Annexure I

B. Tech. (Chemical) Curriculum (2023 Course)- Structure and Syllabi of Courses of Sem. VII and VIII

BHARATI VIDYAPEETH (DEEMED TO BE UNIVERSITY)

COLLEGE OF ENGINEERING, PUNE

B. Tech. Chemical (2023 COURSE)- Sem. VII and VIII

Module I

Sr. No.	Category	Course Code	Course	Teaching Scheme			Examination Scheme (Marks)						Credits			
				L	P	T	ESE	IA	TW	PR	OR	Total	L	P	T	Total
1			Professional Elective Course- I/II	4	-	-	60	40	-	-	-	100	4	-	-	4
2			Seminar	-	4	-	-	-	50	-	50	100	-	2	-	2
3			Internship*	-	-	-	-	-	150	-	100	250	-	14	-	14
Total				**4**	**4**	**-**	**60**	**40**	**200**	**-**	**150**	**450**	**4**	**16**	**-**	**20**

* Students can opt for either Industry or In-house Internship for one semester

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Module II

Sr. No.	Category	Course Code	Course	Teaching Scheme			Examination Scheme (Marks)						Credits			
				L	P	T	ESE	IA	TW	PR	OR	Total	L	P	T	Total
1			Chemical Project Engineering and Economics	3	2	-	60	40	25	-	25	150	3	1	-	4
2			Industrial Management	4	-	-	60	40	-	-	-	100	4	-	-	4
3			Professional Elective Course- I/II	4	-	-	60	40	-	-	-	100	4	-	-	4
4			Project Work	-	16	-	-	-	100	-	50	150	-	8	-	8
Total				**11**	**18**	**-**	**180**	**120**	**125**	**-**	**75**	**500**	**11**	**9**	**-**	**20**

PROFESSIONAL ELECTIVE COURSES (PEC)

(Students can opt for any two electives from the following list of PECs for Module I and II)

1. Food Process Engineering
2. Nano-material synthesis and application
3. Hydrogen Energy Technologies
4. Petroleum Refining
5. Advanced Oxidation Processes
6. Agrochemical- Synthesis and Application
7. Carbon Capture, Utilization & Storage (CCUS)
8. Artificial Intelligence

PROFESSIONAL CORE COURSES/BASIC SCIENCE AND HUMANITIES COURSES

CHEMICAL PROJECT ENGINEERING AND ECONOMICS

Designation: Professional Core Course

Pre-requisite Courses: Basic knowledge of Engineering Mathematics, Core Chemical Engineering subjects and Process Modeling

Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 03 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 03
Practical	: 02 Hours/Week	Internal Assessment	: 40 Marks	Oral	: 01
Total	: 05 Hours/Week	TW	: 25 Marks	Total Credits	: 04
		Oral	: 25 Marks		
		Total	: 150 Marks		

Course Outcomes:

1	Formulate preliminary techno economic feasibility report.
2	Elaborate the criteria for process selection and justification of the selected chemical process.
3	Estimate the total product cost.
4	Estimate the depreciation charges for various assets.
5	Evaluate the break even chart and its significance.
6	Estimate the critical path method (CPM) for project planning of given chemical process.

Topics covered

UNIT-I	**Introduction** Plant design and development: Design basis, process selection, material of construction, plant location, plant layout and installation, plant operation and control, safety, start up, shut down and operating guidelines; Preliminary techno economic feasibility report.	**(06 Hours)**
UNIT-II	**Optimization and feasibility of plant design** Preliminary design: Design and selection of process equipment, standard versus special equipment selection criteria, specification sheets; Comparison of different processes; Importance of laboratory development and pilot plant; Utilities; Complete engineering flow sheet drawing; Flow diagrams: Process flow diagram, qualitative flow diagram, quantitative flow diagram.	**(06 Hours)**
UNIT-III	**Cost estimation** Cash flow and cumulative cash position for industrial operations; Factors affecting investment and production cost; Capital investments: Fixed capital investment, working capital, method for estimating capital investment; Estimation of total product cost: Direct production cost, fixed charges, plant overhead costs, administrative expenses, distribution and marketing expenses; Cost indexes.	**(06 Hours)**
UNIT-IV	**Depreciation** Introduction; Basic terminologies related to depreciation; Types of depreciation:	**(06 Hours)**

	Functional depreciation, physical depreciation; Methods for determining depreciation: Straight line method, Declining balance method, Double declining balance method, Sum of the years digits method, Sinking fund method.	
UNIT-V	**Interest and investment costs** Types of interest; Present worth and discount; Annuities: Relation between amount of ordinary annuity and the periodic payments, present worth of an annuity; Balance sheet; Evaluation of break-even point and its significance; Profitability, Alternative investments and replacement: Methods for profitability evaluation, % rate of return, practical factors in alternative investment and replacement studies	**(06 Hours)**
UNIT-VI	**CPM and PERT** Bar charts; Milestone charts; Introduction to Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT); Applications of CPM and PERT; Basic Steps in PERT / CPM: Planning, scheduling, allocation of resources, controlling; Network Diagram Representation: Activity, classification of activities, event, classification of events, sequencing; Rules for drawing network diagram; Common errors in drawing networks; Advantages of CPM and PERT project planning; Detail calculation procedure of CPM and PERT project planning.	**(06 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 tools may be selected for each course from the following list of tools: Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g) MCQ, h) Modelling and Simulation, i) Group discussion, j) Role play , k) Term paper/Review paper

1	Preparation of quantitative/qualitative flow diagram for chemical process plant
2	Preparation of feasibility report for any chemical product/process
3	Estimation of total product cost by describing direct production cost, fixed charges, plant overhead costs, administrative expenses, and distribution & marketing expenses.
4	Calculate the annual depreciation for the given asset using an appropriate depreciation method.
5	Calculate the depreciation of the given asset for each year of its useful life, considering the specified cost, salvage value, and service life.
6	(a) Calculate the break-even point in terms of units and sales value. (b) Define the break-even point. (c) Explain its significance in project evaluation and decision-making for industrial operations.
7	(a) Explain different types of interest (simple and compound interest). (b) Calculate the present worth of the future cash flows using the concept of discounting. (c) Comment on whether the specified project is financially feasible based on present worth analysis.
8	Develop the Critical Path Method (CPM) network for the specified chemical process or case study.
9	Prepare the PERT network diagram and estimate the expected project completion time for the given chemical process.

