
1.	Origin of petroleum crude oil. Evaluation of crude oil – evaluation and characterization of crude oil: TBP and other distillation tests. Petroleum products, their properties, specification and testing – different properties like flash point, fire point, smoke point, aniline point, carbon residue, kinematic viscosity, pour point, freezing point etc. Use of crude book data.	To understand the origin of Crude , understand different petroleum products and their properties.
2.	Petroleum refinery distillation – pre-fractionation and atmospheric distillation of crude. Process design for atmospheric distillation. Stabilization of naphtha. Vacuum distillation of RCO.	Understand various distillation processes of crude refining.

3.	Reforming of naphtha. Isomerization and Alkalization, Other secondary processes like Vis-breaking, Furfural/Phenol/NMP extraction, Solvent dewaxing, propane deasphalting. Delayed coking process. FCC unit.	Understanding processing of Naphtha reforming.
4.	Hydrotreatment processes in refining: Hydro-Desulfurisation, Hydrofinishing, Hydrocraking, and Production of lube oil base stock. Residual Hydrocracking.	Understanding Hydrotreatment processes in Refining.
5	Refinery equipment: furnaces, distillation columns, reactors, pumps, compressors and piping.	Understanding refinery Equipment Design and Environmental Impact.
6	Elements of design of stream reformer naphtha cracker, catalytic reformer etc.	
7	Environmental impact of refineries.	

Text Book:

1. Petroleum Refinery Engineering by W. L. Nelson,4th Edition, McGraw-Hill, (1958).
2. Petroleum Refining, Technology & Economics by J. H. Gray & G. E. Handwerk,5th Edition, CRC Press, (2007).
3. Petroleum Refinery Distillation by R. N. Watkins,2nd Edition, Gulf publishing company,(1979).
4. Modern Petroleum Refining Processes by B. K. B. Rao, 6th Edition, CBS Publishers,(2014).
5. Fundamentals of Petroleum and PetroChemical Engineering by Uttam Ray Chaudhuri, CRC Press,1st Edition,(2011).

Reference:

1. The Chemistry & Technology of Petroleum by J. G. Speight, CRC Press, 5th Edition, 2014.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-IV	CH 30009	Air Pollution Control	3	0	0	3

Course Objective

- To provide the scientific and technical background of air pollution, its monitoring techniques, transport and dispersion modeling, and air pollution control technologies.

Learning Outcomes

- Identify the major sources of air pollution and understand their adverse effects on health and environment.
- Evaluate the dispersion of air pollutants in the atmosphere and to develop air quality models.
- Choose and design control techniques for particulate and gaseous emissions.

Unit No.	Topics to be Covered	Learning Outcome
1.	**Introduction**: Introduction to principal aspects of air pollution; History of air pollution; Sources of air pollution; Effects of major air pollutants; Current policies, standards and objectives; Air pollution legislation.	Identify the major sources of air pollution and understand their adverse effects.
2.	**Meteorology and air quality modeling:** Meteorology as applied to air pollution and dispersion of air pollutants; Atmospheric chemistry, Aerosol behaviour; Transport and dispersion modeling. Commercial air quality models (ADMS and USEPA).	Understand the dispersion of air pollutants in the atmosphere and to develop air quality models.
3.	**Monitoring and control techniques:** Monitoring of emissions and air pollutants in ambient air; Engineering control of stationary sources; Modeling and control of emission from road transport and from industrial sources. Selection of control equipments; Process change, fuel change; pollutant removal and disposal of pollutants; Control devices and systems, removal of dry particulate matter, liquid droplets and mist removal, gaseous pollutants and odor removal.	Learn fundamental aspects of sampling techniques and design aspects of air pollution control techniques.

4.	Indoor air pollution: Indoor air pollution; Personal exposure to air pollution.	Learn Indoor air pollution, causes, and their control techniques.
5.	Economics in air pollution control: Economics and trends in air pollution control.	Economic aspects associated with air pollution.

Text Books:

1. H.S. Peavy, D. R. Rowe, G. Tchobanoglous, Environmental Engineering, Mcgraw-Hill (1985).
2. M.N. Rao, H.V.N. Rao, Air Pollution. McGraw Hill, Indian Edition (2017).

