2025-26

CURRICULUM FRAMEWORK FOR PG PROGRAMMES

NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI

VISION OF THE INSTITUTE

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

- To meet the industrial and domestic need of energy in a sustainable manner by developing technical human resource and technology.

MISSION OF THE DEPARTMENT

- To create awareness among the public for economic use of energy.
- To create the necessary environment for the stakeholders to update the analytical, technical, management and creative skill to meet the challenge in energy.
- To develop adaptable technology through research and development, and implement them through consultancy and other services.
- To test and evaluate the performance of energy devices.
- To fulfill the energy demand by using environmentally benign sources for sustainable growth of nation.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1	Train students to be employable in public/private industrial energy sectors, Government energy agencies, consultancy energy services, and educational institutions or being a successful entrepreneur for sustainable progress of the society.
PEO2	Train students to get admission for higher studies /employed in a research organization working in the field of energy and environment.
PEO3	Prepare students to lead an ethical life and continuously progress in any profession, through practicing a lifelong learning attitude.

PROGRAMME OUTCOMES (POs)

PO1	An ability to independently carry out research /investigation, and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery in Energy Engineering. The mastery should be at a level higher than the requirements in the appropriate bachelor's program

Note: Program may add up to three additional POs.

CURRICULUM

SEMESTER I

Code	Course of Study	Credit
EN601	Solar energy engineering	4
EN603	Advanced fuel technologies	4
EN605	Smart energy systems	4
	Programme Elective I	3
	Programme Elective II	3
	Programme Elective III / Online (NPTEL)	3
EN607	Energy and material-characterization laboratory	2
EN609	Smart energy systems laboratory	2
		25

SEMESTER II

Code	Course of Study	Credit
EN602	Wind and Hydro Energy Systems	4
EN604	Data analytics and AI in energy systems	4
EN606	Energy audit and management	4
	Programme Elective IV	3
	Programme Elective V	3
	Programme Elective VI / Online (NPTEL)	3
EN608	Energy modelling, simulation and data analytics laboratory	2
		23

SUMMER TERM (evaluation in the III semester)

Code	Course of Study	Credit
EN671	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	2

SEMESTER III

Code	Course of Study	Credit
EN673	Project Work (Phase I)	12

SEMESTER IV

Code	Course of Study	Credit
EN674	Project Work (Phase II)	12

OPEN ELECTIVES (OE) / ONLINE COURSE (OC) (To be completed between I to IV semester)

Sl. No.	Code	Course of Study	Credit
1.		Open Electives (OE) / Online Course (OC)	3
2.		Open Electives (OE) / Online Course (OC)	3

PROGRAMME ELECTIVES (PE)

Sl. No.	Code	Course of Study	Credit
1.	EN610	Direct energy conversion	3
2.	EN611	Environmental engineering and pollution control	3
3.	EN612	Energy storage systems	3
4.	EN613	Emerging renewable energy technologies	3
5.	EN614	Hydrogen energy	3
6.	EN615	Professional skill development	3
7.	EN616	Computational fluid dynamics	3
8.	EN617	Foundation for energy engineering	3
9.	EN618	Energy systems modeling and analysis	3
10.	EN619	Air conditioning and refrigeration	3
11.	EN620	Energy efficient buildings	3
12.	EN621	Thermal engineering	3
13.	EN622	Optimum utilization of heat and power	3
14.	EN623	Power plant technology	3
15.	EN624	Power generation and systems planning	3
16.	EN625	Electrical energy technology	3
17.	EN626	Applied thermodynamics	3
18.	EN627	Power generation, transmission and distribution	3
19.	EN628	Advanced heat transfer	3
20.	EN629	Power systems planning and operation	3
21.	EN630	Advanced thermodynamics	3
22.	EN631	Instrumentation and control in energy systems	3
23.	EN632	Advanced reaction engineering	3
24.	EN633	Computational heat transfer	3
25.	EN634	Batteries and fuel cells	3

26.	EN635	Environmental impact assessment	3
27.	EN636	Smart grid systems	3
28.	EN637	Nuclear reactor theory	3
29.	EN638	Optimization techniques	3
30.	EN639	Power sources for electric vehicles	3
31.	EN640	IPR, startup and entrepreneurship	3
32.	EN641	Carbon sequestration techniques	3
33.	EN642	Design of heat transfers equipments	3
34.	EN643	Waste management and energy generation technology	3
35.	EN644	Blockchain technologies	3
36.	EN645	Heat and mass transfer	3

OPEN ELECTIVES (OE)

Sl. No.	Code	Course of Study	Credit
1.	EN610	Direct energy conversion	3
2.	EN611	Environmental engineering and pollution control	3
3.	EN612	Energy storage systems	3
4.	EN613	Emerging renewable energy technologies	3
5.	EN614	Hydrogen energy	3
6.	EN615	Professional skill development	3
7.	EN616	Computational fluid dynamics	3
8.	EN617	Foundation for energy engineering	3
9.	EN618	Energy systems modeling and analysis	3
10.	EN619	Air conditioning and refrigeration	3
11.	EN620	Energy efficient buildings	3
12.	EN621	Thermal engineering	3
13.	EN622	Optimum utilization of heat and power	3
14.	EN623	Power plant technology	3
15.	EN624	Power generation and systems planning	3
16.	EN625	Electrical energy technology	3
17.	EN626	Applied thermodynamics	3
18.	EN627	Power generation, transmission and distribution	3
19.	EN628	Advanced heat transfer	3

20.	EN629	Power systems planning and operation	3
21.	EN630	Advanced thermodynamics	3
22.	EN631	Instrumentation and control in energy systems	3
23.	EN632	Advanced reaction engineering	3
24.	EN633	Computational heat transfer	3
25.	EN634	Batteries and fuel cells	3
26.	EN635	Environmental impact assessment	3
27.	EN636	Smart grid systems	3
28.	EN637	Nuclear reactor theory	3
29.	EN638	Optimization techniques	3
30.	EN639	Power sources for electric vehicles	3
31.	EN640	IPR, startup and entrepreneurship	3
31.	EN641	Carbon sequestration techniques	3
33.	EN642	Design of heat transfers equipment	3
34.	EN643	Waste management and energy generation technology	3
35.	EN644	Blockchain technologies	3
36.	EN645	Heat and mass transfer	3

MICROCREDITS (MC) (Students can opt 3 courses of 1 credit (4 weeks) each as microcredits instead of 1 OE/OC)

Sl. No.	Code	Course of Study	Credit
1	EN680	Building energy management using IoT	1
2	EN681	Carbon markets	1
3	EN682	Carbon capture and utilization, sequestration	1
4	EN683	Life cycle assessment	1
5	EN684	Decarbonization of industry	1
6	EN685	Safety management in electrical vehicles	1
7	EN686	Introduction to blockchain technologies	1
8	EN687	Digital twinning	1
9	EN688	Energy Economics	1
10	EN689	Energy markets and carbon trading	1
11	EN690	Solar PV systems – ON/OFF Grid	1

COURSE OUTCOME AND PROGRAMME OUTCOME MAPPING

PROGRAMME CORE (PC)

Course Outcomes: On successful completion of the course, students will be able to:

Course Code	Course title	CO	Course outcomes At the end of the course student will be able	PO1	PO2	PO3
EN601	Solar energy engineering	CO1	Calculate and apply solar radiation parameters in real-world solar energy system design.	3	3	3
		CO2	Evaluate the efficiency and suitability of solar thermal systems for residential and industrial applications.	3	2	3
		CO3	Design photovoltaic systems with correct selection of modules, inverters, and storage options.	2	3	2
		CO4	Perform life cycle assessment and cost-benefit analysis for different solar energy and storage systems.	2	3	2
EN602	Wind and Hydro Energy Systems	CO1	Understand the fundamentals of wind and hydro energy systems, including wind characteristics, turbine design, and hydro plant components.	3	2	1
		CO2	Analyze the performance and control of different wind turbine configurations (HAWT, VAWT), hybrid systems, and grid integration techniques.	2	2	3
		CO3	Evaluate site selection, civil works, and operation strategies for small hydro and offshore wind systems, considering real-world case studies.	1	3	2

		CO4	Apply engineering economic principles for energy system decision-making, comparing design and investment options for standalone and hybrid systems.	2	2	2
EN603	Advanced Fuel Technologies	CO1	To explain or comprehend the various types of conventional fossil fuel technologies.	3	3	3
		CO2	To explain and design various types biomass-based technologies	3	2	3
		CO3	To explain or comprehend about hydrogen production methods and its utilization	2	3	2
		CO4	To demonstrate the skill to develop systems for waste to energy applications.	2	3	2
EN604	Data analytics and AI in Energy Systems	CO1	Use Data analytics in energy systems.	3	2	2
		CO2	Apply supervised/unsupervised learning algorithms preparation of data for analysis in energy systems.	3	2	2
		CO3	Use Python and R-programming.	3	2	2
		CO4	Explain the issues in alternate energy with simple case studies.	3	2	2
EN605	Smart energy systems	CO1	Design the Convertor /Invertor suitable for PV and WECS	3	2	2
		CO2	Model the Energy Storage system	3	3	2
		CO3	Understand the Smart Energy Monitoring systems	3	3	2
		CO4	Identify suitable communication networks and IOT for smart energy applications	3	3	2

EN606	Energy audit and management	CO1	Appreciate the role of energy managers in industries carrying out energy monitoring, auditing and targeting	1	1	2
		CO2	Elaborate principles of steam engineering with application of associated equipment like steam traps	2	3	1
		CO3	Frame energy conservation measures in systems involving pumps, fans, blowers, compressors, cooling systems including cooling towers, etc.	3	3	2

LABORATORY

Course Code	Course title	CO	Course Outcomes At the end of the course student will be able	PO1	PO2	PO3
EN607	Energy and material-Characterization laboratory	CO1	To provide the hands-on experience on the various material characterization techniques.	3	3	2
		CO2	To provide the hands-on experience on the various Environmental Engineering related instruments and data analysis.	3	3	2
		CO3	To provide the hands-on experience on the various biomass energy related instruments and data analysis.	3	3	3
		CO4	To provide the hands-on experience on the various solar thermal energy Engineering related instruments and data analysis.	3	3	3

EN608	Energy modelling, simulation and data analytics laboratory	CO1	Analyze & simulate fluid dynamics and heat transfer in various components.	3	2	2
		CO2	Model and evaluate renewable energy systems and thermal storage.	3	2	2
		CO3	Simulate solar and PV systems for performance and efficiency.	3	2	2
		CO4	Analyze big data using Machine Learning	3	2	2
EN609	Smart energy systems laboratory	CO1	To draw characteristics and analyze the performance of a solar PV panel and wind generator.	2	3	1
		CO2	To draw characteristics and analyze performance batteries.	2	3	1
		CO3	To analyze performance of Electrical Motors	2	3	1
		CO4	To experiment on performance of power convertors used in renewable power applications.	2	3	1

PROGRAMME ELECTIVES (PE)

Course Code	Course title	CO	Course outcomes	PO1	PO2	PO3
EN610	Direct energy conversion	CO1	Explain direct energy conversion processes	3	2	1
		CO2	Analyze semiconductor properties and its impact on performance characteristics of energy devices	3	2	1
		CO3	Design and optimize direct energy conversion systems	3	3	1
		CO4	Assess the performance of batteries and fuel cells in tandem with direct energy conversion technologies	3	3	1
EN611	Environmental engineering and pollution control	CO1	Explain conservation laws for environmental pollution and units of measurements.	3	2	2
		CO2	Illustrate the air, water and noise pollution standards and suitable control methods.	3	1	3
		CO3	Classify solid waste and the suggest the suitable treatment techniques.	2	2	2
		CO4	Apply indoor quality standards and parameters for comfort living.	2	2	2
EN612	Energy storage systems	CO1	To examine global and local energy use, renewable sources, and superconductors	3	2	1
		CO2	To Explore storage	3	2	1

			needs, methods (pumped hydro, flywheel, compressed air), and types (chemical, electrical, solar ponds).			
		CO3	To study sensible/latent heat storage, phase change materials, and design criteria for energy storage systems	3	3	1
		CO4	To Compare battery types, and study superconductors, capacitors, and super-capacitors.	3	3	1
EN613	Emerging Renewable Energy Technologies	CO1	Demonstrate a comprehensive understanding of the working principles and applications of diverse emerging renewable energy technologies.	1	3	2
		CO2	Critically evaluate the efficiency and sustainability of various biomass, geothermal, ocean, and emerging renewable energy systems.	1	2	1
		CO3	Design and optimize standalone or grid-connected renewable energy systems for various applications.	3	1	1
		CO4	Generate possible solutions for challenges related to emerging renewable energy technologies	2	1	1
EN614	Hydrogen energy	CO1	To explain and understand about hydrogen as a	3	2	2

			potential fuel			
		CO2	To perform comparison of hydrogen generation techniques both conventional and non-conventional	3	2	2
		CO3	To demonstrate hydrogen storage and safety	3	2	2
		CO4	To do detailed case studies with hydrogen generation with various renewable energy options and applications.	3	2	2
EN615	Professional skill development	CO1	Demonstrate improved communication skills across various mediums	1	1	3
		CO2	Apply various communication techniques for success in professional settings	1	1	3
		CO3	Address diverse set of audiences leveraging effective communication, technological tools and information literacy	1	1	3
EN616	Computational fluid dynamics	CO1	Apply Finite Difference, Finite Volume, and Finite Element Methods to fluid flow equations.	3	3	2
		CO2	Use pressure correction techniques and understand Multi-grid Methods and Boundary Conditions.	3	3	1
		CO3	Understand	3	2	2

			structured/unstructured meshes and CAD data exchange standards.			
		CO4	Analyze turbulent, rotating machinery, combusting, and multiphase flows in various applications.	3	3	1
EN617	Foundation for energy engineering	CO1	To understand the laws and principles of thermodynamics	3	2	1
		CO2	To explain the principles of fluid mechanics.	3	2	1
		CO3	To illustrate the modes of heat transfer.	3	2	1
		CO4	To explain the fundamentals of electrical machines.	3	2	1
EN618	Energy systems modeling and analysis	CO1	Assess the capabilities and limitations of various modelling methods	3	3	1
		CO2	Apply innovative modelling and simulation methods to solve complex multi-disciplinary energy system problems individually and in teams	3	3	1
		CO3	Demonstrate knowledge and comprehension of theoretical principles underlying modelling programmes	3	3	1
EN619	Air conditioning and refrigeration	CO1	To explain and understand the various refrigeration and air conditioning systems and their underlying thermodynamic principles.	3	1	3
		CO2	To compare work production, work consumption devices,	3	1	3