10	Group discussions on any of the following topics: (a) Importance of project engineering techniques in chemical industries. (b) Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) (c) Discuss the importance of economic analysis in chemical process design.
11	Read recent research papers related to this subject area and prepare report.
12	Prepare question bank with appropriate answers based on Chemical Project Engineering and Economics
13	Solving numerical based on each unit of this subject Chemical Project Engineering and Economics
14	Enhancement in collaborative learning is done through, group assignments that will be given to encourage students to work with classmates to discuss and complete homework assignments.
Term Work	
Term work will consist of any six drawings of following:	
1	Process Flow Diagram: Construct a detailed Process Flow Diagram (PFD) incorporating both process description (qualitative) and material/energy balance data (quantitative).
2	Plant Layout and Elevations: Preparation of plant layout and elevation drawings for the given chemical process showing proper equipment arrangement and safety considerations.
3	Utility Diagram: Development of a utility distribution diagram indicating steam, water, electricity, and other service lines for the specified plant.
4	Cumulative Cash Position for Industrial Operations: Preparation and analysis of the cumulative cash position diagram for the given industrial project.
5	Break-Even Chart: Construction of a break-even chart and determination of the break-even point for the specified production system.
6	Critical Path Method (CPM): Preparation of a network diagram using the Critical Path Method (CPM) and identification of the critical path for the given project.
7	Project Evaluation and Review Technique (PERT) : Preparation of a PERT network diagram for the given project and estimation of expected project completion time.
Text Books/References	
1	T. F. Edgar and D. M. Himmblblau, "Optimization of Chemical Processes", 2nd Edition, Tata-McGraw Hill Publications, 2001.
2	S. C. Chapra and R.P. Canale, "Numerical Methods for Engineers", 6th Edition, Tata-McGraw Hill Publications, 2015.
3	A. Ravindran, K. M. Ragsdell, and G. V. Reklaitis, "Engineering Optimization: Methods and Applications", 2nd Edition, Wiley India, 2006.
4	S. S. Rao, "Engineering Optimization: Theory and Practice", 4th Edition, John Wiley & Sons, Inc, 2009.

5	M. S. Peters and K. D. Timmerhaus, “Plant Design and Economics for Chemical Engineers”, Mc Graw Hill Publications, 2002.

INDUSTRIAL MANAGEMENT					
Designation: Basic Science and Humanities					
Pre-requisite Courses: Management concepts					
Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		

Course Outcomes:	
1	Interpret given organization structure, culture, climate and major provisions of factory acts and laws.
2	Understand the financial management
3	Know the concepts of material management
4	Know the concepts quality management
5	Understand Production planning and Control functions
6	Learn recent practices being adopted in industrial management

Topics covered		
UNIT-I	**Introduction** Management: System- concept, definition, types, parameters, variables and behavior. Management – definition and functions. Organization structure: Concept, meaning and importance of division of labor, scalar & functional processes, span of control, delegation of authority, centralization and decentralization in industrial management. Important provisions of factory act and labor laws.	**(08 Hours)**
UNIT-II	**Financial Management** Objectives & Functions, Capital Generation & Management, Budgets and accounts, Taxation (Excise Tax, Service Tax, Income Tax, Value Added Tax and Custom Duty)	**(08 Hours)**
UNIT-III	**Material management** Definition, functions, importance, relationship with other departments, purchasing systems, purchase procedure, Storekeeping, classification of stores as centralized and decentralized with their advantages, disadvantages and application in actual practice, Material Resource Planning (MRP)	**(08 Hours)**
UNIT-IV	**Quality Management** Quality Control, Quality Circle, Quality Assurance, Total Quality and TQM, Kaizen,5'S',6 Sigma	**(08 Hours)**
UNIT-V	**Production planning and Control** Types and examples of production. Scheduling- meaning and need for productivity and utilization, Gantt chart- Format and method to prepare, Critical ratio scheduling-method, CPM & PERT-meaning, features, difference,	**(08 Hours)**

	applications, Floats, its types and determination of floats, Crashing of network, updating and its applications.	
UNIT-VI	**Recent Trends in IM ERP (Enterprise resource planning)** Concept, features and applications, Important features of MS Project. Logistics- concept need and benefits. Just in Time (JIT) - concept and benefits. Supply chain management concept and benefits.	**(08 Hours)**

Internal Assessment

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1	Prepare the network diagram and determine critical path for given data
2	Prepare the scheduling using Gantt chart for given data
3	Perform value analysis for given case
4	Give seminar on “Globalization in India”
5	Give a seminar on “Important provisions of factory act and labour laws”
6	Schedule the operations based on available data using PPC techniques
7	Give a seminar on “Various forms of ownership”
8	Prepare a presentation on “Capital Generation for an organization”

Text Books/References

1	L. S. Shrinath, “PERT and CPM Principles and Applications” 3rd Edition, East-West Press (Pvt.) Ltd. 2001
2	Dr. R. Shankar, “Industrial Engineering and Management” 2nd Edition, 2012
3	O. P. Khanna, “Industrial Engineering & Management” Dhanpat Rai & Sons New Delhi, 2020
4	S. Chand, “Industrial Engineering And Production Management” 3rd Edition, S.Chand Publishing, 2018
5	K. Kumar and D, Zindani, “Industrial Engineering and Management”, Dreamtech Press,2020

PROFESSIONAL ELECTIVE COURSES

PEC I/II- FOOD PROCESS ENGINEERING					
Designation: Professional Elective Course					
Pre-requisite Courses: Basics of Food Processing, Separation Technology, Chemical Conversions					
Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		

Course Outcomes:	
1	Describe and classify various types of food and explain their characteristics.
2	Identify, compare and select appropriate food processing methods for different types of food products.
3	Identify and select suitable drying methods and equipment for specific food material.
4	Analyze food preservation operations and select appropriate membrane processes for specific food processing applications
5	Explain and differentiate various material handling and conveying systems used in food industries
6	Compare, evaluate, and discuss different food packaging and transportation systems for various applications.