References:

1. Richard C. Flagan, John H. Seinfeld, Fundamentals of Air Pollution Engineering. Prentice Hall (1988).
2. Noel de Nevers, Air Pollution Control Engineering, Waveland Press, Inc (2010).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective IV	-	Tribology & Introduction to the Lubricants	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	The fundamentals of lubricants business: • Lubricant value chain. • Types of Lubricants- Automotive, Industrial, Marine, Railroad, Air. • Applications of lubricants – Automotive (Trucks, Cars, 2-Wheelers, Tractors, Gear Oils, Natural Gas. • Engine Oils etc.) and Industrial (Cutting Oils, Rust Preventives, Rolling Oils, Compressor Oils, Hydraulic, Drilling Oils etc.) • Properties of Lubricants. • Bio-Lubricants.	
2.	• Fundamentals of Base Oils. • Type of Crude Oils. • Refinery process – Brief introduction. • Base Oil Groups. • Properties of Base Oils.	
3.	Fundamentals of Additives • Properties & key characteristics. • Composition of additives for various applications. • Additive Chemistry. • Types of additives. • Performance contribution of additive to Lubricants.	
4.	Lubricants – Automotive • Understanding of Key specifications like API, JASO, ACEA. • Global Specifications and Viscometrics. • India- Current scenarios of Lubricants in India & Future trends.	

5.	Lubricants-Industrial, Marine, Railroad, Air sector Indian Lubricant Market- • Current size & key players. • Growth Potential.	
6.	New trends impacting lubricants, base Oils and additive industry • BS IV to BS VI Transition by 2020. • Transition towards high-quality lighter lubricants. • New slate of Base Oils over next 10 years.	
7.	Finance and Cost optimization of Lubricants • Tools and techniques: value engineering and collaborative optimization. • Global best practices to drive down the total costs of ownership.	

Text Books:

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective IV		Energy Storage Systems	4	0	0	4

Course Objective

1. This course covers the necessary technical knowledge of the fundamental principles and application areas of proven technologies for energy storage solutions. And to study details of various energy storage systems along with applications and enable to identify the optimal solutions to a particular energy storage application.

Learning Outcomes

1. After successful completion of the course, students will be able to: Students can identify available technologies for energy storage and their typical application areas with their advantages and development challenges and summarize the demand for further development, potential improvements, and possibilities for innovative solutions in the energy storage subject field.

Unit No.	Topics to be Covered	Learning Outcome
1.	Scientific and engineering fundamentals of all significant energy storage methods, different types of energy storage systems (ESS), and their working principals;	Students can discuss energy storage systems and provide an understanding and appreciation of the scientific principles.
2.	Storage of energy as hydroelectric pumped storage, thermal, compressed air storage, flywheel storage, mechanical, electrostatic, and magnetic systems, phase transitions and reversible chemical reactions, organic fuels and hydrogen, and electrochemical systems;	Student will be able to relate with various upcoming energy storage technology.
3.	Energy storage technologies; basics of batteries; materials and methods; electrochemical ESS types.	They learned about the various parts of the battery and their functions.
4.	Safety issues; model codes and standards; traditional and emerging battery systems, EV and automotive technologies.	Understand how cells are used for everyday purposes: road, water, and air transport vehicles, portable and stationary use.

Text Book:

1. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience, New York.
2. Fundamentals and Application of Lithium-ion Battery Management in Electric Drive Vehicles by San Ping Jiang, Wiley.
3. Modern electric, hybrid electric, and fuel cell vehicles fundamentals, theory, and design by Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, CRC press.

Reference:

1. Energy Storage: Fundamentals, Materials, and Applications, by Robert Huggins, Springer Nature; 2nd ed.
2. Grid-Scale Energy Storage Systems and Applications, Fu-Bao Wu, Bo Yang, Ji-Lei Ye, Elsevier; 1st ed.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective V	PE40007	Prospecting, Field Development and Asset Management	3	0	0	3

Course Objective

The objective of this course is to impart knowledge on various operations that are performed in the field to develop, manage and improve the value of a hydrocarbon asset. This course also aims to introduce basic knowledge on petroleum economics and helps students to make decisions based on technical and economic feasibility.

Learning Outcomes

Upon successful completion of this course, the students will:

- Have a detail understanding on different activities performed in a field from exploration to abandonment phase.
- Have broad knowledge on petroleum economics and learn to make economic decisions.
- Have gained knowledge on developing, managing and improving the asset value by different reservoir management practices.

Unit No.	Topics to be Covered	Learning Outcome
1.	Life cycle of a hydrocarbon field; Field development workflow; Production scheduling; Probabilistic reserve estimation.	Students will understand about various activities that are performed during different phases (i.e., exploration, appraisal, development, production & abandonment) in life cycle of a hydrocarbon field. Familiarization on probabilistic reserve estimation by Monte-Carlo simulation.
2.	Project economic evaluation: Capital expenditures and Operating expenditures; cash flow statement; balance sheet; Net Present Value (NPV).	Students will learn in detail about the capital and operating expenditures that incurs during different phases of a hydrocarbon field. Students will learn to: prepare a cash flow statement and balance sheet; and calculate NPV.