			and evaluate their performance.			
		CO3	To demonstrate knowledge on VCRS, VARS, their sub-components and do energy analysis for each sub-component.	3	1	3
		CO4	To do heat load estimation and able to come up power saving options possible with case studies in HVAC systems.	3	1	3
EN620	Energy efficient buildings	CO1	To measure indoor air quality.	3	3	2
		CO2	To create human comfort parameters through ventilation of building	3	3	2
		CO3	To evaluate solar passive cooling and heating concepts applicable for buildings.	3	3	2
		C04	To carry out energy audit of the building and suggest energy conservation methods	3	3	2
EN621	Thermal engineering	CO1	Understand reciprocating compressors, compression work, and efficiencies.	3	3	2
		CO2	Analyze Rankine, reheat, regenerative cycles, and compare with Carnot. Compare Otto, Diesel, Dual, and Brayton cycles, including their applications.	3	3	2
		CO3	Learn about refrigeration cycles, heat pumps, and ice production. Study steam turbine operation, classification, and performance.	3	3	2
		CO4	Explore engine	3	3	2

			components, cycles, and performance metrics.			
EN622	Optimum utilization of heat and power	CO1	Explain CHP concepts and applications	3	3	1
		CO2	Perform techno-economic analysis of cogeneration systems by calculating full load and part load performance characteristics for financial assessment	3	3	1
		CO3	Calculate pinch temperature differences, optimum stream splitting conditions, and suggest design and retrofit of components to heat exchanger network for process heat optimization	3	3	1
		CO4	Conduct economic feasibility evaluations of energy projects using concepts of Simple Payback Period, Net Present Value, Internal Rate of Return, etc.	3	3	1
EN623	Power plant technology	CO1	Understand thermodynamic principles, systems, equilibrium, and phase transitions.	3	2	1
		CO2	Analyze power plant features, components, layouts, and economic aspects.	3	3	2
		CO3	Classify and evaluate various boiler types, including fire tube, water tube, and fluidized bed.	3	1	1
		CO4	Examine steam and gas turbine performance, losses, and troubleshooting; compare power plant technologies.	3	2	1

EN624	Power generation and systems planning	CO1	Illustrate the operation of thermal power plants and power cycles.	3	2	1
		CO2	Comment on the working of steam turbines.	3	2	1
		CO3	Analyze the system planning parameters like scheduling, load factor and loss of load probability.	3	2	1
		CO4	Apply generation planning for economic load dispatch.	3	2	1
EN625	Electrical energy technology	CO1	To understand the fundamental of electrical energy systems and its components.	3	2	1
		CO2	To analyze the working and operation of electric machines.	3	2	1
		CO3	To analyze the working and operation of transformers.	3	2	1
		CO4	To illustrate Protection and Switchgear components.	3	2	1
EN626	Applied thermodynamics	CO1	To explain and understand the thermodynamic principles of combustion systems	3	1	1
		CO2	To perform chemical equilibrium and kinetics calculations	3	1	1
		CO3	To demonstrate knowledge on flame structures and their dynamics	3	1	2
		CO4	To conduct detailed case studies of various combustion devices and explore possible optimizations for maximizing the	3	1	2

			efficiency of such systems.			
EN627	Power generation, transmission and distribution	CO1	To analyze the characteristics of synchronous generator.	3	2	1
		CO2	To illustrate the reactive power compensation of overhead transmission lines.	3	2	1
		CO3	To analyze the HVDC link performance	3	2	1
		CO4	To calculate the performance analysis of distribution systems.	3	2	1
EN628	Advanced heat transfer	CO1	Apply governing equations and solution methods for steady and unsteady states.	3	3	2
		CO2	Use conservation equations, boundary layer approximations, and solutions for forced and natural convection.	3	2	2
		CO3	Examine heat transfer mechanisms, properties, and correlations for black and nonblack surfaces.	3	3	1
		CO4	Utilize correlations for various configurations and understand mass transfer principles and heat exchanger design.	3	3	1
EN629	Power systems planning and operation	CO1	To Assess the generation adequacy in power system using probabilistic approach.	3	2	1
		CO2	To Develop the solution methodology for optimizing the cost of power system under operation.	3	2	1
		CO3	To perform economic operation of thermal	3	2	1

			units using lambda iteration method and first order gradient method.			
		CO4	To schedule hydro-thermal units and pumped storage hydro plants.	3	2	1
EN630	Advanced thermodynamics	CO1	Understand fundamental thermodynamic concepts, phase equilibria, and properties of real fluids.	3	2	1
		CO2	Apply the classical and quantum statistical mechanics, and apply statistical ensembles and distribution laws.	3	3	1
		CO3	Analyze phase space, Liouville equation, and molecular simulations for various gases and intermolecular forces.	3	3	2
		CO4	Study solution theories, activity coefficients, lattice models, and phase equilibria for single and multi-component systems.	3	2	1
EN631	Instrumentation and control in energy systems	CO1	To calculate the measurement errors in measuring instruments.	3	2	1
		CO2	To demonstrate the operation of temperature and flow measuring instruments.	3	2	1
		CO3	To illustrate the power and energy measuring instruments.	3	2	1
		CO4	To design the analog and digital controller.	3	2	1
EN632	Advanced reaction engineering	CO1	Explain the concepts of homogenous reactor design	3	2	1
		CO2	Apply residence time	3	3	1

			distribution and mixing models concepts in reactor analysis calculations			
		CO3	Perform technical evaluation of design calculations of gas-solid catalytic reactors for various reactor designs and diffusion scenarios.	3	3	1
		CO4	Implement design principles for gas-liquid reactor columns by incorporating basic mass transfer in chemical reaction calculations to select case studies.	3	3	1
EN633	Computational heat transfer	CO1	Understand and apply differential equations for energy and momentum.	3	2	1
		CO2	Use discretization methods like explicit, implicit, and Crank-Nicholson in Cartesian and polar coordinates.	3	2	2
		CO3	Solve heat and convection problems using control volume, power law schemes, and simpler algorithms.	3	3	2
		CO4	Apply numerical methods (Raleigh's, Galerkin, isoparametric) and ANSYS for heat transfer.	3	3	2
EN634	Batteries and fuel cells	CO1	Describe the basic concepts of fuel cells and batteries	3	3	1
		CO2	Assess different types of batteries, its components, chemistry and performance characteristics	3	3	1
		CO3	Apply fuel cell and battery fundamentals	3	3	1

			to address the challenges in the research problems			
		CO4	Describe the application of fuel cells and batteries in various industrial and commercial areas	3	3	1
EN635	Environmental impact assessment	CO1	Demonstrate an understanding of the principles, evolution, and methodologies of Environmental Impact Assessment.	3	1	3
		CO2	Assess the environmental impact of air, noise, water, soil, and biological environment.	3	1	3
		CO3	Apply economic measurement techniques and perform Life Cycle Assessments to evaluate and mitigate environmental impacts.	3	1	3
		CO4	Develop EIA reports for various environmental projects.	3	1	3
EN636	Smart grid systems	CO1	To distinguish conventional grid and smart grid.	3	3	2
		CO2	To illustrate the substation automation and PMU for wide area monitoring.	3	3	2
		CO3	To recognize AMI and AMI protocols.	3	3	2
		CO4	To identify the power quality challenges in smart grid.	3	3	2
EN637	Nuclear reactor theory	CO1	Explain in detail the nuclear reactions and fission processes taking place in a nuclear reactor	3	2	1
		CO2	Apply neutron transport and diffusion	3	3	1

			theories to solve the diffusion equation for various source configurations and to understand energy loss in elastic collisions			
		CO3	Apply concepts of neutron moderation and absorption phenomena for energy approximations	3	3	1
		CO4	Apply concepts of reactor kinetics, control strategies to reactor design calculations for multi-region and multi-group diffusion in thermal and heterogeneous reactors	3	3	1
EN638	Optimization techniques	CO1	Formulate and classify optimization problem based on its characteristics using the concepts and properties of concave and convex functions	3	2	1
		CO2	Perform optimization calculations for one-dimensional functions by applying necessary and sufficient conditions using appropriate optimization technique.	3	3	1
		CO3	Solve unconstrained and constrained optimization problems by applying concepts of search methods, linear programing, and quadratic programming	3	3	1
		CO4	Perform optimization of staged and discrete engineering processes using advanced optimization techniques such as	3	3	1

			dynamic programming.			
EN639	Power sources for electric vehicles	CO1	To summarizes the primary energy sources and secondary energy sources.	3	2	1
		CO2	To explain the principles and operation of Aqueous Electrolyte Batteries and Non-Aqueous Electrolyte Batteries.	3	2	1
		CO3	To analyze the performance of batteries and fuel cell.	3	2	1
		CO4	To distinguish Combustion Engine and electric vehicles.	3	2	1
EN640	IPR, startup and entrepreneurship	CO1	To understand IPR and Concept Of Entrepreneurship.	3	3	2
		CO2	To implement methodology of project identification.	3	2	1
		CO3	To apply sale strategies, implement business ethics, and utilize knowledge management.	3	3	2
		CO4	To apply Accounting Principles-Accounting principles - conventions and concepts	3	2	1
EN641	Carbon sequestration techniques	CO1	Give an overview of importance of carbon abatement and its impacts	3	3	2
		CO2	Explain different carbon sequestration techniques	3	3	2
		CO3	Compare various CO_2 removal technologies	3	2	2
		CO4	Choose carbon reduction systems based on carbon taxes and carbon credits	3	2	2
EN642	Design of heat transfers equipment	CO1	Elaborate on fundamentals of heat transfer equipment	3	3	1

			design			
		CO2	Perform the sizing calculations for the equipment by analyzing the system thermal behavior	3	3	1
		CO3	Design heat exchanger for a given application considering the particular purpose and standards	3	3	1
EN643	Waste management and energy generation technology	CO1	To explain and understand about different types and characterization of waste	3	1	3
		CO2	To apply strategies to collect and handle bio-medical waste and MSW	3	1	1
		CO3	To demonstrate knowledge hazardous waste management	3	1	2
		CO4	To do detailed studies agro-residue based conversion techniques and its environmental assessment.	3	1	2
EN644	Blockchain technologies	CO1	Understand the core concepts and cryptographic foundations of blockchain technology.	3	2	1
		CO2	Gain practical experience with Bitcoin Blockchain and its scripting applications.	3	2	1
		CO3	Develop and deploy Ethereum-based decentralized applications (DApps).	3	3	1
		CO4	Apply blockchain technology to various sectors, including identity management and e-governance, through a capstone project.	3	3	1
		CO1	Analyze heat	3	3	1

EN645	Heat and mass transfer		conduction problems in various geometries and apply appropriate boundary conditions and solution techniques.			
		CO2	Evaluate convective heat transfer in both natural and forced convection systems, including laminar and turbulent flows.	3	3	1
		CO3	Apply radiation heat transfer principles to calculate heat exchange between surfaces and understand radiation shielding.	3	3	1
		CO4	Solve basic mass transfer problems involving diffusion and convection, and analyze combined heat and mass transfer scenarios relevant to energy systems.	3	3	1

PROGRAMME CORE (PC)

Course Code	:	EN601
Course Title	:	SOLAR ENERGY ENGINEERING
Type of Course	:	PC
Prerequisites	:	Nil
Contact Hours		48
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To acquire knowledge of solar radiation principles, measurement techniques, and estimation models.
CLO2	To understand design, function, and applications of solar thermal collectors and systems.
CLO3	To develop understanding of photovoltaic system components, operation, and hybrid integrations.
CLO4	To gain insights into energy storage methods and perform economic and environmental assessments of solar energy systems.

Course Content

Solar geometry, sun-earth dynamics, solar angles; measurement and estimation of global, diffuse, and beam radiation; isotropic and anisotropic sky models; empirical relations (Ångström, Hottel, Liu–Jordan); solar constant, air mass, and clearness index.
Unit 2: Solar Collectors and Thermal Systems

Types of solar collectors – flat plate, concentrating (trough, dish, Fresnel, heliostats), and advanced concentrators; selective surfaces and absorber materials; optical and thermal performance; applications in water, space, and industrial heating.

Solar thermal power – Rankine, Brayton, Stirling cycles; plant design and industrial heat; solar lanterns, lighting, and pumping systems; comparison with PV systems; techno-economic analysis (LCOE, payback). Solar thermal applications – water heating, cooking, drying, distillation, refrigeration; active/passive building systems and solar chimneys.

Principles of photovoltaic energy conversion; PV cell structure, I–V characteristics, and efficiency; cell arrays and CPV systems; module types – monocrystalline, polycrystalline, thin-film; grid-connected, standalone, and hybrid PV systems (PV/thermal, solar-wind, solar-bio); power electronics – MPPT, inverters, batteries, charge controllers; overall system efficiency and energy yield.

Thermal energy storage – sensible (water, rocks, pebble bed) and latent (PCMs – paraffin, Glauber's salt, organic compounds); thermo-chemical and chemical storage methods; electrochemical systems – lead-acid, lithium-ion, flow batteries; solar ponds; life cycle assessment of storage technologies.