Topics covered		
UNIT-I	**Introduction:** Characteristics and nutritional properties of food: texture, taste, flavor and aroma. Geometric, physical and functional properties of food material. Principle of food processing: Rheology of solid, semi-solid and liquid foods. Preparation for food processing, energy conservation, heat transfer and thermal death time, material and energy balance.	**(08 Hours)**
UNIT-II	**Processing Methods:** Heating: Blanching and pasteurization, freezing, dehydration, canning, additives, Ultra-high temperature thermal processing, Fermentation: Extrusion cooking, hydrostatic pressure cooking. Dielectric heating microwave processing and aseptic processing, infrared radiation processing, concepts and equipment used in these methods.	**(08 Hours)**
UNIT-III	**Drying:** Moisture content: Definition, methods of determination, direct and indirect methods. Equilibrium moisture content and hysteresis Effect. Psychometric of air-water vapour mixture, Drying mechanism, Convective drying of food, constant rate period and falling rate period, Methods and equipment used, factor affecting the rate of drying.	**(08 Hours)**
UNIT-IV	**Food conservation Operations:** Size reduction of foods: fibrous foods, dry foods and liquid foods. Theory and equipment used, Membrane processing of liquid foods: Principles, membrane configuration, types of membrane.	**(08 Hours)**

UNIT-V	**Material handling:** Types of material handling and conveying system for food products, and their design, belt conveyors, screw conveyors, bucket elevator and pneumatic conveyors.	**(08 Hours)**
UNIT-VI	**Preservation of food materials:** Preservation by drying, preservation by low temperature, chemical preservation, thermal death time curve, Packaging of foods: packaging materials, shelf life, water transmission rate, prediction of packaging life.	**(08 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 assessment tools may be selected for each course from the following list of tools: a) Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g) MCQ, h) Modeling and Simulation i) Group discussion, j) Role play, k) Term paper/Review paper.

1	Prepare a report on the characteristics and nutritional properties of food
2	Preparation of power point presentation on food processing methods
3	Group discussions on any of the following topics: a) Drying mechanism and moisture content b) Food conservation Operation c) Membrane processing of liquid foods d) Handling and conveying system of food products
4	Prepare a report on food packaging and transportation systems.
5	Visit a nearby food processing industry and prepare a detail report.
6	Prepare a report based on design of food processing equipment.
7	Study any three recent research papers related to processing of conductive and convective foods and prepare/present power point presentation.

Text Books/References

1	C. W.Frazier, C. W.Westhoff,"Food Microbiology", 4th Edition, McGraw-Hill publishing Company Limited, New Delhi, 2008.
2	B. D. Smith, "Design of Equilibrium Stage Processes", McGraw Hill Book Company Ltd, New York, 1963.
3	C. J. King, "Separation Processes", 2nd Edition, McGraw Hill Book Company Ltd, 1980
4	R. E. Treybal, "Mass Transfer Operation", 3rd Edition, McGraw Hill, 1981
5	R. E. Treybal, "Liquid Extraction", 2nd Edition, McGraw Hill Book Company Ltd., 1963.
6	Phillip C. Wankat, "Equilibrium Staged Separations", Prentice Hall, 1988.
7	Norman W. Desrosier, James N. Desrosier, "The technology of food preservation", 4th Edition,AVI publishing Company, 1977.

PEC I/II- NANO-MATERIALS SYNTHESIS AND APPLICATIONS					
Designation: Professional Elective Course					
Pre-requisite Courses: Basic chemistry, Physical chemistry, Mass transfer, Fluid flow operations, Chemical Engineering Thermodynamics					
Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		
Course Outcomes:					
1	Define the importance of nanotechnology and their property optimization				
2	Design the methodology for synthesis of nanomaterials				
3	Determine suitable process for analysis of nanomaterials and evaluate their properties				
4	Define the applications of nanomaterials and their property requirements for desired applications				
5	Explain environmental issues and risks involved during nanomaterial applications and design safe pathway				
6	Define suitable methodology for design of product from nanomaterials				
Topics covered					
UNIT-I	**Introduction to Nano-Materials** Importance of Nanotechnology, opportunity at the nano scale; Inter-dynamic aspects of inter molecular forces; Classification based on the dimensionality, nanoparticles, nanoclusters, nanotubes, nanowires and nanodots, semiconductor nanocrystals carbon nanotubes; Influence of nano structuring on mechanical, optical, electronic, magnetic and chemical properties.				**(08 Hours)**
UNIT-II	**Nano-materials synthesis** **Top-down Techniques:** Mechanical milling/ball milling, Lithography (photolithography, e-beam lithography—basic concepts), Laser ablation, Physical vapor deposition (PVD), Sputtering techniques **Vapor and Plasma-Based Methods:** Chemical vapor deposition (CVD), Atomic layer deposition (ALD), Plasma-enhanced methods **Bottom-up Chemical Approaches:** Sol-gel method, Co-precipitation, hydrothermal/solvothermal synthesis, Microemulsion and reverse micelle techniques, Chemical reduction for metallic nanoparticles, Polymer-based synthesis & self-assembly **Green & Biological Synthesis:** Plant-extract-mediated synthesis, Microbial synthesis (bacteria, fungi), Advantages & challenges of bio-nanotechnology				**(08 Hours)**
UNIT-III	**Nanomaterial Characterization Techniques** **Microscopy Techniques:** SEM, TEM, AFM, FESEM – working principles and sample preparation				**(08 Hours)**