		Students will learn on how to select a economically feasible project among multiple options based on NPV.
3.	Production profile of each field architecture; Offshore field architectures and production systems, Seabed boosting, Field processing facilities and product control; Flow assurance; Flow design of well; Reservoir depletion and field performance.	Students will learn about how production profile varies for different field architectures and how production profile for a field can be improved by technology intervention. Students will learn about how production systems, processing facilities and subsea systems are operated and managed in offshore fields. Students will learn about: flow assurance (i.e., it's importance, different flow assurance problems encountered during production and ways to mitigate the flow assurance); and factors and procedure to be adopted to design a well. Students will learn about: why and how reservoir depletion occurs recovery; how to evaluate the production performance of a field during depletion phase.
4.	EOR screening; Production optimization and integrated asset modeling; Data processing and management; Reservoir management case studies.	Students will learn about: How to select a suitable EOR for a field by manual and computational methods. How hydrocarbon production is optimized and how integrated asset modeling is performed; Different data available and how it can be effectively used for improving the asset value.

		Ways to manage and improve the asset value by analyzing different cases/fields across the world.

Text Books:

1. Oil and Gas Exploration and Production: Reserves, Costs, Contracts. Technip 2011: Nadine Bret-Rouzaut, Jean-Pierre Favennec.
2. Real Time Reservoir Management. SPE (2012): K. Shah, O. Izgec,
3. Integrated Reservoir Asset Management: Principles and Best Practices: J. Fanchi,

References:

1. Integrated Petroleum Reservoir Management: A Team Approach: Abdus Satter, Ganesh Thakur.
2. Advanced Reservoir Management and Engineering:T. Ahmed, D. Nathan Meehan.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective V	BS 40004	Petrochemical Technology	3	0	0	3

Unit No.	Topics to be Covered	Learning Outcome
1.	• Survey of petrochemical industry; Availability of different feed stocks; Production, purification and separation of feed stocks; • Chemicals from methane; Production and utilization of synthesis gas, oxo reactions, etc.; Production of and chemicals from acetylene; Naphtha cracking; • Chemicals from C2, C3, C4 and higher carbon compounds; Polymers - properties, production and utilization; • Catalytic reforming of naphtha and isolation of aromatics; Chemicals from aromatics; Synthetic fibres, detergents, rubbers and plastics; Petroleum coke; • Integration of Petroleum Refining and Petrochemicals	

Text Books:

1. Hydrocarbon Chemistry by G. A. Olah and A. Molna.
2. A. Text on Petrochemicals by B. K. B. Rao.
3. Petroleum Refining, Technology and Economics by J. H. Gary and G. E. Handwerk.

Reference Books:

1. Industrial Organic Chemicals by H. A. Wittcoff and B. G. Reuben.
2. Handbook of Petrochemicals and processes by G. M. Wells.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective V	CH 40008	Nano Materials for Hydrocarbon Industry	3	0	0	3

Course Objective

- This course aims to train students to understand the concept Nanomaterial science and their application in hydrocarbon Industry.

Learning Outcomes

- Students will understand the concept and science behind Nanomaterials: Synthesis, Characterization and Properties.
- Students will be well ware about the application of nanomaterials specially in Hydrocarbon Industry.

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction to metallic nanoparticles, metal oxide nanoparticles, carbon nanotubes, magnetic nanoparticles, nanoporous materials.	Students will be acquainted with the nanomaterials world.
2.	Synthesis: Chemical, electrochemical, thin films – CVD, PVD, Langmuir-Blodgett, mechanical (attrition), sol-gel, nanolithography.	Students will know the design and synthesis routes for nanomaterial production.
3.	Functionalization: Ligand incorporation, biomolecule conjugation, polymer coating.	Students will be acquainted with various functionalization techniques.
4.	Physical and chemical properties at nanoscale; Nanomaterial characterization: SEM, TEM, AFM, scanning probe microscopy, scanning tunneling microscopy, diffraction and scattering techniques, vibrational spectroscopy.	Students will be acquainted with various characterization techniques.
5	Use of nanomaterials in exploration and reservoir characterization, drilling, cementing, production, stimulation, petroleum refining, fuel production, and chemical sensing, Use of nanomaterials in lubricants.	Students will be well aware about the application of nanomaterials in Hydrocarbon Industry.

Text Books:

1. Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications. Wiley VCH (2013).

2. Ratna Tantra, Nanomaterial Characterization: An Introduction. Wiley (2016).

References:

1. Dieter Vollath, Nanoparticles – Nanocomposites Nanomaterials: An Introduction for Beginners. Wiley VCH (2013).
2. Daniel L. Fedlheim and Colby A. Foss, Metal Nanoparticles: Synthesis, Characterization, and Applications. CRC Press (2001).