Reference Books:

1.	*J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, 4th Edition, John Wiley & Sons, 2013.*
2.	*C. S. Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, 3rd Edition, PHI Learning Pvt. Ltd., 2015.*
3.	*D. Yogi Goswami, Frank Kreith, Jan F. Kreider, Principles of Solar Engineering, 2nd Edition, Taylor & Francis, 2000; Indian Reprint, 2003.*
4.	*S. P. Sukhatme, Solar Energy: Principles of Thermal Collection and Storage, 2nd Edition, Tata McGraw-Hill, New Delhi, 1996.*
5.	*G. N. Tiwari and M. K. Ghosal, Fundamentals of Renewable Energy Sources, Narosa Publishing House, New Delhi, 2007.*
6.	*W. Shepherd and D. W. Shepherd, Energy Studies, 2nd Edition, Imperial College Press, London, 2004*
7.	*Edward E. Anderson, Fundamentals for Solar Energy Conversion, Addison Wesley Publishing Co., 1983.*
8.	*M. A. S. Malik, G. N. Tiwari, A. Kumar, and M. S. Sodha, Solar Distillation, Pergamon Press, New York, 1982.*
9.	*M. S. Sodha, N. K. Bansal, P. K. Bansal, A. Kumar, and M. A. S. Malik, Solar Passive, Wiley Eastern Ltd. (1986)*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Calculate and apply solar radiation parameters in real-world solar energy system design.
CO2	Evaluate the efficiency and suitability of solar thermal systems for residential and industrial applications.
CO3	Design photovoltaic systems with correct selection of modules, inverters, and storage options.
CO4	Perform life cycle assessment and cost-benefit analysis for different solar energy and storage systems.

Course Code	**:**	EN602
Course Title	**:**	WIND AND HYDRO ENERGY SYSTMES
Type of Course	**:**	PC
Prerequisites	**:**	Nil
Contact Hours	**:**	48
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn about the various parameter like Betz limit
CLO2	To learn about the structure and force analysis of wind and Hydro turbines
CLO3	To learn about the classification of wind turbines and hydro power systems
CLO4	To learn about the maintenance of wind turbines and hydro power systems

Course Content

Measurement and instrumentation – Beau fort number -Gust parameters – wind type – power law index -Betz constant -Terrain value. Energy in wind– study of wind applicable Indian standards – Steel Tables, Structural Engineering. Variables in wind energy conversion systems – wind power density – power in a wind stream– wind turbine efficiency – Forces on the blades of a propeller – Solidity and selection curves.

HAWT, VAWT– tower design-power duration curves- wind rose diagrams- study of characteristics- actuator theory- controls and instrumentations. Grid-combination of diesel generator- Battery storage - wind turbine circuits - Wind farms -fatigue stress.

Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection

Distribution and marketing issues, case studies, Wind and hydro-based stand-alone / hybrid power systems, Control of hybrid power systems, Wind diesel hybrid systems.

Overview of offshore wind technology, Design of offshore turbines, Installation challenges, Operation and maintenance, Emerging trends.

Hydropower Plant Maintenance, Strategies for improving efficiency and output, Automation technologies for optimal hydropower operation, Analyzing successful and challenging hydropower projects.

References

1.	*Chakraverthy A, “Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes”, Oxford & IBH publishing Co, 1989.*
2.	*Mital K.M, “Biogas Systems: Principles and Applications”, New Age International publishers (P) Ltd., 1996.*
3.	*Nijaguna, B.T., Biogas Technology, New Age International publishers (P) Ltd., 2002.*

4.	*VVN Kishore, Renewable energy engineering and Technology, Principles and Practices, TERI, 2009.*
5.	*Venkata Ramana P and Srinivas S.N, "Biomass Energy Systems", Tata Energy Research Institute, 1996.*
6.	*S. Rao& B. B. Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.*
7.	*Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, John Wiley & Sons, 2001*
8.	*Wind and Solar Power Systems, Mukund. R. Patel, 2nd Edition, Taylor & Francis,2001*
9.	*L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.*
10.	*D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press*
11.	*Logan (EARL),"Turbo Machinery Basic theory and applications", 1981.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the fundamentals of wind and hydro energy systems, including wind characteristics, turbine design, and hydro plant components.
CO2	Analyze the performance and control of different wind turbine configurations (HAWT, VAWT), hybrid systems, and grid integration techniques.
CO3	Evaluate site selection, civil works, and operation strategies for small hydro and offshore wind systems, considering real-world case studies.
CO4	Apply engineering economic principles for energy system decision-making, comparing design and investment options for standalone and hybrid systems.

Course Code	**:**	EN603
Course Title	**:**	ADVANCED FUEL TECHNOLOGIES
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	48
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowlegde on the basics classification, types and formation of fossil fuels and its technologies
CLO2	To discuss in detail about various advancements in conventional solid, liquid and gas fuel technologies. To extend the knowledge further on emissions and its mitigation techniques
CLO3	To discuss in detail about various alternative fuels from biomass conversion techniques
CLO4	To elucidate technical knowledge on green hydrogen generation, storage and utilization.

Course Content

Conventional Fossil Fuel Conversion Technologies; Fossil fuels, types and conversion techniques; Fuel combustion technologies; stoichiometry

Advanced Fossil Fuel Technologies
Fluidized Bed Combustion; pressurized pulverized coal combustion, pressurized oxy-fuel combustion, Calcium and Chemical looping combustion; Co-firing technologies; Supercritical/Ultra-supercritical CO_2 power cycles; Integrated Gasification Combined Cycle (IGCC); Premixed Combustion Systems; dry low NO_x(DLN) systems; gas turbines cogeneration systems; binary cycle

Biomass to energy and fuels:
Introduction and characterization of biomass resources; Biomass Preprocessing and Pretreatment; Biomass conversion technologies – Thermochemical (combustion, gasification, pyrolysis) and Biochemical conversion (anaerobic digestion, fermentation, composting); Next generation Biofuels; Waste to energy

Hydrogen production methods; electro-chemical; bio-chemical methods; hydrogen storage and safety; hydrogen liquefaction; utilization of hydrogen in various sectors, global status and future directions of green hydrogen.

References

1.	*L. Douglas Smoot and Philip J. Smith, Coal Combustion and Gasification, Plenum Press, 1985.*
2.	*Paul Fennell and Ben Anthony, Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO2) Capture, Woodhead Publishing, 2015*
3.	*Hartmut Spliethoff, Power Generation from Solid Fuels, Springer, 2010*

4.	*Dr. H.S. Mukunda, "Understanding clean and fuels from biomass", Wiley India, 2011*
5.	*Jaap Koppejan and Sjaak van Loo, The Handbook of Biomass Combustion and Co-firing, Routledge, 2012*
6.	*Mark Crocker (Ed.), 2010. Thermochemical Conversion of Biomass to Liquid Fuels and Chemicals. RSC Publishing*
7.	*Donald L. Klass, 1998. Biomass for Renewable Energy, Fuels and Chemicals. Academic Press, San Diego, CA.*
8.	*Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.*
9.	*Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985*
10.	*L Zheng, Oxy-fuel combustion for power generation and carbon dioxide (CO2) capture, Woodhead Publishing Series, 2011*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain or comprehend the various types of conventional fossil fuel technologies.
CO2	To explain and design various types biomass-based technologies
CO3	To explain or comprehend about hydrogen production methods and its utilization
CO4	To demonstrate the skill to develop systems for waste to energy applications.

Course Code	**:**	EN 604
Course Title	**:**	DATA ANALYTICS AND AI IN ENERGY SYSTEMS
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	48
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the role AI and Data analytics in Energy Systems
CLO2	To understand the statistics related to Data Analytics, fundamentals of Data Analytics.
CLO3	To familiarize the supervised and unsupervised learning techniques
CLO4	To learn application of AI in Renewable Energy Systems.

Course Content

Introduction to Role of Artificial Intelligence/ Machines Learning in Energy Systems, Introduction to Data Analytics, Basics of statistics related to data analysis (Central Tendency, Dispersion, normal distribution, Hypothesis Testing, Probability Distributions, Central Limit Theorem, ANOVA, Z-test, T-test, Chi-square tests)

Data Analytics
Types of Data Analytics, Descriptive Analytics, Diagnostic Analytics, Predictive Analytics, Prescriptive Analytics, Benefits of Data Analytics, Data Visualization and Preparation Techniques, Chart Creation and Data Preparation, Data Analytics Skills, Basic concepts of Python Programming, R-Programming.

AI/ML
Introduction to Machine Learning,
Supervised Learning – Regression, Linear regression, Gradient descent, Weighted Least Squares, Logistic Regression. Supervised Learning - Classification -k Nearest Neighbor (kNN), Discriminant function analysis, , decision Trees and Random Forest.
Unsupervised Learning – Clustering-The k-Means algorithm, Hierarchical clustering, Density-Based Spatial Clustering of Applications with Noise (DBSCAN)

Application of AI/ Data Analytics to Power and Energy Systems (Examples : estimation of energy generation from RE sources, Estimation of building energy demand, System fault detection and diagnostics)

References

1.	*T. Agami Reddy. 2011. Applied Data Analysis and Modeling for Energy Engineers and Scientists, Boston, MA: Springer US.*
2.	*Richard O. Duda, Peter E. Hart, and Stork G. Devid. 2014. Pattern Classification*
3.	*Applied Data Analysis and Modeling for Energy Engineers and Scientists By T. Agami Reddy · 2011 (Has all the syllabus content) can use this a text book*

4.	*Intelligent Data Analytics for Power and Energy Systems, D.P. Kothari, Hasmat Malik, Md. Waseem Ahmad, 2022*
5.	*Artificial Intelligence for Renewable Energy Systems Ajay Kumar Vyas, S. ,Balamurugan, Kamal Kant Hiran, 2022*
6	*Artificial Intelligence and Internet of Things for Renewable Neeraj Priyadarshi, ,Sanjeevikumar Padmanaban ,Kamal Kant Hiran,2021 ·*
7	*Predictive Analytics for Energy Efficiency and Energy Retailing, By Konstantin Hopf · 2019 (Chapter 4,5,6)*
8	*Data Science for Engineers, by Raghunathan Rengaswamy and Reshmi Suresh, CRC Press: 2022*

CO1	Use Data analytics in energy systems.
CO2	Apply supervised/unsupervised learning algorithms preparation of data for analysis in energy systems.
CO3	Use Python and R-programming.
CO4	Explain the issues in alternate energy with simple case studies.

Course Code	**:**	EN605
Course Title	**:**	SMART ENERGY SYSTEMS
Type of Course	**:**	PC
Prerequisites	**:**	Nil
Contact Hours	**:**	48
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the importance of energy efficiency and sizing of convertors and invertors.
CLO2	To familiarize sizing of solar PV and wind energy systems.
CLO3	To learn the smart monitoring of energy using IEDs and smart devices.
CLO4	To illustrate the IoT devices functioning and operational methods.

Course Content

Energy Efficiency and standards, Star rating of the appliances (like motors, Air conditioners, pumps, water heaters and other devices) and Energy Economics and energy saving. Need of Smart Energy Systems.

Electrical Power Conditioning devises, Design of Rectifier- DC/DC converter (Buck, boost, buck boost) and Inverters.

Microgrid Energy systems design and sizing
Design of PV systems- Design of Wind energy systems- Design of energy storage - Systems, Demand side management

Smart Energy monitoring & Management
Sensors and types, Intelligent electronic devices (IED) and application-Current, Voltage, power, kWh measurement sensors- Digital controllers (Aurdino UNO,TMS320F28379D)- Energy monitoring systems- - Smart home automation- Smart meter, Automatic meter reading(AMR).

Internet of Things (IoT) on Energy sectors
Definition -, Characteristics, Physical design, Logical design, Functional blocks of IoT, Communication- models & Application Programming Interface (APIs), Machine to Machine, Difference between IoT and M2M, Software defined Network- (SDN). IoT applications- Raspberry Pi Interfaces Controlling AC Power devices with Relays, Controlling servo motor, speed control of DC Motor

References

1.	*Ali Keyhani, " Design of Smart power grid renewable energy systems", Wiley IEEE,2011.*
2.	*Clark W. Gellings, " The smart grid Enabling Energy Efficiency and Demand Response.*
3.	*Vijay Madisetti, Arshdeep Bahga, "Internet of Things: A Hands-On Approach" Orient Blackswan Pvt. Ltd., New Delhi, 2015.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Design the Convertor /Invertor suitable for PV and WECS
CO2	Model the Energy Storage system
CO3	Understand the Smart Energy Monitoring systems
CO4	Identify suitable communication networks and IOT for smart energy applications

Course Code	**:**	EN606
Course Title	**:**	ENERGY AUDIT AND MANAGEMENT
Type of Course	**:**	PC
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand energy management principles and practices
CLO2	Learn to analyse energy efficiency in thermal systems
CLO3	Develop understanding on energy conservation strategies for various equipment
CLO4	Master various energy audit tools and instruments to optimize energy consumption and improve energy efficiency for given case studies

Course Content

Energy Scenario - Role of Energy Managers in Industries – Energy monitoring, auditing, targeting and Energy policies – Economics of various Energy Conservation schemes. Total Energy Systems Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation. EC act 2001.

Steam engineering, steam traps and various Energy Conservation Measures in Steam; Boilers - types, losses and efficiency calculation methods. Boiler controls, Furnace – Performance calculation.

Energy conservation in Centrifugal pumps, Fans & Blowers, Air compressor – energy consumption & energy saving potentials – Design consideration.

Refrigeration & Air conditioning - Heat load estimation -Energy conservation in cooling towers & spray ponds –Case studies

Electrical Energy Audit – performance analysis of motors, compressors, blowers and fans- power factor correction techniques, load factor, variable frequency drive (VFD), Energy Efficiency in Lighting – Case studies. Instruments used for energy auditing.

Organizational background desired for energy management motivation, detailed process of M&T; Specific energy consumption and energy cost calculation methodologies - CUSUM, balanced ratio etc. Case studies across industries. Visit to energy generation / consumption facility.

References

1.	*Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists, Logman Scientific & Technical, ISBN-0-582-03184, 1990.*
2.	*Reay D.A, Industrial Energy Conservation, 1st edition, Pergamon Press, 1977*
3.	*Bureau of Energy Efficiency - Energy Management Series*
4.	*Larry C Whitetal, Industrial Energy Management & Utilization*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Appreciate the role of energy managers in industries carrying out energy monitoring, auditing and targeting
CO2	Elaborate principles of steam engineering with application of associated equipment like steam traps
CO3	Frame energy conservation measures in systems involving pumps, fans, blowers, compressors, cooling systems including cooling towers, etc.

LABORATORY

Course Code	**:**	EN607
Course Title	**:**	ENERGY AND MATERIAL-CHARACTERIZATION LABORATORY
Type of Course	**:**	LABORATORY
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide the hands-on experience on the various energy material characterization techniques.
CLO2	To provide the hands-on experience on the various Environmental Engineering related instruments and data analysis.
CLO3	To provide the hands-on experience on the various biomass energy related instruments and data analysis.
CLO4	To provide the hands-on experience on the various solar thermal energy Engineering related instruments and data analysis.