	Spectroscopy Techniques: XRD (crystallinity & Scherrer equation), FTIR, UV-Vis spectroscopy, Raman spectroscopy **Surface & Size Analysis:** BET surface area analysis, DLS (Dynamic Light Scattering), Particle size distribution	
UNIT-IV	**Applications of nanonaterials** Industrial applications of nanomaterials, in the areas of electronics, photonics, biology, health and environment, medicine, defense, chemicals, catalysts, textiles, etc. Application of nanotechnology in remediation of pollution, photocatalysis and other nanocatalysts, greenhouse gases, global warming.	**(08 Hours)**
UNIT-V	**Environmental aspects and risk analysis of nanomaterials** Identification of Nano-specific risks, responding to the challenge, human health hazard, risk reduction, standards, safety, transportation of nanoparticles, emergency responders. Risk assessment, environmental impact, predicting hazard, environmental and policy making, ecotoxicity measurement of nanomaterials, vacuum packaging under inert gas atmosphere, methodology for stabilization, human safety in nanomaterial processing area.	**(08 Hours)**
UNIT-VI	**Product Development with Nanomaterials** Criteria for selection of product, product development process, design for manufacture, estimate the manufacturing cost, reduce the support cost, prototyping, economics of product development projects, elements of economic analysis, financial models, sensitive analysis and influence of the quantitative factors	**(08 Hours)**

Internal Assessment

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1	Prepare a report on detail of Nano material, preparation, characterization, module and process design for anyone application
2	Technical interview based on knowledge of Nano technology.
3	Students have to study any five NPTEL/you-tube videos related to Nano technology and prepare/present power point presentation.
4	Group discussions on Nano science and technology related topics.
5	Prepare a report on innovations in Nano technology and their practical importance.
6	Students have to study any five research papers related to specific topic and prepare/present power point presentation
7	With the help of this subject knowledge, write a report on how you would apply your concepts in industry.
8	Case study on emerging trends in process/product innovation considering nano-technology.
9	Students have to visit chemical industry and make a detailed report on nano-technologies used in the process.
10	Write a report on your visit to research and development laboratory of national/international repute.

11	Write a report on nano-technologies for addressing the problems of Water and Energy.
Text Books/References	
1	P.P. Simeonova, N. Opopol and M.I. Luster, Nanotechnology - Toxicological Issues and Environmental Safety, Springer USA 2006.
2	Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkar Raguse, Nanotechnology: Basic sciences and emerging technologies, Overseas Press, 2005
3	Charles P. Poole, Frank J. Owens, Introduction to Nanotechnology‖, Wiley Interscience, USA 2003.
4	Mark A. Ratner, Daniel Ratner, Nanotechnology: A gentle introduction to the next Big Idea‖, 1st Ed. Prentice Hall P7R:USA, 2002
5	G. Cao and Y. Wang, Nanostructures and Nanomaterials: synthesis, properties and applications, 2nd Ed., World Scientific, Singapore, 2011
6	H. S. Nalwa, Encyclopedia of nanoscience and nanotechnology, American Scientific Publishers, USA 2007
7	Willard, H. H, Merritt Jr., L. L, Dean, J. A., Settle Jr., F. A, Instrumental methods of analysis, Van Nostr and New York, N.Y. USA, 2014

PEC I/II- HYDROGEN ENERGY TECHNOLOGIES

Designation: Professional Elective Course

Pre-requisite Courses: Thermodynamics, Transport Processes, Chemical and Bio-chemical Reaction Engineering

Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		

Course Outcomes

1	Enumerate the role of hydrogen as an energy carrier and its importance in the global energy transition.
2	Analyse different hydrogen production technologies from renewable and non-renewable sources.
3	Elaborate hydrogen storage and transportation methods with safety considerations.
4	Analyse the principles and performance of fuel cells and hydrogen-based power systems.
5	Evaluate hydrogen utilization in industrial, transportation, and power sectors.
6	Assess techno-economic, environmental, and sustainability aspects of hydrogen energy systems.

Topics covered

UNIT-I	**Introduction to Hydrogen Energy** Hydrogen as an energy carrier; historical perspective; hydrogen economy concept; physical and chemical properties of hydrogen; comparison with conventional fuels; global and Indian hydrogen energy scenario; applications and challenges.	**(08 Hours)**
UNIT-II	**Hydrogen Production Technologies** Conventional hydrogen production methods: steam methane reforming, partial oxidation, and autothermal reforming; water electrolysis (alkaline, PEM, and solid oxide electrolysis); renewable hydrogen production; thermochemical and photoelectrochemical water splitting; process flow diagrams and basic calculations.	**(08 Hours)**
UNIT-III	**Hydrogen Storage and Transportation** Compressed and liquefied hydrogen storage; cryogenic storage; material-based storage (metal hydrides, chemical hydrides, adsorption materials); hydrogen pipelines; transportation by road and ship; safety, codes, and standards.	**(08 Hours)**
UNIT-IV	**Fuel Cell Technologies** Fundamentals of fuel cells; thermodynamics and electrochemistry of fuel cells; types of fuel cells (PEMFC, AFC, PAFC, MCFC, SOFC); components and materials; performance characteristics; efficiency and losses; applications of fuel cells.	**(08 Hours)**
UNIT-V	**Hydrogen Utilization and Integration** Hydrogen in transportation (fuel cell vehicles); hydrogen for power generation; hydrogen blending in natural gas networks; industrial applications (refining,	**(08 Hours)**

	ammonia, steel); integration of hydrogen with renewable energy systems; hybrid energy systems.	
UNIT-VI	**Economics, Safety, and Sustainability of Hydrogen Energy** Techno-economic analysis of hydrogen systems; life cycle assessment; environmental impacts; hydrogen safety and risk assessment; regulations and policies; green hydrogen initiatives; future trends and challenges.	**(08 Hours)**

Internal Assessment

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1	Written assignments to assess understanding of fundamental concepts.
2	MCQ-based tests to evaluate conceptual clarity and factual knowledge.
3	Open book tests to assess analytical and problem-solving abilities.
4	Technical quizzes to test quick recall and application of concepts.
5	Case study analysis related to renewable energy systems.
6	Mini projects focusing on design or analysis of renewable energy technologies.
7	Technical report writing to develop documentation and communication skills.
8	Seminar or oral presentation on recent advancements in renewable energy.
9	Industrial live problem or field-based study to relate theory with practice.
10	Unit-wise class tests to evaluate overall learning outcomes.