Course Type	Course Code	Name of Course	L	T	P	Credits
Elective V	PE 40013	Process Modelling and Simulation	3	0	0	3

Course Objective

This course is intended to learn development of mathematical models using first principles and data for different chemical engineering and allied processes and also to apply numerical methods for solving the developed mathematical models. Further, different simulation tools will be demonstrated.

Learning Outcomes

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

1. Apply conservation laws for different chemical engineering and allied processes.
2. Analyze ill-conditionality, stiffness and nature of steady states.
3. Develop empirical and grey-box models.
4. Solve ODEs, PDEs, DAEs.
5. Use different software tools for simulation.

Unit No.	Topics to be Covered	Learning Outcomes
1.	Introduction to modeling, a systematic approach to model building, classification of models. Conservation principles, thermodynamic principles of process systems.	Apply conservation laws for different chemical engineering and allied processes.
2.	Development of steady state and dynamic lumped and distributed parameter models based on first principles. Analysis of ill-conditioned systems.	Apply conservation laws for different chemical engineering and allied processes, Analyze ill-conditionality, stiffness and nature of steady states.
3.	Development of grey box models. Empirical model building. Regression. Statistical model calibration and validation. Population balance models. Examples.	Develop empirical and grey-box models.
4.	Solution strategies for lumped parameter models. Stiff differential equations. Solution methods for initial value and boundary value problems. Euler's method. R-K method, shooting method, finite difference methods. Solving the problems using MATLAB/SCILAB.	Solve ODEs, DAEs, Use different software tools for simulation.

5	Solution strategies for distributed parameter models. Solving parabolic, elliptic and hyperbolic partial differential equations. Finite element and finite volume methods.	Solve PDEs, Use different software tools for simulation.

Text Books:

1. Chemical Process Modelling and Computer Simulation, Amiya K. Jana, Prentice Hall, 2011, 2nd Edition.
2. Process Modelling and Simulation in Chemical, Biochemical and Environmental Engineering, Ashok Kumar Verma, CRC Press, 2014.
3. Process Modelling, Simulation and control for Chemical Engineers, William L. Luyben, McGraw-Hill Publishing Company, 1996, 2nd Edition.

References:

1. Process Modelling and Model Analysis, K. M. Hangos and I. T. Cameron, Academic Press, 2001.
2. Mathematical Modelling and Simulation in Chemical Engineering, M. Chidambaram, Cambridge University Press, 2018.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective V		Hydrogen Energy	3	0	0	3

Course Objective

This course has essential theoretical knowledge to recognize the methods of hydrogen production, purification, storage, and utilization. And to study details of various hydrogen production processes and storage systems along with applications and enable to identify the optimal solutions to a particular hydrogen storage application.

Learning Outcomes

On successful completion of this course, students:

Have a basic knowledge of Hydrogen Energy, Properties of Hydrogen, Production methods and purification, Storage methods, Safety, Environmental benefits, and Applications in the Hydrogen Economy.

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction of hydrogen energy systems, the current status of production, storage, and utilization.	To provide comprehensive and logical knowledge of hydrogen production, storage, and utilization.
2.	Hydrogen production processes, steam reformation, gasification, pyrolysis, oxidative and non-oxidative processes, green hydrogen production using nuclear energy and renewables- wind, biomass, solar;	To know about the chemical and physical foundations of hydrogen fuel production.
3.	Separation and purification; storage, compressed storage, liquid-state storage, solid-state storage, different materials for storage, Zeolites, Metal hydride storage, chemical hydride storage;	To design and develop a suitable hydrogen storage system to be used along with different types of the cell system.
4.	Hydrogen sensing, hydrogen utilization, hydrogen safety.	To minimize environmental hazards associated with the use of hydrogen storage technology.

Text Book:

1. Michael Hirscher, Hand Book of Hydrogen Storage, McGraw-Hill Professional.
2. J O'M Bockris, Energy options: Real Economics and the Solar Hydrogen System, Halsted Press and London publisher, 1980.

3. M.K.G. Babu, K.A. Subramanian, Alternative Transportation Fuels: Utilization in Combustion Engines, CRC Press, 2013.

Reference:

1. M. Ball and M. Wietschel, The Hydrogen Economy Opportunities and Challenges, Cambridge University Press, 2009.
2. S.A Sherif, D. Yogi Goswami, E.K. Lee Stefanakos, Aldo Steinfeld, Hand Book of Hydrogen Energy CRC Press 2014