List of Experiments

1 Determination of Chemical oxygen demand (COD, O2 eq. mgL-1) of the given wastewater samples
2 Measurement of reduction in level of ambient noise by noise-absorbing material using noise dosimeter
3 Characterization of ligno-cellulosic biomass using single particle experiment.
4 Measurement of pH, electrical conductivity, and total solids of given water samples
5 Biomass thermochemical conversion – A study experiment on packed bed reactor
6 Study Experiment of Heat pipe characterization
7 Determination of luminous efficacy of various light sources using lux meter.
8 Thermal Conductivity measurement for a given material.
9 Determination of Bio-chemical oxygen demand (BOD, O2 eq. mgL-1) of the given wastewater sample
10 Electrochemical characterization of electrode materials
11 Heat loss through pipes - with/without insulation.
12 Comparison of efficiencies of Solar Flat plate collector and Evacuated tube collector

Course Outcomes (CO)

At the end of the course student will be able

CO1	To provide the hands-on experience on the various material characterization techniques.
CO2	To provide the hands-on experience on the various Environmental Engineering related instruments and data analysis.
CO3	To provide the hands-on experience on the various biomass energy related instruments and data analysis.
CO4	To provide the hands-on experience on the various solar thermal energy Engineering related instruments and data analysis.

Course Code	**:**	EN608
Course Title	**:**	ENERGY MODELLING, SIMULATION AND DATA ANALYTICS LABORATORY
Type of Course	**:**	Laboratory
Prerequisites	**:**	36
Contact Hours	**:**	Nil
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To analyze and optimize fluid flow and heat transfer in complex systems using computational fluid dynamics.
CLO2	To simulate and evaluate the performance of renewable energy systems and their integration.
CLO3	To analyze big data using machine learning techniques

Course Content

ANSYS FLUENT
1. Flow in static mixer and Flow in a process injection-mixing pipe
2. Flow from a circular vent and Flow in an Axial rotor /stator arrangement
3. Multiphase flow in mixing vessel
4. External flow over Ahmed body
5. Supersonic flow in a Laval nozzle
6. Conjugate heat transfer in a process-heating coil
7. Combustion and radiation in a Can Combustor

TRNSYS

8. Solar Water Heating System Simulation
9. Photovoltaic (PV) System Analysis
10. Hybrid Renewable Energy System
11. Thermal Energy Storage
12. Electric Vehicle Charging Station

Data Analytics

13. . Install, configure and run python, numPy and Pandas.
14. 2. Install, configure and run Hadoop and HDFS.
15. 3. Visualize data using basic plotting techniques in Python

References

1.	Lab Manual
2.	Computational Fluid Dynamics: International Edition (McGraw-Hill InternationalEditions :Mechanical Engineering Series) John D.Anderson.
3.	An Introduction to Computational Fluid Dynamics: The Finite Volume Method H.Versteeg, W.Malassekra
4.	Computational Fluid Dynamics An Introduction for Engineers. M B ABBOTT and D R BASCO
5.	Heat Transfer Calculations Using the Finite Difference Equations, D.R.Croft,David G.Lilley,J.A.R.Stone

Course Outcomes (CO)

At the end of the course student will be able

CO1	Analyze & simulate complex fluid dynamics and heat transfer in various components.
CO2	Model and evaluate renewable energy systems and thermal storage.
CO3	Simulate solar and PV systems for performance and efficiency.
CO4	Analyze big data using Machine Learning

Course Code	**:**	EN609
Course Title	**:**	SMART ENERGY SYSTEMS LABORATORY
Type of Course	**:**	LABORATORY
Prerequisites	**:**	Nil
Contact Hours	**:**	24
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn characteristics and performance of a solar PV panel and wind generator.
CLO2	To learn characteristics and performance batteries.
CLO3	To learn performance analysis of Electrical Motors

Course Content

1. Experiment on characteristics of a solar PV panel (I-V, P-V, FF).
2. Performance evaluation of solar PV panels with various configurations.
3. Experiment on Variables Affecting Solar PV Panel Output.
4. Performance evaluation and characteristics of micro wind generator.
5. Performance analysis of hybrid (solar-wind) energy system.
6. Charging and discharging characteristics of Lead acid and Li-ion batteries.
7. MPPT of solar PV and wind generator.
8. Experimental study on EV simulator.
9. Experimental study on power convertors used in renewable power applications.
10. Power and energy measurements for DC/AC homes.
11. Power quality and hormonic analysis.
12. Study on electrical safety for stand alone and grid connected renewable systems.
13. Performance analysis of Electrical Motors (AC and DC)

Course Outcomes (CO)

At the end of the course student will be able

CO1	To draw characteristics and analyze the performance of a solar PV panel and wind generator.
CO2	To draw characteristics and analyze performance batteries.
CO3	To analyze performance of Electrical Motors
CO4	To experiment on performance of power convertors used in renewable power applications.

PROGRAMME ELECTIVES (PE)

Course Code	**:**	EN610
Course Title	**:**	DIRECT ENERGY CONVERSION
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand principles of direct energy conversion technologies
CLO2	Apply concepts of semiconductor physics to energy conversion technologies
CLO3	Analyze various advanced direct energy conversion technologies such as Thermionic, Magnetohydrodynamic conversion including design, configuration, and performance characteristics
CLO4	Analyze and design various energy storage systems such as batteries/fuel cells using thermodynamics and gain overview of emerging direct conversion technologies

Course Content

Energy conversion process, indirect and direct energy conversion. Preview of semiconductor physics: Basic ideas of quantum physics, Fermi Energy, band diagram, Intrinsic and extrinsic semiconductors, p-n junction

Introduction to irreversible thermodynamics. Thermoelectric conversion: thermoelectric effects, analysis of thermoelectric generators and coolers, figure of merit, device configuration

Photovoltaic conversion, Optical effects of p-n junction, design and analysis of PV cells. PV cell fabrication, System design

Thermionic conversion: thermionic effects, analysis of converters, application of heat pipes.

Magneto hydrodynamic conversion: gaseous conductors, analysis of MHD generators.

Batteries and fuel cell: Thermodynamic analysis, design and analysis of batteries and fuel cells.

Other modes of direct energy conversion.

References

1.	*Kettani, M.A., Direct energy conversion, Addison-Wesley, Reading, Mass,1970*
2.	*Angrist S.W., Direct Energy Conversion. 4th Ed. Allyn and Bacon, Boston, 1982*
3.	*A. M. Mitofsky, Direct Energy Conversion, 2018*
4.	*Green M.A., Solar Cells, Prentice-Hall, Englewood Cliffs, 1982*
5.	*Handbook Batteries and Fuel Cells. Linden, McGraw Hill, 1984.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain direct energy conversion processes
CO2	Analyze semiconductor properties and its impact on performance characteristics of energy devices
CO3	Design and optimize direct energy conversion systems
CO4	Assess the performance of batteries and fuel cells in tandem with direct energy conversion technologies

Course Code	**:**	EN611
Course Title	**:**	ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours		36
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce conservation laws for environmental pollution and units of measurements.
CLO2	To familiarize with air, water and noise pollution standards and suitable control methods.
CLO3	To learn the classification of solid waste and the treatment techniques.
CLO4	To learn indoor quality standards and parameters for comfort living.

Course Content

Environmental Pollution- units of measurements, material balance and energy fundamentals, classification of pollution - Zero waste concept, 3 R and 5 R concept.

Air Pollution, Climate change, Global warming, Ozone layer depletion, Regional and Local Environmental Issues, Control Methods & Equipment- sources and effects of air pollution – Sampling measurement and analysis of air pollutants- design, control and modeling. Air pollution Act, standards.

Water Pollution – sources and effects of water pollutants -Characterization of waste water – Classification and Treatment methods–Modelling of water pollutants-Water pollution Laws and Standard.

Solid Waste Management 2016 rules - Sources & Classification –Solid Waste Disposal Options – Toxic Waste Management.

Environment for Comfort Living & Working - Temperature, humidity and ventilation Control, AC load, Natural & Artificial Lighting, Noise Sources and control.

Reference Books:

1.	*Rao C .S. "Environmental Pollution Control Engineering," 2nd Edition, New Age International Publishers, 2006*
2.	*Gilbert M. Masters, "Introduction to Environmental Engineering and Science", 2ndEdition, Prentice Hall, 1998.*

3.	*A. P. Sincero and G.A. Sincero , Environmental Engineering: A Design Approach, Prentice Hall of India pvt Ltd, N.Delhi.1996m*
4.	*Pandey G.N and Carney G.C., "Environmental Engineering", Tata McGraw HillPublishing Co., 1989.*
5.	*Bishop P., Pollution Prevention: Fundamentals and Practice,McGraw-Hill InternationalEdition, McGraw-Hill book Co, Singapore, 2000*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain conservation laws for environmental pollution and units of measurements.
CO2	Illustrate the air, water and noise pollution standards and suitable control methods.
CO3	Classify solid waste and the suggest the suitable treatment techniques.
CO4	Apply indoor quality standards and parameters for comfort living.

Course Code	**:**	EN612
Course Title	**:**	ENERGY STORAGE SYSTEMS
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours		36
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To examine global energy use, sources in developing countries, and the role of renewable and non-conventional energy sources.
CLO2	To understand various energy storage methods including pumped hydro, flywheel, compressed air, capacitors, and chemical storage.
CLO3	To learn about sensible and latent heat storage, phase change materials, and their applications with solar energy.
CLO4	To explore battery types and chemistries, and compare superconducting magnets and super capacitors.

Course Content

Energy Demands and Energy Sources
World energy consumption. Energy in developing countries. Firewood crises. Indian energy sources. Non-conventional renewable energy sources. Potential of renewable energy sources. Solar energy types. Wind energy. Wave, tidal and OTEC. Super-conductors in power system.

Need of Energy Storage; Different modes of Energy
Need for Energy storage. Potential energy: Pumped hydro storage; KE and Compressed gas system: Flywheel storage, compressed air energy storage; Electrical and magnetic energy storage: Capacitors, electromagnets; Chemical Energy storage: Thermo-chemical, photo-chemical, bio-chemical, electro-chemical, fossil fuels and synthetic fuels. Hydrogen for energy storage. Solar Ponds for energy storage.

Thermal Energy Storage Systems
Thermal energy storage- sensible and latent heat storage systems. Phase change materials- properties- types. Solid-Liquid and Solid – Solid PCM; characterization, selection criterion and design of TES systems. Solar energy and TES. Energy savings with TES. Case studies.

Electrochemical Energy Storage Systems
Batteries: Primary, Secondary batteries; difference between primary and secondary batteries, chemistries of primary batteries such as Zinc-Carbon, Alkaline and secondary batteries such as Lead acid, Nickel Cadmium, Metal hydrides, lithium ion, lithium phosphate and high temperature batteries- sodium-sulphur. Advantages, disadvantages, limitations and application each above mentioned batteries

Magnetic and Electric Energy Storage Systems
Superconducting Magnet Energy Storage (SMES) systems; Capacitor and Batteries:

Comparison and application; Super capacitor: Electrochemical Double Layer Capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nano-tube.

Reference Books:

1.	*Robert A. Huggins, "Energy Storage: Fundamentals, Materials, and Applications", Second Edition, Springer 2016*
2.	*Ibrahim Dincer, Marc A. Rosen, Third Edition, "Thermal Energy Storage: Systems and Applications", Wiley 2021.*
3.	*Johannes Jensen Bent Sorensen, "Fundamentals of Energy Storage", John Wiley, NY , 1984.*
4.	*J. Garche, Encyclopedia of Electrochemical Power Sources, Elsevier, 2009*
5.	*P.D.Dunn, "Renewable Energies". First Edition, Peter Peregrinus Ltd, London, United Kingdom, 1986*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	To examine global and local energy use, renewable sources, and superconductors
CO2	To Explore storage needs, methods (pumped hydro, flywheel, compressed air), and types (chemical, electrical, solar ponds).
CO3	To study sensible/latent heat storage, phase change materials, and design criteria.
CO4	To Compare battery types, and study superconductors, capacitors, and super-capacitors.

Course Code	**:**	EN613
Course Title	**:**	EMERGING RENEWABLE ENERGY TECHNOLOGIES
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Analyze the principles and applications of various emerging renewable energy technologies.
CLO2	Evaluate the technical and economic feasibility of different emerging renewable energy technologies for specific applications.
CLO3	Assess the environmental impact and sustainability considerations associated with emerging renewable energy technologies.
CLO4	Analyze the current state of research and development in emerging and alternative renewable energy technologies.

Course Content

Geothermal Energy:
Basics of geothermal energy and its sources; Power generation – Types of geothermal power plants (Dry steam, flash steam, binary cycle) and their design considerations; Direct use applications of geothermal energy – Geothermal heat pumps- Hydrogeology of the site, Heating and cooling demand calculations, equipment sizing and selection, environmental and cost analysis

Ocean Energy:
Introduction to Ocean Energy, Historical Development and Milestones, The Role of Ocean Energy in the Renewable Energy Sector, The Importance of Ocean Energy, Types of Ocean Energy, Tidal Energy, Tidal Energy Technologies and Projects, Merits of Tidal Energy, Demerits of Tidal Energy.

Wave Energy, Merits of Wave Energy, Demerits of Wave Energy, Ocean Thermal Energy, Conversion (OTEC), Working principle of OTEC, Brief History of Ocean Thermal Energy Conversion, OTEC cycle and system, Components of an OTEC System, Heat Exchangers, Turbine, Sea Water Pumps, Cold Water Conduit, Station keeping and mooring, Data acquisition and control, Startup and Shutdown, Indian efforts on OTEC, Challenges and Future Directions.

Emerging Renewable Energy Technologies:
Renewable Energy Integration and storage – Smart grids, energy storage technologies, and grid stability with high renewable energy penetration; Hydrogen energy generation (from renewable energy resources) and storage technologies; Algal biofuels; Waste-to-energy technologies, their component and environmental impacts.