Text Books/References

1	Bockris, J. O'M. and Veziroğlu, T. N., "Hydrogen Energy System", Springer, USA, 1975.
2	Momirlan, M. and Veziroğlu, T. N., "The Properties of Hydrogen as Fuel Tomorrow in Sustainable Energy System", International Journal of Hydrogen Energy, 2005.
3	Barbir, F., "PEM Fuel Cells: Theory and Practice", 2nd Edition, Academic Press, USA, 2013.
4	Sorensen, B., "Hydrogen and Fuel Cells: Emerging Technologies and Applications", Elsevier, UK, 2005.
5	Stolten, D. (Ed.), "Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", Wiley-VCH, Germany, 2010.
6	Kaltschmitt, M., Streicher, W. and Wiese, A., "Renewable Energy: Technology, Economics and Environment", Springer, Germany, 2007.
7	Bockris, J. O'M. and Veziroğlu, T. N., "Hydrogen Energy System", Springer, USA, 1975.

PEC I/II- PETROLEUM REFINING					
Designation: Professional Elective Course					
Pre-requisite Courses: Basic knowledge of Chemical Process Industry, Mass Transfer, Chemical reaction engineering					
Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		
Course Outcomes:					
1	Know the composition of crude oil and its products, along with its properties and characterization methods.				
2	Demonstrate knowledge of petroleum products, quality control and understand processing of crude oil.				
3	Understand the thermal and catalytic cracking process.				
4	Learn the process of catalytic reforming, Hydrotreating and Hydrocracking.				
5	Get conversant with the process of purification and fractionation of crude oil.				
6	Analyze theoretical and practice skills in environmental issues of petroleum refinery.				
Topics covered					
UNIT-I	**Introduction** Introduction to petroleum refinery; Classification of Crude oil; Characterization of crude oil; Composition of crude Physical properties: Crude oil; analysis and distillation; Introduction to refinery "feedstock/s" and refinery products; ASTM nomenclature (ASTM test numbers and their meaning) Introduction to various codes required for petroleum industry			**(08 Hours)**	
UNIT-II	**Evaluation of crude oil properties and Design of crude oil distillation column** Dehydration and desalting of crude; Crude Assay ASTM TBP distillations evaluation of crude oil properties; API gravity various average boiling points and mid percent curves; Evaluation of properties of crude oil and its fractions; Design concept of crude oil distillation column design			**(08 Hours)**	
UNIT-III	**Thermal and Catalytic cracking** Coking and thermal process; delayed coking; Catalytic cracking; cracking reactions; cracking feedstock; Effect of process; FCC cracking; catalyst ; New designs for fluidized bed catalytic cracking.			**(08 Hours)**	
UNIT-IV	**Catalytic Reforming** Objective and application of catalytic reforming; process reforming Catalysts; Reformer feed; reforming reactor design; continuous and semi regenerative process; Hydrotreating and Hydrocracking reactions.			**(08 Hours)**	
UNIT-V	**Isomerization, Alkylation and Polymerization**			**(08 Hours)**	

	Isomerization process, Reactions; Effects of process variables; Alkylation process; Feedstock, reactions, products, catalysts and effect of process variables; Polymerization: Objectives, process, Reactions, catalysts and effect of process variables; Visbreaking	
UNIT-VI	**Environmental issues and New Trends in petroleum refinery operations** Ecological consideration in petroleum refinery; Waste water treatment; control of air pollution; New trends in refinery; Alternative energy sources; Safety aspects in petroleum industry	**(08 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 tools may be selected for each course from the following list of tools: Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g) MCQ, h) Modelling and Simulation, i) Group discussion, j) Role play , k) Term paper/Review paper

1	New Catalyst used in petroleum industry.
2	Recent method used in reforming.
3	Use of Pengtool for the petroleum calculations.
4	Ecological considerations in petroleum industry.
5	Difference between petroleum and petrochemical industry.
6	CAPEX and OPEX in refinery.

Text Books/References

1	B.K.Bhaskar Rao, "Modern Petroleum Refining Processes", 2ndEd., Oxford and IBH publishing Co. Pvt. Ltd., New Delhi 1990.
2	W.C. Edmister, "Applied Hydrocarbon Thermodynamics", Gulf Publishing, Houstan, Texas, 1961.
3	S. Kumar, "Gas Production Engineering", Gulf publishing Co., 1987.
4	B. Graham, Moody, "Petroleum exploration hand book" McGraw-Hill Inc., US , **1961**
5	C.L.William, C.P.Garry, M.D.Lorenz, "Standard Handbook of petroleum and Natural Gas Engineering" 3nd Edition. Gulf Profession, 2016
6	W.L. Nelson, "Petroleum Refinery Engineering", McGraw Hill, 1964.