References

1.	*S. Rao & B. B. Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.*
2.	*M.H. Dickson, M. Fanelli, "Geothermal Energy", John Wiley & Sons, 1995*
3.	*P. J. Lienau, B.C. Lunis, "Geothermal Direct Use Engineering and Design Guide Book", Geo-Heat Center, 2nd Edition, 1991*
4.	*Lyn Peppas, "Ocean Tidal and Wave Energy: Power from the Sea (Energy Revolution", Crabtree Publishing Co,US; 1st edition (20 June 2008)*
5.	*Deborah Greaves and Gregorio Iglesias, "Wave and Tidal Energy", John Wiley & Sons Inc; 1st edition (23 July 2018).*
6.	*G. Boyle, "Renewable Energy: Power for a Sustainable Future", Second Edition, Oxford University Press, 2004*
7.	*Bent Sørensen, "Hydrogen and Fuel Cells: Emerging Technologies and Applications", 2nd Edition, Elsevier Ltd., 2012*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Demonstrate a comprehensive understanding of the working principles and applications of diverse emerging renewable energy technologies.
CO2	Critically evaluate the efficiency and sustainability of various biomass, geothermal, ocean, and emerging renewable energy systems.
CO3	Design and optimize standalone or grid-connected renewable energy systems for various applications.
CO4	Generate possible solutions for challenges related to emerging renewable energy technologies

Course Code	**:**	EN614
Course Title	**:**	HYDROGEN ENERGY
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To explain about hydrogen production using conventional methods and properties of hydrogen
CLO2	To know more on hydrogen separation and purification techniques
CLO3	To give a detailed methods of hydrogen storage and handling
CLO4	To present a overview on hydrogen generation through renewable energy sources

Course Content

Hydrogen Production
Production of hydrogen from hydrocarbons –Oxidative and nonoxidative processes, coal. H_2 production using nuclear energy and renewables- wind, biomass, solar.

Hydrogen separation and purification
Pressure swing adsorption; Solvent based absorption, membrane separation, cryogenic separation etc. Hydrogen storage – compressed storage, liquid state storage, solid state storage, different materials for storage – metal hydrides, high surface area materials, complex and chemical hydrides.

Hydrogen storage system
Design and materials aspects. Hydrogen sensing – Traditional methods of hydrogen sensing using thermal conductivity measurements or GC, MS or laser gas analysis; Solid state sensors- their working principle and applications in industrial scale applications.

Hydrogen Safety
History of accident;, physiological, physical and chemical hazards; hydrogen properties associated with hazards; Hazard spotting, evaluation and safety guidelines; Hydrogen safety codes and standards.

References

1.	*Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation, Oklahoma (2005)*
2.	*Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications, Elsevier, UK (2005)*
3.	*Kordesch, K and G.Simader, Fuel Cell and Their Applications, Wiley-Vch, Germany (1996).*
4.	*Hart, A.B and G.J.Womack, Fuel Cells: Theory and Application, Prentice Hall,*

	NewYork Ltd., London (1989)
5.	*Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA (2002).*
6.	*Viswanathan, B and M AuliceScibioh, Fuel Cells – Principles and Applications, Universities Press (2006)*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain and understand about hydrogen as a potential fuel
CO2	To perform comparison of hydrogen generation techniques both conventional and non-conventional
CO3	To demonstrate hydrogen storage and safety
CO4	To do detailed case studies with hydrogen generation with various renewable energy options and applications.

Course Code	**:**	EN615
Course Title	**:**	PROFESSIONAL SKILL DEVELOPMENT
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Enhance communication skills across various mediums by actively participating in various exercises, presentations, and discussions.
CLO2	Develop effective technical communication by learning strategies to improve report writing, proposal writing, CV/resume writing, using appropriate tools
CLO3	Master professional communication techniques like public speaking, group discussions, and interview skills by using appropriate body language and non-verbal cues.
CLO4	Imbibe the use of technology for effective communication

Course Content

Communication:

Concepts, goals and levels of communication - General and technical communication - Significance of technical communication - Barriers to effective communication - Psychology of communication.

Oral Communication:
Tools and skills of communication - Presentation skills and Use of PowerPoint Slides, Public Speaking - Extempore / Prepared Speech - Requirements of oral communication - Body language and Nonverbal Cues - Difference between Group Discussion and Debate - Interview techniques.

Written Communication:
Effective Writing - Focus on Writing; Coherence and Cohesion - Report Writing - CV and Resume Writing - Drafting Proposals, Research papers - preparation of technical / software manuals - Reader Perspective - Comprehending and Summarizing a text - Nonverbal cues in Writing.

Developing Listening Skills:
Listening as an active skill - Kinds of Listening- Listening for general content; Listening for specific information - Intensive Listening - Developing effective listening skills; Barriers to effective listening skills - Listening Comprehension - Retention of facts, data & figures - Role of speaker in listening, Difference between note taking and note making.

Technology and Communication:
Telephone etiquette - Effective email messages - Editing skills - Use of charts and graphs using computer software - Elements of style in technical writing - Role of media in technology and communication - Library and Reference skills.
Sustainability – CSR initiatives

References

1.	*Andrea J. Rutherford. Basic Communication Skills for Technology. New Delhi: Pearson Education in South Asia (2007).*
2.	*R.C. Sharma and Krishnamohan Business Correspondence and Report Writing. New Delhi: Tata McGraw Hill. (2011).*
3.	*J. Herbert The Structure of Technical English, London: Longman. (1965)*
4.	*Ashraf Rizvi Effective Technical Communication. New Delhi: Tata McGraw Hill(2005).*
5.	*David Lindsay A Guide to Scientific Writing. Macmillan. (1995).*
6.	*Leo Jones & Richard AlexanderNew International Business English Cambridge University Press. . . (1996).*
7.	*Christopher Turk & John Kirkman Effective Writing; Improving Scientific,Technical and Business Communication. 2nd Ed., London: Taylor & Francis Ltd. (1989).*
8.	*L.J. Gurak & J.M. Lannon Strategies for Technical Communication in the Workplace. 2nd Ed., New York: Pearson Education, Inc. (2010).*
9.	*M. Monippally Business Communication Strategies. Tata McGraw Hill. (2001).*
10.	*V.R. Narayanaswami Strengthen Your Writing, 3rd ed. Hyderabad: Orient Longman Pvt. Ltd. (2005).*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Demonstrate improved communication skills across various mediums
CO2	Apply various communication techniques for success in professional settings
CO3	Address diverse set of audiences leveraging effective communication, technological tools and information literacy

Course Code	**:**	EN616
Course Title	**:**	COMPUTATIONAL FLUID DYNAMICS
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge on the basics of computational fluid dynamics and its application
CLO2	To thermo-fluid problems to obtain and analyses numerical solutions.
CLO3	To create confidence to solve complex problems in the field of heat transfer and fluid dynamics by using high speed computers.
CLO4	To identify fluid flow types, apply suitable model equations for detailed analysis, and clearly communicate the findings

Course Content

Governing Equations of Fluid Flow, Finite Difference, Finite Volume, Finite Element Methods, Laplace Equation, Diffusion Equation or Wave Equation

Application of Finite Volume Method to Fluid Flow problems - Pressure Correction Techniques Gauss Siedel - Gauss Jordan. Introduction to Multi grid Methods - Boundary Conditions

Structured and Unstructured Mesh- Introduction to CAD systems and Different Standards used for DATA Exchange. Governing Equations for Turbulent Flow

Simple Internal Flows: T-Junction, Driven Cavity, Manifold, Valves, External Flows: Flow Over Ahmed Body

References

1.	*H.K. Versteeg& W. Malalasekera, "An Introduction to Computational Fluid Dynamics - The finite volume approach" Longman, 1995*
2.	*Segerlind .L. J., "Applied finite Element Analysis", 2nd edition, John Wiley, 1989*
3.	*Anderson, “Computational Fluid Dynamics” McGraw Hill Company, 1995*
4.	*D.A. Caughey and M.M.Hafez, "Frontiers of Computational Fluid Dynamics 1994" JohnWiley & Sons, 1994*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Apply Finite Difference, Finite Volume, and Finite Element Methods to fluid flow equations.
CO2	Use pressure correction techniques and understand Multi-grid Methods and Boundary Conditions.
CO3	Understand structured/unstructured meshes and CAD data exchange standards.
CO4	Analyze turbulent, rotating machinery, combusting, and multiphase flows in various applications.

Course Code	**:**	EN617
Course Title	**:**	FOUNDATION FOR ENERGY ENGINEERING
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours		36
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the laws and principles of thermo dynamics.
CLO2	To familiarize principles of fluid mechanics.
CLO3	To learn the modes and properties of heat transfer.
CLO4	To learn the fundamentals of electrical machines.

Course Content

Thermodynamics:
first law and its application, second law and its application, Irreversibility and energy, basic power generation cycles.

Fluid Mechanics:
stress-strain relations, viscosity and other fluid properties, mass, momentum and energy balance, flow through pipe, boundary layer theory, dimensional analysis.

Heat Transfer:
conduction, radiation, convective and heat transfer.

Basic electrical Machines:
DC machines, Transformer, Induction motor and generators, Synchronous generators, Introduction to modern speed control techniques

Power systems:
Introduction to power transmission and distribution

Network analysis:
Simple electrical network analysis, power factor improvement.

References

1.	*M. W. Zemansky, Heat and Thermodynamics 4th Edn. McGraw Hill, 1968.*
2.	*A. L. Prasuhn, Fundamentals of Fluid Mechanics, Prentice Hall, 1980.*
3.	*S. P. Sukhatme, A Text book on Heat Transfer, Orient Longman, 1979.*
4.	*P. C. Sen, Modern Power Electronics, Wheeler, New Delhi, 1998.*
5.	*N. Balbanian, T. A. Bickart, Electrical network theory, John Wiley, New York, 1969.*
6.	*B. L. Theraja, A. K. Theraja, Text-book of electrical technology: in S.I. units: v.2 AC and DC machines, Nirja Construction & development, New Delhi, 1988.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To understand the laws and principles of thermo dynamics
CO2	To explain the principles of fluid mechanics.
CO3	To illustrate the modes of heat transfer.
CO4	To explain the fundamentals of electrical machines.

Course Code	**:**	EN618
Course Title	**:**	ENERGY SYSTEMS MODELING AND ANALYSIS
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand and develop energy system models by analyzing and comparing conventional methods of energy conversion/transfer, identifying workable and optimal systems
CLO2	Apply mathematical modelling techniques for data analysis and to model energy transfer devices such as heat exchangers
CLO3	Perform simulation and optimization techniques to create flow diagrams and formulate mathematical optimization problems for energy systems
CLO4	Analyze energy systems using Lagrange's multiplier, sensitivity analysis and various optimization techniques.

Course Content

Overview of technologies and conventional methods of energy conversion, Workable and optimum systems, Steps in arriving at a workable system, Creativity in concept selection

Mathematical modelling, Exponential forms- Method of least squares - Counter flow heat exchanger, Evaporators and Condensers, Effectiveness, NTU, Pressure drop and pumping Power

Classes of simulation, flow diagrams, Sequential and simultaneous calculations, Newton Raphson method- Optimization procedure, mathematical statement of the problem

The Lagrange multiplier equations, Sensitivity coefficients- Single variable – Exhaustive, Dichotomous and Fibonacci, Multivariable unconstrained - Lattice, Univariable and Steepest ascent

Dynamic Programming-Geometric Programming-Linear Programming- Linear regression analysis, Internal energy and enthalpy, Pressure temperature relationship at saturated conditions.

References

1	*Yogesh Jaluria: "Design and Optimization of Thermal Systems", 3rd Ed., CRC Press, 2020*
2.	*W.F. Stoecker: "Design of Thermal Systems", 3rd Ed., McGraw Hill,1989.*
3.	*B.K. Hodge: "Analysis and Design of Thermal Systems", Prentice Hall Inc., 1990*
4.	*J. Nagrath & M. Gopal: "Systems Modelling and Analysis", Tata McGraw Hill,1982*
5	*D.J. Wide: "Globally Optimal Design", Wiley- Interscience, 1978*
6	*C. Balaji: "Thermal System Design and Optimization", 2nd Ed., Springer, 2021.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Assess the capabilities and limitations of various modelling methods
CO2	Apply innovative modelling and simulation methods to solve complex multi-disciplinary energy system problems individually and in teams
CO3	Demonstrate knowledge and comprehension of theoretical principles underlying modelling programmes

Course Code	**:**	EN619
Course Title	**:**	AIR CONDITIONING AND REFRIGERATION
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To teach the underlying thermodynamic principles of refrigeration and air conditioning
CLO2	To know more different types of modern AC and refrigeration systems with their limitations
CLO3	To give a detailed overview on air compressor and its performance evaluation
CLO4	To present a overview on vapour absorption, air steam jet refrigeration and sub-components of VCRS systems.

Course Content

Thermodynamic concepts, Thermodynamic systems and postulates, thermodynamic equilibrium, thermodynamic relations, stability and phase transition. Principles of air conditioning, methods of refrigeration.

Vapour and combined power cycles Simple steam power cycle-Rankine cycle-comparison of Rankine& Carnot Cycle- reheat cycle-regenerative cycle-direct contact and surface contact regenerators- characteristics of an ideal working fluid in vapor cycle-binary vapor cycle thermodynamics of combined cycles.

Refrigeration cycle:Refrigerators - Heat pumps - Thee reversed Carnot cycle - Refrigeration by non-cyclic process - Reversed heat engine cycle - Ideal & actual vapor compression Refrigeration cycle-absorption refrigeration cycle - gas refrigeration cycle - Absorption refrigeration systems - Liquefaction of gases.

Air Compressor:Reciprocating air compressors. Types. Construction. Work ofcompression without clearance. Effect of clearance. Multistaging. Optimum intermediate pressure for perfect inter cooling. Compressor efficiencies and mean effective pressure

Vapour compression system adsorption and adsorption cycles, Air-cycle steam jet. Refrigeration systems and their performances: compressors, expansion devices, evaporators, condensers, absorbers, Cooling towers etc.

Comfort factors-specifications –Limits for humidity, temperature etc Heat load estimation, air distribution, ventilation, instrumentation.

References

1.	*Stoecker W.F. "Refrigeration and Air Conditioning", TMH edition, McGraw Hillpublication, (1980).*
2.	*Ballaney P.L. "Refrigeration and Air Conditioning" V Ed. Khanna Publishers (1980)*
3.	*Trott A.R." Refrigeration and Air Conditioning" 2nd Ed. ButterworthPublishers.1980.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain and understand the various refrigeration and air conditioning systems and their underlying thermodynamic principles.
CO2	To compare work production, work consumption devices, and evaluate their performance.
CO3	To demonstrate knowledge on VCRS, VARS, their sub-components and do energy analysis for each sub-component.
CO4	To do heat load estimation and able to come up power saving options possible with case studies in HVAC systems.

Course Code	**:**	EN620
Course Title	**:**	ENERGY EFFICIENT BUILDINGS
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours		36
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the impact of building science on indoor quality.
CLO2	To learn the human comfort parameters and ventilation for building
CLO3	To learn solar passive cooling and heating concepts
CLO4	To learn energy conservation methods by carrying out energy audit of the building

Course Content

Architecture- Building Science and its significance. Indoor Environment. Components of Indoor Environment. Quality of Indoor Environment.

Human Comfort-Thermal, Visual, Acoustical and Olfactory comfort. Concept of Sol- air temperature and its significance. Ventilation and is significance.

Cooling and heating concepts, Passive concepts appropriate for the various climatic zones in India. Classification of building materials based on energy intensity.

Energy Management of Buildings and Energy Audit of Buildings. - Energy management matrix monitoring and targeting. Energy Efficient Landscape Design **-**Modification of microclimate through landscape elements for energy conservation.

Reference Books:

1.	*Sodha M.,Bansal N.K., Bansal,P.K Kumar, A. and Malik, M.A.S.,"SolarPassiveBBuildings", Pergamon Press, 1986.*
2.	*Koenigsberger, O.H., Ingersoll, T.G., Mayhew Alan and Szokolay, S. V., "Manual of Tropical Housing and Building part 1: Climatic Design", OLBN 0 002120011,OrientLongman Limited, 1973.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To measure indoor air quality.
CO2	To create human comfort parameters through ventilation of building
CO3	To evaluate solar passive cooling and heating concepts applicable for buildings.
CO4	To carry out energy audit of the building and suggest energy conservation methods.

Course Code	**:**	EN621
Course Title	**:**	THERMAL ENGINEERING
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the principles, construction, and performance of reciprocating air compressors.
CLO2	To provide an in-depth understanding of various vapor and combined power cycles used in steam power plants and explore different gas power cycles and their applications in automotive and aircraft propulsion.
CLO3	To study the principles, cycles, and systems used in refrigeration and air conditioning and understand the operation, classification, and performance analysis of steam turbines.
CLO4	To provide comprehensive knowledge about the components, operation, and performance of internal combustion engines.

Course Content

Air Compressor:
Reciprocating air compressors. Types – Construction, work of compression without clearance, effect of clearance. Multi staging. Optimum intermediate pressure for perfect inter cooling. Compressor efficiencies and mean effective pressure.

Vapour and combined power cycles:
Simple steam power cycle - Rankine cycle- comparison of Rankine & Carnot cycle - Reheat cycle - Regenerative cycle – Actual vapour cycle processes - Characteristics of an ideal working fluid in vapor cycle - Binary vapour power cycle – Efficiencies in steam power plant.

Gas power cycles:
Otto cycle - Diesel Cycle - Dual cycle - Comparison of Otto, Diesel & Dual cycles - Brayton cycle – Aircraft propulsion - Brayton cycle with intercooling, reheating & regeneration.

Refrigeration & Air conditioning:
Refrigerators - Heat pump systems - Ideal & actual vapor compression Refrigeration cycle – Vapour absorption refrigeration cycle - Gas refrigeration cycle – Production of solid ice.

Steam Turbines:
Principles of operation - Classification of turbines - Simple impulseturbine - Velocity, Pressure compounded impulse turbine - Turbine velocity diagrams for flow of steam thro turbine blades - Forces on the blades & work done - Blade or diagram efficiency - Steam turbine performance.

Internal combustion Engines :
Classification of IC Engine components - Four stroke cycles, valve timing - Spark ignition - Air Fuel mixtures - Mixture requirements of automotive Engines & four stroke Engine - Comparison of two stroke with four stroke 0Engines – Engine power - Indicated power - Break horse power - Engine efficiency - Performance analysis of IC Engine.

References

1.	*Khurmi. R.S, Gupta. J.K, " A textbook of Thermal Engineering", 2002*
2.	*Moran, Shapiro, Munson and Dewitt, "Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics and Heat Transfer", John Wiley, N. Y 2000*
3.	*Ballaney, P.L., Thermal Engineering, Khanna Publishers, 1996.*
4.	*Nag. P.K., " Engineering Thermodynamics ",Tata McGraw-Hill Publishing Co., Ltd.,1994*
5.	*Sonntag, R.E and Van Wylen, G.J.., "Fundamentals of Thermodynamics", Sixth Edition,2003.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand reciprocating compressors, compression work, and efficiencies.
CO2	Analyze Rankine, reheat, regenerative cycles, and compare with Carnot. Compare Otto, Diesel, Dual, and Brayton cycles, including their applications.
CO3	Learn about refrigeration cycles, heat pumps, and ice production. Study steam turbine operation, classification, and performance.
CO4	Explore engine components, cycles, and performance metrics.

Course Code	**:**	EN622
Course Title	**:**	OPTIMUM UTILIZATION OF HEAT AND POWER
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Comprehend and analyze the fundamentals of CHP systems
CLO2	Design and analyse cogeneration and poly-generation systems
CLO3	Apply pinch technology principles to industrial processes for optimum heat recovery and utilization
CLO4	Evaluate waste heat recovery, advanced cogeneration technologies and develop understanding of various energy economic

Course Content

Basic concepts of CHP:
The benefits and problems with CHP–Balance of energy demand–Types of prime movers–Economics–CHP in various sectors.

Application & techno-economics of Cogeneration:
Cogeneration – Performance calculations, Part load characteristics – financial considerations – Operating and Investments – Poly generation

Pinch Technology:
Significance – Selection of pinch temperature difference – Stream splitting – Process retrofit – Installation of heat pumps, heat engines – Grand composite curve – Insulation – Recuperative heat exchanger – Runaround coil systems – Regenerative heat exchangers – Heat pumps – Heat pipes

Waste Heat Recovery and Cogeneration Technology:
Sources of waste heat, Cogeneration – Principles of Thermodynamics – Combined Cycles Topping and Bottoming – Organic Rankine Cycles – Advantages of Cogeneration Technology

Energy Economics:
Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation

References

1.	*Charles H. Butler, Cogeneration, McGraw Hill Book Co., 1984*
2.	*D.E. Garrett, Chemical Engineering Economics. Springer, reprint of the original 1st ed. 1989 edition (13 February 2012)*
3.	*Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford,1987*

4.	*Osborn, peter D, "Handbook of energy data and calculations including directory of products and services", Butterworths, 1980*
5.	*O'Callaghan, Paul W, "Design and Management for energy conservation", Pergamon,1993*
6.	*Eastop, T.D. & Croft D.R, "Energy efficiency for engineers and Technologists", 2nd edition, Longman Harlow, 1990.*
7.	*Christos A. Frangopoulos, "Cogeneration: Technologies, Optimisation, and Implementation", The Institution of Engineering and Technology, 2017.*
8.	*Joel K. Wilson, "Cogeneration Power Plants: Planning and Evaluation", PennWell Corporation, 2019.*
9.	*W. Stephen Comstock, "Combined Heat and Power Design Guide", ASHRAE, 2015.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain CHP concepts and applications
CO2	Perform techno-economic analysis of cogeneration systems by calculating full load and part load performance characteristics for financial assessment
CO3	Calculate pinch temperature differences, optimum stream splitting conditions, and suggest design and retrofit of components to heat exchanger network for process heat optimization
CO4	Conduct economic feasibility evaluations of energy projects using concepts of Simple Payback Period, Net Present Value, Internal Rate of Return.

Course Code	**:**	EN623
Course Title	**:**	POWER PLANT TECHNOLOGY
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide a deep understanding of fundamental thermodynamic concepts and principles and To familiarize students with the components, operation, and economics of different types of power plants.
CLO2	To understand the different types of boilers, their construction, and working principles.
CLO3	To provide comprehensive knowledge about steam and gas turbines, their performance, and troubleshooting methods.
CLO4	To introduce students to advanced power plant technologies and their future potential.

Course Content

Thermodynamic concepts, Thermodynamic systems and postulates, thermodynamic equilibrium, thermodynamic relations, stability and phase transition

Power Plants - Features, Components and Layouts - Working of Power Plants, Power Plant Economics

Boiler Classification - Boiler Types - Fire Tube & Water Tube Boilers - Fluidized Bed Boilers
- Positive Circulation Boilers - Thermal Liquid Heaters & Vaporizers

Classification - Features - Working - Performance of Steam Turbines - Losses in Steam Turbines - Trouble Shooting - Classification and Comparison of Different Types Gas Turbine Power Plants Components - Economics & Future of Combined Cycles

Integrated Gasification Combined Cycle (IGCC) – Indirect Fired Combined Cycle (IFCC) – Magneto Hydrodynamics (MHD) – Fuel Cells – Micro turbines– RDF based power plants.

References

1.	*Thomas C. Elliott ,"Standard Hand Book of Power Plant Engineering"*
2.	*E L Wakil, "Power Plant Engineering", McGraw-hill Book Co, N.Y. 2001*
3.	*Arora and Domkundwar, A course in Power Plant Engineering, Dhanpat Ra, N.Delhi.2003*
4.	*Nag, P.K., "Power Plant Engineering", 2nd Edition, TMH, 2001*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand thermodynamic principles, systems, equilibrium, and phase transitions.
CO2	Analyze power plant features, components, layouts, and economic aspects.
CO3	Classify and evaluate various boiler types, including fire tube, water tube, and fluidized bed.
CO4	Examine steam and gas turbine performance, losses, and troubleshooting; compare power plant technologies.

Course Code	**:**	EN624
Course Title	**:**	POWER GENERATION AND SYSTEMS PLANNING
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the Thermodynamic analysis of Conventional Power Plants.
CLO2	To learn the working and operation of steam turbines ,Electrostatic Precipitator and ID fans.
CLO3	To learn the components of Power plant control systems such as combustion control and pressure control.
CLO4	To learn the analysis of System load curve and generation planning.

Course Content

Overview of the Indian power sector, Thermodynamic analysis of Conventional Power Plants. Advanced Power Cycles, Kalina (Cheng) Cycle, IGCC, AFBC/PFBC

Steam Turbine - Superheater, reheater and partial condenser vacuum. Combined Feed heating and Reheating. Hydro power plants - turbine characteristics. Electrostatic Precipitator / Flue gas De-sulphurisation, Coal crushing / Preparation - Ballmills / Pulverisers, ID/FD Fans

Power plant control systems- Review of control principles, Combustion control, pulveriser control, control of air flow, Furnace pressure and feed water, steam temperature control, Safety provisions / Interlocks

Analysis of System load curve -plant load factor, availability, Loss of load Probability calculations for a power system, Maintenance Scheduling Pricing of Power - Project cost components, Analysis of Power Purchase Agreements (PPA), Debt/Equity Ratio and effecton

Generation planning fundamentals, economic analysis in Generation planning optimized according to generating unit categories, Optimal Dispatch Scheduling of Hydro-Thermal plants. Load Forecasting - Time series, Econometric, end use techniques. Least Cost Power Planning - Integration of DSM, Renewable into supply.

References

1.	*R.W.Haywood, Analysis of Engineering Cycles, 4th Edition, Pergamon Press, Oxford, 1991.*
2.	*D. Lindsay, Boiler Control Systems, Mcgraw Hill International, London, 1992.*
3	*H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.*
4	*Wood, A.J., Wollenberg, B.F., Power Generation, operation & control, John Wiley, New York, 1984.*
5	*Vijay Madisetti, Arshdeep Bahga, “Internet of Things: A Hands-On Approach” Orient Blackswan Pvt. Ltd., New Delhi, 2015.*
6	*Sullivan , “Power System Planning” McGraw Hill.*
7	*Makridakis and Spyrox , “Forecasting methods and application”, John Wiley.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Illustrate the operation of thermal power plants and power cycles.
CO2	Comment on the working of steam turbines.
CO3	Analyze the system planning parameters like scheduling, load factor and loss of load probability.
CO4	Apply generation planning for economic load dispatch.

Course Code	**:**	EN625
Course Title	**:**	ELECTRICAL ENERGY TECHNOLOGY
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the concept of electricity, conductors and magnetic fields.
CLO2	To learn the working and operation of AC and DC motors.
CLO3	To learn the working and operation transformers.
CLO4	To learn the principles of switch gear and protection.

Course Content

Introduction to Electrical Systems

Essence of electricity, Conductors, semiconductors and insulators. Electric field; electric current, potential and potential difference, electromotive force, electric power, Magnetic field, Faradays laws of electromagnetic induction. Faradays laws of electromagnetic induction ac fundamentals, waveforms and basic definitions, phasor representation of alternating quantities.

Motors

AC Induction: Three phase induction motor, principle of operation, slip and rotor frequency, torque. Synchronous: Principle of operation, EMF equation. HT Motors: Difference between HT and LT motors, Advantages, Construction. DC: Direct current machines: Principle of operation of dc machines, armature windings, e.m.f equation in a dc machine, Types of motor controllers, Motor starters DOL, Reduce voltage starters, ASD, Overload relays, Servo controllers

Transformers

Power Transformers: Principles of operation, Constructional Details, Losses, Transformer Test, Efficiency and Regulation, New type of transformers like hermetically sealed and amorphous. Distribution Transformers: Definition, types and Classification, Connections, Load, No load losses, efficiency.

Switch Gears

Protection and Switchgear: Power conducting components, such as switches, circuit breakers, fuses, and lightning arrestor.

Control systems such as control panels, current transformers, potential transformers, protective relays, and associated circuitry, that monitor, control, and protect the power conducting components.

References

1.	*Mac.E Van Valkenburg, “Network Analysis”,*
2.	*“Electric Machines”, Nagrath and Kothari, Tata McGraw-Hill.*
3.	*“Electric Machinery”, Fitzgerald, Kingslay, Umans, Tata McGraw-Hill.*
4.	*Joseph A. Edminister, Mahmood Maqvi, “Theory and Problems of Electric Circuits”, Schaum's Outline Series, TMH*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To understand the fundamental of electrical energy systems and its components.
CO2	To analyze the working and operation of electric machines.
CO3	To analyze the working and operation of transformers.
CO4	To illustrate Protection and Switchgear components.