PEC I/II- ADVANCED OXIDATION PROCESSES

Designation: Professional Elective Course

Pre-requisite Courses: Wastewater treatment and Engineering Chemistry

Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		

Course Outcomes:

1	Demonstrate the basics of advanced oxidation processes (AOPs)
2	Apply the method of ozonation and photon induced AOPs
3	Learn the method and mechanism of heterogeneous photo-catalysis.
4	Understand the methods and mechanism of homogeneous and heterogeneous Fenton processes.
5	Analyze various emerging AOPs and their mechanism
6	Describe the industrial applications of AOPs

Topics covered

UNIT-I	**Introduction to advanced oxidation processes (AOPs)** Conventional waste water treatment processes, Fundamentals and background of AOPs for water and wastewater treatment, basic reaction mechanism of AOPs, Role of hydroxyl radicals and their generation, Reaction kinetics and degradation mechanisms of organic pollutants by hydroxyl radicals, Effects of process parameters and scavenging media on degradation efficiency, oxidation potential of AOPs, merits and demerits of various AOPs	**(08 Hours)**
UNIT-II	**Ozonation and Photo induced AOPs** Ozonation: background and fundamentals, reaction kinetics and mechanisms, Application of homogeneous and heterogeneous catalytic ozonation in water treatment; Fundamentals of UV irradiation: Absorption and bond dissociation energy, UV sources and their characteristics, Choice of photo source–used in AOPs; Photo induced AOPs: Mechanism of photo induced AOPs Oxidation using ultraviolet irradiation and hydrogen peroxide (UV/H_2O_2), oxidation using ultraviolet irradiation and ozone (UV/Ozone), oxidation using combination of ultraviolet irradiation, hydrogen peroxide and ozone (UV/H_2O_2 /Ozone).	**(08 Hours)**
UNIT-III	**Heterogeneous Photo-Catalysis** Fundamentals of semiconductor photo-catalysis: various semiconductor particles used in photocatalytic applications, visible light driven photo-catalysts, photocatalytic reactions and kinetic studies and introduction to nano photo-catalysis; Photocatalytic reactors: solar energy driven or artificial light photo reactors, solar collectors, design of slurry or supported catalyst reactors, comparing reactor efficiencies and reuse of catalyst.	**(08 Hours)**

UNIT-IV	**Homogeneous and Heterogeneous Fenton processes** Fenton process; photo-Fenton process; advanced Fenton process; the mechanism of Fenton based processes; merits and demerits of homogeneous and heterogeneous Fenton processes.	**(08 Hours)**
UNIT-V	**Emerging AOPs** Electrochemical oxidation; Ultrasound processes; principles of sonochemistry and acoustic cavitation; ultrasound cavitation and its combination with other AOPs; synergistic and antagonistic effects; hydrodynamic cavitation and its combination with other AOPs.	**(08 Hours)**
UNIT-VI	**Industrial applications of AOPs** Application of AOPs for industries such as textile, petroleum, pharmaceutical, petrochemical, pesticide industry etc.; Decontamination of ground water; Cost or economic analysis of various AOPs.	**(08 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 assessment tools may be selected for each course from the following list of tools: a) Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g)MCQ, h) Modeling and Simulation i) Group discussion, j) Role play, k) Term paper/Review paper.

1	Preparation of a technical report on conventional wastewater treatment methods used in the chemical industry.
2	Preparation of a power point presentation on recent trends in ozonation and photo induced AOPs.
3	Group project on the application of ultraviolet irradiation and hydrogen peroxide for the degradation of dyes
4	Study any three recent research papers related to advanced oxidation processes and prepare/present a power point presentation.
5	Group discussions on any of the following topics: a) Merits and demerits of various AOPs b) Ozonation and Photo induced AOPs c) Homogeneous and Heterogeneous Fenton processes
6	Determination of the ultrasonic power density of a given ultrasonic processor
7	Visit to a nearby wastewater treatment plant and prepare a detail report.
8	Determine the hydraulic characteristics of any cavitating device
9	Prepare a technical report on recent trends in waste water treatment by hydrodynamic cavitation
10	Preparation of technical report based on industrial applications of advanced oxidation processes
11	Industrial case study - Application of AOPs in textile/ petroleum/ pharmaceutical industry

Text Books/References

1	Simon Parsons, “Advanced oxidation processes for water and wastewater treatment”, IWA Publishing, 2004.
2	Metcalf & Eddy, “Waste Water Engineering Treatment & Reuse”, Tata McGraw-Hill, Fourth Edition, 2003.
3	Thomas Oppenlander, “Photochemical Purification of Water and Air: Advanced Oxidation

	Processes (AOPs): Principles, Reaction Mechanisms, Reactor Concepts", Wiley-VCH Publishing, 2003.
4	Vincenzo Belgiorno, Vincenzo Naddeo and Luigi Rizzo, "Water, wastewater and soil treatment by Advanced Oxidation Processes (AOP)", Lulu Enterprises, 2011.
5	Jean-Pierre Franc, Jean-Marie Michel, "Fundamentals of Cavitation", Kluwer Academic Publishers, Dordrecht, 2004
6	T. J. Mason, J. P. Lorimer, "Applied sonochemistry: Uses of power ultrasound in chemistry and processing", Wiley-VCH publishers, 2002.

PEC I/II- AGROCHEMICAL- SYNTHESIS AND APPLICATION

Designation: Professional Elective Course

Pre-requisite Courses: Biology, Chemistry

Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		

Course Outcomes:

1	Elaborate the classification, importance, and industrial relevance of agrochemicals in modern agriculture.
2	Elaborate the basic synthesis routes and manufacturing concepts of major insecticides.
3	Illustrate the synthesis and applications of important herbicides and fungicides used in crop protection.
4	Describe formulation techniques and application methods of agrochemicals in agricultural practices.
5	Analyze the environmental impact, toxicity, and safety regulations associated with agrochemicals.
6	Evaluate green and sustainable approaches in the development and use of modern agrochemicals.