Course Code	**:**	EN626
Course Title	**:**	APPLIED THERMODYNAMICS
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To explain the underlying principles of thermodynamics and the relations of combustion systems
CLO2	To know more about combustion mechanisms and chemical kinetics
CLO3	To give a detailed analysis of flame structures and their importance
CLO4	To present an overview of liquid and solid combustion devices design

Course Content

Second Law. Review of entropy. Irreversibility and availability. Exergy balance equation and Exergy analysis.

Thermodynamic relations for homogeneous phase. Maxwell relations: Relations involving enthalpy, internal energy, and entropy. Equilibrium between two phases of a pure substance. Clausius- Clapeyron equation

Review of Ideal Gas, Ideal gas mixtures, and mixing rules. Real gas behavior. Real gas equations of state. Property relations for mixtures and Psychrometry.

Combustion. Combustion reactions – Stoichiometry. First law analysis, Heat calculations, and Adiabatic flame temperature. Chemical Equilibrium. Chemical potential. Second law analysis of reacting systems. Free energies. Equilibrium flame temperature. Equilibrium products of combustion. Fundamentals of combustion kinetics, Governing equations for a reacting flow.

Volumetric combustion, explosion, and detonation, Laminar flame propagation, deflagration, premixed flame burners, theories, Flammability limits, partial premixing and quenching of laminar flames, Ignition, Flame stabilization, Gas jets and combustion of gaseous fuel jets, Turbulent premixed and non-premixed flames, Droplet evaporation and combustion, Combustion of a carbon particle.

References

1.	*Moran, M. J. and Shapiro, H. N. Fundamentals of Engineering Thermodynamics, 5th edition, 203, John Wiley Sons*
2.	*Sonntag, R. E, Borgnakke, C and Van Wylen, G. J. and., 1976, Fundamentals of Classical Thermodynamics, Wiley Eastern Ltd.*
3.	*Jones, J. B. and Hawkins, G. A., Engineering Thermodynamics, John Wiley Sons, 1986*
4.	*Nag, P.K, Engineering Thermodynamics, Tata McGraw-Hill Publishing Co, Ltd. 1986*

5.	*Turns, S.R. An Introduction to Combustion Concepts and Applications , McGraw Hill*
6.	*Kenneth Kuo, Principles of Combustion, John Wiley.*
7	*Mukunda, H.S., Understanding Combustion, Macmillan India*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain and understand the thermodynamic principles of combustion systems
CO2	To perform chemical equilibrium and kinetics calculations
CO3	To demonstrate knowledge of flame structures and their dynamics
CO4	To conduct detailed case studies of various combustion devices and explore possible optimizations for maximizing the efficiency of such systems.

Course Code	**:**	EN627
Course Title	**:**	POWER GENERATION, TRANSMISSION AND DISTRIBUTION
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To Familiarize the working of Synchronous generator and characteristics.
CLO2	To Learn the regulation and losses of overhead transmission lines.
CLO3	To Distinguish the HVAC and HVDC transitions systems.
CLO4	To Design the distribution systems.

Course Content

Generation:

Synchronous generator operation, Power angle characteristics and the infinite bus concept, Dynamic analysis and modeling of synchronous machines, Excitation systems, Prime-mover governing systems, Automatic generation control, Auxiliaries, Power system stabilizer, Artificial intelligent controls,

Power quality of AC Transmission:

Overhead and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission.

HVDC Transmission:

HVDC converters, Advantages and economic considerations converter control characteristics, Analysis of HVDC link performance, Multi terminal DC system, HVDC and FACTS,

Distribution:

Distribution systems, Conductors size, Kelvin's law performance calculations and analysis, Distribution inside and commercial buildings entrance terminology, Substation and feeder circuit design considerations, Distributions automation, Futuristic power generation

References

1.	*Wadhawa, C.L. „Electrical Power Systems", New Age International Publishers, 6th edition, 2009.*
2.	*D. P. Kothari and IJ Nagrath, „Power System Engineering" Tata Mcgraw – Hill, 2nd edition, 2008.*

3.	*Gupta B.R.,' Power system Analysis & Design', S. Chand and Company Ltd.,2nd edition, 2008.*
4	*Padiyar, K.R., "HVDC transmission systems", Wiley Eastern Ltd., New Delhi, 1992.*
5	*Allen J.Wood and Wollenberg B.F., "Power Generation Operation and control", JohnWiley & Sons, Second Edition,1996.*
6	*Pabla, A.S., „Electrical Power Distribution System", 5th edition,Tata McGraw-Hill, 2004.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To analyze the characteristics of synchronous generator.
CO2	To illustrate the reactive power compensation of overhead transmission lines.
CO3	To analyze the HVDC link performance
CO4	To calculate the performance analysis of distribution systems.

Course Code	**:**	EN628
Course Title	**:**	ADVANCED HEAT TRANSFER
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide a thorough understanding of the basic laws of heat conduction, convective heat transfer, and radiation heat transfer mechanisms.
CLO2	To teach the derivation and application of governing equations for heat and mass transfer, including differential forms and solution methods for steady and unsteady state problems.
CLO3	To apply theoretical concepts to practical situations such as fins, moving boundaries, condensation, boiling, and the design of heat exchangers.
CLO4	To develop analytical and numerical problem-solving skills necessary for solving complex heat and mass transfer problems, and to use appropriate correlations and models for practical engineering applications.

Course Content

Heat conduction - basic law, governing equations in differential form, solution methods, steady state, unsteady state problems, moving boundaries.

Convective heat transfer - conservation equations, boundary layer approximations. Forced convective laminar and turbulent flow solutions.

Natural convection solutions, correlations. Radiation heat transfer mechanism; properties; exchange between black and nonblack surfaces, condensation - mechanism, controlling parameters.

Nusselt Theory: solution to laminar film modifications, influence of other parameters, correlations for single horizontal tube, vertical bank of horizontal tubes, other configurations.

Dropwise condensation. Boiling mechanisms regimes. Basic models, correlations. Mass Transfer- governing laws, transfer coefficients; application. Heat exchangers. Design principles.

References

1.	*E.R.G. Eckerst and R.M. Drake Jr, Analysis of Heat Transfer, McGraw-Hill, 1972.*
2.	*W.M. Roshenow and P. Choi, Heat, Mass and Momentum Transfer, Prentice - Hall, 1961.*
3.	*B. Gebhart, Heat Transfer, McGraw-Hill, 1971.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Apply governing equations and solution methods for steady and unsteady states.
CO2	Use conservation equations, boundary layer approximations, and solutions for forced and natural convection.
CO3	Examine heat transfer mechanisms, properties, and correlations for black and nonblack surfaces.
CO4	Utilize correlations for various configurations and understand mass transfer principles and heat exchanger design.

Course Code	**:**	EN629
Course Title	**:**	POWER STSTEM PLANNING AND OPERATION
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the stages in power system planning and design.
CLO2	To apply least cost optimization in power system expansion planning.
CLO3	To analyze the economic operation of thermal units.
CLO4	To learn the scheduling of energy using fast scheduling techniques and state estimation.

Course Content

Introduction:

Power system planning, Objective, Stages in planning and design, Transition from planning to operation. Generating System capability Planning: Probabilistic models of generating units, Growth rate, Rate of generation capacity, Outage performance and system evaluation of loss of load and loss of energy indices, Power supply availability assessment.

Optimal power system expansion planning:

formulation of least cost optimization problem incorporating the capital, operating and maintenance costs of candidate plants of different types (thermal, hydro, nuclear, non conventional etc.).

Economic operation**:**

Review of thermal units, lambda iteration method, first order gradient method, base point and participation factors. Generation with limited supply, take or pay fuel contract, composite generation production cost function, solution of gradient search techniques.

Scheduling energy, short-term hydro-thermal scheduling problem, pumped storage hydro plants, pumped storage hydro scheduling, λ -γ iteration, fast scheduling techniques. Inter change evaluation and power pools, economy interchange evaluation with unit commitments, types of interchange, energy banking. State estimation: detection and identification of bad measurements, estimation of quantities not being measured, network observability and pseudo-measurements, synchronized measurements-PMU.

References

1.	*Sullivan, R.L., „Power System Planning", Heber Hill, 1987.*
2.	*Roy Billington, „Power System Reliability EvaluatGordan Breach ScainPublishers, 1990.*
3.	*Allen J.Wood and Wollenberg B.F., „Power Generation Operation and control", JohnWiley & Sons, Second Edition,1996.*
4	*Kirchmayer L.K., „Economic Control of Interconnected Systems", John Wiley &Sons,n1959.*
5	*Nagrath, I.J. and Kothari D.P., „Modern Power System Analysis", TMH, New Delhi,2006.*
6	*Eodrenyi, J., „Reliability modelling in Electric Power System" John Wiley.*
7	*Pabla, A.S., Electric Power Distribution, Tata McGraw–Hill (2008).*
8	*McDonald, J.R., Modern Power System Planning, McGraw–Hill (2007).*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To Assess the generation adequacy in power system using probabilistic approach.
CO2	To Develop the solution methodology for optimizing the cost of power system under operation.
CO3	To perform economic operation of thermal units using lambda iteration method and first order gradient method.
CO4	To schedule hydro-thermal units and pumped storage hydro plants.

Course Code	**:**	EN630
Course Title	**:**	ADVANCED THERMODYNAMICS
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To revisit and deepen the understanding of fundamental thermodynamic principles and relations.
CLO2	To introduce students to the principles of classical and quantum mechanics and their application in statistical mechanics.
CLO3	To explore classical statistical mechanics, intermolecular forces, and computational methods.
CLO4	To study the properties and behaviors of ideal and non-ideal solutions and understand different types of phase equilibria.

Course Content

Review of Basic Postulates, Maxwell`s relations, Legendre Transformation, Pure Component properties, Theory of corresponding states, real fluids, Equilibrium, Phase Rule, Single component phase diagrams, Introduction to Multicomponent Multiphase equilibrium

Introduction to Classical Mechanics, Quantum Mechanics, Canonical Ensemble, Microcanonical Ensemble, Grand Canonical Ensemble, Boltzmann, Fermi-Dirac and Bose-Einstein Statistics, Fluctuations, Mono atomic and Diatomic Gases

Introduction to Classical Statistical Mechanics, phase space, Liouville equation, Crystals, Intermolecular forces and potential energy functions, imperfect Monoatomic Gases, Molecular theory of corresponding states, introduction to Molecular Simulations, Mixtures, partial molar properties, Gibbs-Duhem's equations, fugacity and activity coefficients,

Ideal and Non-ideal solutions, Molecular theories of activity coefficients, lattice models, multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Chemical Equilibrium and Combined phase and reaction equilibria.

References

1.	*McQuarrie D.A, Statistical Mechanics, Viva Books Private Limited, 2003.2. Hill Terrel, An Introduction to Statistical Thermodynamics, Dover, 1960*
2.	*Callen, HB. Thermodynamics and an Introduction to Thermostatics, 2nd Edition, John Wiley and Sons, 1985*
3.	*Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics of fluid- phase Equilibria (3rd edition), Prentice Hall Inc., New Jersey,1996*
4.	*J.M. Smith. H.C.Van Ness and M.M.Abott. "Introduction to Chemical Engineering Thermodynamics:. McGraw Hill International edition (5th ed.). 1996*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Explain the fundamental thermodynamic concepts, phase equilibria, and properties of real fluids.
CO2	Apply classical and quantum statistical mechanics, and apply statistical ensembles and distribution laws.
CO3	Analyze phase space, Liouville equation, and molecular simulations for various gases and intermolecular forces.
CO4	Study solution theories, activity coefficients, lattice models, and phase equilibria for single and multi-component systems.

Course Code	**:**	EN631
Course Title	**:**	INSTRUMENTATION AND CONTROL IN ENERGY
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn about the Measurement Errors in measuring instruments .
CLO2	To familiarize oneself with temperature measuring instruments.
CLO3	To learn the working and operation of power and energy meters.
CLO4	To learn the applications of analog and digital controllers along with controller design.

Course Content

Measurement systems – An overview and basic concepts; Characteristics of Instruments; Errors. Transducers and measurement of displacement.

Temperature Measurement, Pressure thermometers, Thermocouples, RTD, Thermistors, and Pyrometry. Measurement of pressure: Manometers, Bourdon tube, and the McLeod Gauge, and Thermal conductivity gauges.

Flow Measurement- Variable head flow meters- Rota meters, Electromagnetic flow meters, anemometers, Ultrasonic flow meters, Flow Visualization

Moving Iron/coil Instruments, Energy measurement, power factor meters, Analog signal conditioning, Amplifiers, A/D and D/A converters.

Digital data processing and display, Computer data processing and control, Feedback control system, Stability and transient analysis of control systems, Application of PID controllers, General-purpose control devices, and controller design

References

1.	*A.K. Sawhney. PuneetSawney:A course in Mechanical Measurements and Instrumentation. Dhanpat Rai&Co 2002*
2.	*Bechwith. Marangoni.Lienhard: Mechanical Measurements Fifth edition. Addison-Wesley 2000*
3.	*J.P. Holman: Experimental methods for engineers Sixth edition, McGraw-Hill .1994*
4.	*N.V.S.Raju, Instrumentation, BS Publications 2016*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To calculate the measurement errors in measuring instruments.
CO2	To demonstrate the operation of temperature and flow measuring instruments.
CO3	To illustrate the power and energy measuring instruments.
CO4	To design the analog and digital controller.

Course Code	**:**	EN632
Course Title	**:**	ADVANCED REACTION ENGINEERING
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Analyze ideal homogenous reactor design and performance by applying design principles for isothermal batch, semi-batch, and flow reactors
CLO2	Evaluate non-ideal reactor behaviour for real time applications by applying concepts of residence time distribution and mixing models.
CLO3	Design and analyze heterogeneous Gas-Solid reactors by applying reaction kinetics to fixed and fluidized bed systems with/ without diffusion limitations.
CLO4	Design and analyze heterogeneous gas-liquid reactors by applying concepts of mass transfer theory for mechanically agitated and bubble column reactors

Course Content

Homogeneous reactor design and analysis-I: Ideal reactors, Review of isothermal design for batch, semi-batch and flow reactors, Multiple reactions and reaction networks: Yield-selectivity concepts.