Topics covered

UNIT-I	**Introduction** to Agrochemicals Definition and importance of agrochemicals; Types of pesticides (insecticides, herbicides, fungicides); Role in agriculture; Basic industrial overview; Need for safe use.	**(08 Hours)**
UNIT-II	**Synthesis of Insecticides** Basic chemistry and classification of insecticides; Simple reaction pathways; Manufacturing concepts; Safety in production and handling.	**(08 Hours)**
UNIT-III	**Synthesis of Herbicides and Fungicides** Classification and basic chemistry; Simple industrial synthesis routes; Formulation basics; Applications in crop protection.	**(08 Hours)**
UNIT-IV	**Formulation and Application Techniques** Types of formulations (dusts, granules, sprays); Additives and stabilizers; Storage and packaging; Application methods in agriculture.	**(08 Hours)**
UNIT-V	**Environmental and Safety Aspects** Toxicity and environmental effects; Residue problems; Pollution control; Safe disposal; Indian regulatory guidelines.	**(08 Hours)**
UNIT-VI	**Green and Modern Agrochemicals** Bio-pesticides; Integrated pest management; Basics of nanotechnology in agrochemicals; Sustainable and eco-friendly alternatives.	**(08 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 tools may be selected for each course from the following list of tools: a) Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g) MCQ, h) Modeling and Simulation, i) Group discussion, j) Role play , k) Term paper/Review paper	
1	Design a poster illustrating the synthesis route, mode of action, and environmental impact of a selected agrochemical used in India.
2	Explain the differences between organophosphate and carbamate insecticides with respect to their chemical structure and mechanism of action.
3	Analyze a case study on pesticide residue contamination in agricultural produce and suggest suitable chemical engineering solutions to minimize environmental impact.
4	Prepare and deliver a seminar on recent advancements in green agrochemicals and sustainable pest management techniques.
5	With suitable references, compare conventional agrochemical synthesis methods with green chemistry approaches and justify the more sustainable option.
6	Prepare a detailed note on formulation techniques used in agrochemical industries and discuss their advantages and limitations.
7	Which of the following factors most significantly influences the environmental persistence of an agrochemical? (a) Molecular weight, (b) Biodegradability, (c) Color, (d) Odor
8	Discuss the advantages and disadvantages of chemical pesticides versus bio-pesticides in modern agriculture.
9	Write a review paper on the synthesis, formulation, and environmental impact of a selected class of agrochemicals, supported by recent research articles.
Text Books/References	
1	T. P. Puzyn and A. Leszczynski, “Agrochemicals: Composition, Production, Toxicology, Applications”, 1st Edition, CRC Press, Boca Raton, 2010.
2	H. M. Hull, “Pesticide Formulations and Application Systems”, 1st Edition, ASTM International, West Conshohocken, 2001.
3	K. H. Buchel, H. H. Moretto and P. Woditsch, “Industrial Inorganic Chemistry”, 2nd Edition, Wiley-VCH, Weinheim, 2000.
4	K. H. Krishnamurthy, “Pesticides – Environment and Food Security”, 1st Edition, New India Publishing Agency, New Delhi, 2008.
5	B. K. Sharma, “Industrial Chemistry”, 16th Edition, Krishna Prakashan Media (P) Ltd., Meerut, 2014.

PEC I/II- CARBON CAPTURE, UTILIZATION & STORAGE (CCUS)

Designation: Professional Elective Course

Pre-requisite Courses: Basic knowledge of Chemical Process Industry, Mass Transfer, Heat transfer, Chemical reaction engineering

Teaching Scheme		**Examination Scheme**		**Credits**	
Lectures	: 04 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 04 Hours/Week	Internal Assessment	: 40 Marks	Total Credits	: 04
		Total	: 100 Marks		

Course Outcomes:

1	Develop a strong foundational understanding of carbon emissions and the need for CCUS in achieving net-zero targets
2	Evaluate utilization technologies, including catalytic, electrochemical, biochemical, and mineralization routes for conversion to value-added products
3	To explore geological sequestration and trapping mechanism for CO_2 storage.
4	Provide a systematic overview of CO_2 capture techniques (solvent-based, solid sorbent, membrane-based, and cryogenic)
5	Explore fundamental principles of thermodynamics, reaction engineering, materials science, and system integration in CCUS technologies
6	Evaluate latest technologies, techno-economic parameters and study current policy frameworks, and regulatory aspects relevant to India and globally

Topics covered

UNIT-I	**Introduction to CCUS and Global Context and Fundamentals of CO_2 Capture**: Overview of existing Green House Gas (GHG) emissions issues, Global carbon cycle & Life Cycle Analysis, with emphasis on GHG emissions, CCS, and CCUS options, introduction & Necessity of CCS: global emissions, climate change, evidence of climate change, Concept of carbon credit and carbon footprint.	**(08 Hours)**
UNIT-II	**Introduction to carbon storage and different sequestration (CCUS):** Biological carbon sequestration, Forests and woodlands biological carbon sequestration, Soil biological carbon sequestration, Ocean Biological carbon sequestration, Geological carbon sequestration, Technological Carbon Sequestration, Industrial Carbon Sequestration	**(08 Hours)**
UNIT-III	**CO_2 Storage Mechanisms:** Geological storage: saline aquifers, depleted oil/gas fields - Well drilling and injection techniques – Geo mechanics, Caprock integrity and leakage risks, CO_2 Geological sequestration & Trapping Mechanism, Environmental and risk assessment frameworks	**(08 Hours)**

UNIT-IV	**Carbon capture methods**: Post combustion capture, Pre combustion capture, Oxy fuel combustion, Direct Air capture, Adsorption, absorption, membrane and cryogenic separation processes	**(08 Hours)**
UNIT-V	**CO_2 transport and subsurface injection**: Thermodynamics and kinetics of CO_2 transportation, respective issues (gas hydrates), and their remedial measures, Underground CO_2 sequestration-CO_2 sequestration as hydrates, Emerging materials and digital tools (AI/ML) for CCUS optimization - Hybrid energy systems and CCUS coupling	**(08 Hours)**
UNIT-VI	**Carbon utilization technologies**: Latest advances, promising technologies and their challenges, Modeling of cost and performance of CCUS plants, Techno-Economics, Key CAPEX and OPEX components - Life cycle assessment: GHG reduction potential ,Indian regulatory landscape: MoEFCC, MNRE, NITI Aayog,	**(08 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 tools may be selected for each course from the following list of tools: a) Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g) MCQ, h) Modelling and Simulation, i) Group discussion, j) Role play , k) Term paper/Review paper

1	Existing Green House Gas (GHG) emissions
2	Biological carbon sequestration
3	CO_2 Geological sequestration & Trapping Mechanism
4	Recent Carbon capture methods
5	Thermodynamics and kinetics of CO_2 transportation
6	Latest promising technologies and their challenges

Text Books/References

1	M.Goel, M.Sudhakar, R.V.Shahi, "Carbon Capture, Storage and Utilization: A Possible Climate Change Solution for Energy" CRC Press 2019.
2	A.Kumar, P.D.Agrawal, Y.K.Singla, "Sustainable Development With Carbon Capture: Utilization and Storage Technology" Springer 2025
3	A.Ahmadian, A. Elkamel, A.Almansoori, "Carbon Capture, Utilization, and Storage Technologies: Towards More Sustainable Cities", Springer 2024
4	J.R. Puthalpet, "Carbon Capture-Utilization and Storage: Climate Change Mitigation" B.S. Publication 2024
5	Y.T.Shah, "CO_2 Capture, Utilization, and Sequestration Strategies (Sustainable Energy Strategies)" 1st Edition, CRC Press 2021

PEC I/II- ARTIFICIAL INTELLIGENCE		
Designation: Professional Elective Course		
Pre-requisite Courses: Basic knowledge of Engineering Mathematics, Computer Programming, Computational tools.		
Teaching Scheme	**Examination Scheme**	**Credits**
Lectures : 04 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Total : 04 Hours/Week	Internal Assessment : 40 Marks	Total Credits : 04
	Total : 100 Marks	

Course Outcomes:	
1	Formulate a structured problem statement for a chemical engineering process suitable for artificial intelligence–based modeling and analysis.
2	Apply appropriate artificial intelligence formalisms to model, analyze, and improve chemical engineering processes.
3	Estimate and optimize artificial neural network modeling parameters for accurate prediction of chemical process performance.
4	Estimate and optimize genetic programming modeling parameters for effective modeling of chemical processes.
5	Estimate principal components from process data using statistical techniques for dimensionality reduction and process analysis.
6	Develop an economically feasible artificial intelligence–based optimization procedure for chemical processes.

Topics covered		
UNIT-I	**Introduction** Introduction to Artificial Intelligence (AI); Applications of AI to Chemical Engineering; Introduction to various AI- based formalisms; Principal component analysis; Cause and effect relationships. Black box modeling.	**(08 Hours)**
UNIT-II	**AI-based Modeling Formalisms** Introduction to various AI- based modeling formalisms; Artificial Neural Networks (ANNs); Genetic Programming (GP); Support Vector Regression; Fuzzy Logic (FL); Applications of these formalisms to Chemical engineering.	**(08 Hours)**
UNIT-III	**Artificial Neural Networks (ANNs)** Biological background; ANN classification; Computational properties of ANNs; Modeling a single neuron; Building blocks of feed-forward neural network: Bias, Processing elements, Input layer, hidden layer, Output layer, Learning rate, Momentum, Transfer function; Error back propagation.	**(08 Hours)**
UNIT-IV	**Genetic Programming (GP)** Introduction to evolutionary algorithms; Dependent variables; Independent variables; Mathematical operators; Initial population; Candidate solution; Tree	**(08 Hours)**

	structure; Initialization; Fitness evaluation and selection; Crossover; Mutation.	
UNIT-V	**Evolutionary Algorithms (EA)** Introduction to stochastic evolutionary algorithms; Applications; Genetic algorithms; Particle Swarm method; Ant Colony method.	**(08 Hours)**
UNIT-VI	**Applications and Case Studies** Chemical Engineering based different case studies solution using AI-based modeling and optimization formalisms.	**(08 Hours)**

Internal Assessment

Internal Assessment–I will be based on Units I, II, and III, while Internal Assessment–II will cover Units IV, V, and VI. A maximum of 2–3 tools may be selected for each course from the following list of tools: a) Poster presentation, b) Quiz, c) Case study, d) Presentation/Seminar, e) Open book test, f) Assignment, g) MCQ, h) Modelling and Simulation, i) Group discussion, j) Role play , k) Term paper/Review paper

1	Conduct group discussions on selected topics such as the role of Artificial Intelligence in Chemical Engineering, phenomenological, empirical and AI-based modeling, and the impact of Artificial Intelligence on chemical industries.
2	Prepare a comprehensive chart illustrating various AI-based modeling formalisms with suitable schematics and representations.
3	Prepare a seminar report and deliver an oral presentation on recent advances in Chemical Engineering applications of Artificial Intelligence.
4	Study any five NPTEL lectures related to Artificial Intelligence and prepare and present a PowerPoint presentation based on the selected topics.
5	Solve numerical problems related to core chemical engineering processes using appropriate AI formalisms.
6	Collect and review recent research papers on Artificial Neural Networks in chemical process modeling and prepare a summary report.
7	Collect and review recent research papers on Genetic Programming in chemical process modeling and prepare a summary report.
8	Analyze case study results using Principal Component Analysis and interpret the findings effectively.
9	Prepare a comprehensive question bank with suitable answers covering the entire subject of Renewable Energy.
10	Enhance collaborative learning through structured group assignments that encourage students to work collectively to discuss and complete academic tasks.

Text Books/References

1	C.M. Bishop, “Neural Networks for Pattern Recognition”, Oxford University Press, Oxford, 1995.
2	S.S. Tambe, P.B. Deshpande, B.D. Kulkarni, “Elements of Artificial Neural Networks with Selected Applications in Chemical Engineering, and Chemical & Biological Sciences, Simulation & Advanced Controls”, Inc., Louisville, 1996.
3	J. Koza, “Genetic Programming: On the Programming of Computers by Means of Natural Selection”, MIT Press, Cambridge, M.A, 1992.
4	V. Vapnik, “The Nature of Statistical Learning Theory”, Springer-Verlag, New York, 1995.

5	K. Deb, “Optimization for Engineering Design: Algorithms and Examples”, Prentice-Hall, New Delhi, 1995.
6	D.E. Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Addison-Wesley, Reading, MA, 1989.