Weiz-Prater analysis for first-order networks, reaction networks of general order, Reactor energy balance, and its applications to reactor design and analysis. Homogeneous reactor design and analysis-II: Non-ideal reactors- Review of the basic concepts of residence time distributions, single parameter models for real reactor behaviour

Macromixing and micro mixing, segregated flow model, and Zweitering`s analysis of maximum mixedness, IEM, and other models for micro mixing.

Heterogeneous reactors-I: Gas-solid systems- Review of kinetics of gas-solid catalytic reactions with and without diffusion limitation

Reactor design for fixed and fluidized bed reactors, Selected case studies, non-catalytic gas-solid reactions: review of kinetics; reactor design case studies.

Heterogeneous reactors-II: Gas-liquid systems- Basic theories of mass transfer with chemical reaction model systems and model reactors, Reactor design for mechanically agitated and bubble column reactors. Selected case studies.

References

1.	*Froment, F.G. and Bischoff, K.B., Chemical Reactor Analysis and Design, Wiley, 1990*
2.	*Rawlings, J.B. and Ekerdt, J.G., Chemical Reactor Analysis and Design Fundamentals, Nob Hill, 2002*
3.	*Carberry, J.J., Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976*
4.	*Levenspiel, O., Chemical Reaction Engineering, Third edition, Wiley, 1999*

5.	*Smith, J.M., Chemical Engineering Kinetics, McGraw Hill, 1981.*
6.	*Doraiswamy, L. K, Sharma, M.M., Heterogeneous Reactions, Vol. I and II, Wiley,1984.*
7.	*Danckwerts, P.V., Gas-Liquid Reactions, McGraw Hill, 1970.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the concepts of homogenous reactor design
CO2	Apply residence time distribution and mixing models concepts in reactor analysis calculations
CO3	Perform technical evaluation of design calculations of gas-solid catalytic reactors for various reactor designs and diffusion scenarios.
CO4	Implement design principles for gas-liquid reactor columns by incorporating basic mass transfer in chemical reaction calculations to select case studies.

Course Code	**:**	EN633
Course Title	**:**	COMPUTATIONAL HEAT TRANSFER
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the physical phenomena and governing differential equations, including the energy and momentum equations, and their application in fluid flow and heat transfer analysis.
CLO2	Solve parabolic equations using explicit, implicit, and Crank-Nicholson methods, and understand their application in different coordinate systems and boundary conditions.
CLO3	Develop proficiency in applying numerical methods such as Jacobi, Gauss-Seidel, and Successive Over-Relaxation (SOR) methods for solving fluid flow and heat transfer problems.
CLO4	Use computational tools and software packages like HEAT 2, HEATAX, RADIAT, and ANSYS for modeling and solving conduction, convection, and diffusion equations in one, two, and three-dimensional systems.

Course Content

Physical Phenomena Governing Differential Equation - Energy Equation – Momentum Equation - Nature of Co-ordinates -Discretization Methods

Parabolic Equations - Explicit, Implicit and Crank Nicholson Methods. Cartesian and Polar Co-ordinates - Mixed Boundary Condition -Jacobi - Gauss-siedel and SOR Methods.

Heat Condition And Convection Control Volume Approach - Steady and Unsteady One Dimensional Conduction - Two and Three Dimensional -Power Law Scheme – Simpler Algorithm.

General Applicability of the Method - Approximate Analytical Solution - Raleigh's Method. Galerikin Method, Solution Methods.

Isoparametric Element Formulations Conduction and Diffusion Equations - Heat Transfer Packages - Heat 2, HEATAX, RADIAT, ANSYS

References

1.	*Suhas V.Patnakar, Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Corporation, 1980*
2.	*P.S. Ghoshdastidar, Computational Fluid Dynamics and Heat Transfer, Cengage, 2017*
3.	*O. D. Makinde, Computational analysis of heat transfer in fluids and solids, Trans tech publications, 2018*
4.	*D.A. Anderson, J.C. Tannehill, R.H. Pletcher, R.Munipalli, and V.Shankar,*

	Computational Fluid Mechanics and Heat Transfer, 4th edition, CRC Press, 2020
5.	*Jaluria and Torrance, Computational Heat Transfer, CRC Press, 2nd Ed., 2003*
6.	*R. Mitchell and D.F. Grifths, Finite Difference Method in Partial Differential Equations, John Wiley & Sons, 1980*
7.	*A. A. Samarskii, P. N. Vabishchevich," Computational Heat Transfer, Volume 1: Mathematical Modelling", Wiley, 1996*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand and apply differential equations for energy and momentum.
CO2	Use discretization methods like explicit, implicit, and Crank-Nicholson in Cartesian and polar coordinates.
CO3	Solve heat and convection problems using control volume, power law schemes, and simpler algorithms.
CO4	Apply numerical methods (Raleigh's, Galerkin, isoparametric) and ANSYS for heat transfer.

Course Code	:	EN634
Course Title	:	BATTERIES AND FUEL CELLS
Type of Course	:	PE
Prerequisites	:	Nil
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand battery fundamentals and performance metrics
CLO2	Analyse electrochemical principles in battery operation along with thermodynamic background of battery electrode processes
CLO3	Evaluate and analyze different primary and secondary battery technologies for various applications
CLO4	Comprehend various fuel cell technologies and future opportunities in the space of electrical energy storage

Course Content

Basic concepts
Components of cells and batteries, Classification of cells and batteries, Operation of a cell, Specifications – Free energy, theoretical cell voltage, specific capacity, specific energy, energy density, memory effect, cycle life, shelf life, state of charge (SOC) and depth of discharge (DOD), internal resistance and coulombic efficiency.

Electrochemical principles and reactions
electrical double layer, discharge characteristics of cell and polarization, Electrode processes and Tafel polarization, thermodynamic background and Nernst equation.

Primary and secondary batteries
Zn/C, Zn/air, alkaline cells, lithium primary batteries, lead acid, Ni/Cd, Ni/MH and Lithium secondary batteries (Components, Chemistry and Performance characteristics). Applications of storage batteries.

Fuel cell fundamentals
The alkaline fuel cell, Acidic fuel cells, SOFC (components, chemistry and challenges) - Emerging areas in Fuel cells

Fuel cell outlook, Applications of fuel cells
Industrial and commercial/residential sectors

References

1.	*Handbook of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas. B. Reddy, McGraw Hill Book Company, N.Y. 2002*
2.	*Modern Electrochemistry 2A, Fundamentals of Electronics, 2nd Edition, John O'M Bockris, Amulya K. N. Reddy and Maria Gamboa-Aldeco, Kluwer Academic Publishers, New York.*

3.	*Principles of Fuel Cells, by Xianguo Li, Taylor & Francis, 2006*
4.	*Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M, Universities Press, 2006*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Describe the basic concepts of fuel cells and batteries
CO2	Assess different types of batteries, its components, chemistry and performance characteristics
CO3	Apply fuel cell and battery fundamentals to address the challenges in the research problems
CO4	Describe the application of fuel cells and batteries in various industrial and commercial areas

Course Code	**:**	EN635
Course Title	**:**	ENVIRONMENTAL IMPACT ASSESSMENT
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the principles and methods of EIA
CLO2	To assess and mitigate the environmental impacts of various domains
CLO3	To perform economic analysis and Life Cycle Assessment (LCA)
CLO4	To implement EIA procedures and analyse real-world case studies.

Course Content

Basic Concepts of EIA
Introduction to Environmental Impact Assessment; Principles of EIA; Evolution of EIA – Origin and development; Elements of EIA – Factors affecting EIA Impact evaluation and analysis; Classification of EIA; Steps involved in EIA; EIA report; Role of stakeholders in EIA and EIA in decision-making process

EIA Methodologies
Methodologies for Environmental Impact Assessment – Introduction and Criteria for Selection; Methods – Checklist methods, Ad-hoc methods, matrix methods – Leopold matrix, Network methods, overlay methods, GIS.

Impact Assssment and mitigation
The concept of Environment; Baseline Map construction; Air Quality Impact Assessment, Noise Quality Impact Assessment, Soil and Water Quality Impact Assessment, Biological Environment Impact Assessment – Basic concepts, sources of pollution, Quality standards, Impact prediction, assessment and Mitigation Strategies; Environmental Risk Assessment and Risk management in EIA.
LCA
Life Cycle Assessment – Introduction, Integral Concepts, Inventory methods; LCA Impact Assessment.

EIA Notification by govt.of India and Case Studies
EIA procedure for environmental clearance, impact assessment report, evaluation of EIA report; Environmental Auditing – Concept of ISO and ISO 14000. Case studies and preparation of Environmental Impact assessment statements for various Industries – Renewable and Non-Renewable Energy projects – Coal power plant, Hydropower project, Solar EV project.

References

1.	*Black and Veatch, “Power Plant Engineering”, ISBN 0-412-06401-4, CBS Publishers and Distributors, Chapter 23424*
2.	*S. Rao & Dr. B. B. Parulekar, “Energy Technology”,3rd Edition, Khanna Publishers*

3.	*Samuel Glasstone and Alexander Sesonske "Nuclear Reactor Engineering" Third Edition*

Course Outcomes (CO)

At the end of the course students will be able to

CO1	Demonstrate an understanding of the principles, evolution, and methodologies of Environmental Impact Assessment.
CO2	Assess the environmental impact of air, noise, water, soil, and biological environment.
CO3	Apply economic measurement techniques and perform Life Cycle Assessments to evaluate and mitigate environmental impacts.
CO4	Develop EIA reports for various environmental projects.

Course Code	**:**	EN636
Course Title	**:**	SMART GRID SYSTEMS
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the importance of energy efficiency and sizing of convertors and invertors.
CLO2	To familiarize sizing of solar PV and wind energy systems.
CLO3	To learn the smart monitoring of energy using IEDs and smart devices.
CLO4	To illustrate the IoT devices functioning and operational methods.

Course Content

Evolution of Electric Grid
Concept- Definitions and Need for Smart Grid- Smart grid drivers- Functions- opportunities-challenges and benefits- Difference between conventional & Smart Grid- National and International Initiatives in Smart Grid.

Smart substations
Substation Automation- Feeder Automation – SCADA- Remote Terminal Unit- Intelligent Electronic Devices- Protocols, Phasor measurement Unit- Wide area monitoring protection and control, Smart integration of energy resources - Renewable, intermit power Sources

Transmission systems:
FACTS and HVDC- Distribution systems: DMS, Volt/ Var control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

Introduction to Smart Meters,
Advanced Metering Infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives. Elements of communication and networking.

Power Quality &
EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

References

1.	*Stuart Borlase "Smart Grid :Infrastructure, Technology and Solutions", CRC Press 2012.*
2.	*Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko*

	Yokoyama,"Smart Grid: Technology and Applications", Wiley 2012.
3.	*Vehbi C. Güngör, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, "Smart Grid Technologies: Communication Technologies and Standards" IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011*
4	*Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey" , IEEE Transaction on Smart Grids, vol. 14, 2012.*
5	*Fundamentals of Smart Grid Systems, By Muhammad Kamran · 2022.*
6	*Smart Grid Technology and Applications, By Janaka B. Ekanayake, Nick Jenkins, Kithsiri M. Liyanage, Jianzhong Wu, Akihiko Yokoyama · 2012.*
7.	*Smart Grids and Internet of Things An Energy Perspective 2023 Balamurugan Balamurugan Balusamy, Jens Bo Holm-Nielsen, Malathy Sathyamoorthy, Rajesh Kumar Dhanaraj, Sanjeevikumar Padmanaban*
8.	*EIoT The Development of the Energy Internet of Things in Energy Infrastructure By Steffi O. Muhanji, Alison E. Flint, Amro M. Farid · 2019*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To Distinguish conventional grid and smart grid.
CO2	To illustrate the substation automation and PMU for wide area monitoring.
CO3	To recognize AMI and AMI protocols.
CO4	To identify the power quality challenges in smart grid.

Course Code	**:**	EN637
Course Title	**:**	NUCLEAR REACTOR THEORY
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamentals of nuclear reactions and radioactivity
CLO2	Comprehend neutron transport and diffusion theories
CLO3	Analyze neutron moderation and absorption and its effect on reactor output
CLO4	Explore reactor kinetics and control mechanism for safe reactor operation in thermal and heterogenous reactors

Course Content

Radioactivity, Nuclear reactions, Cross sections, Nuclear fission, Power from fission, Conversion and breeding, Neutron transport equation, Diffusion theory approximation, Fick's law, Solutions to diffusion equation for point source, Planar source, etc. Energy loss in elastic collisions,

Collision and slowing down densities, Moderation in hydrogen, Lethargy concept, Moderation in heavy nucleus.

Moderation with absorption, Resonance absorption, NR and NRIM approximations. Multi-region reactors, Multigroup diffusion methods, Thermal reactors, Heterogeneous reactors.

Reactor kinetics in hour equation, Coefficients of reactivity, Control, Fission product poison, Perturbation theory.

Advances and Development in Nuclear reactors.

References

1.	*Serge Marguet, The Physics of Nuclear Reactors, Springer, 2017*
2.	*J.R. Lamarsh, Introduction to Nuclear Reactor Theory, Wesley, 1966*
3.	*Elmer E Lewis, Fundamentals of Nuclear Reactor Physics, Elsevier, 2008*
4.	*J.J. Duderstadt and L.J. Hamilton, Nuclear Reactor Analysis, John Wiley, 1976*
5.	*Hiroshi Sekimoto, “Nuclear Reactor Theory”, COE-INES Tokyo Institute of Technology, 2007*
6.	*G. I. Bell, S. Glasstone, “Nuclear Reactor Theory”, Van Nostrand Reinhold Company, 1970*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain in detail the nuclear reactions and fission processes taking place in a nuclear reactor
CO2	Apply neutron transport and diffusion theories to solve the diffusion equation for various source configurations and to understand energy loss in elastic collisions
CO3	Apply concepts of neutron moderation and absorption phenomena foe energy approximations
CO4	Apply concepts of reactor kinetics, control strategies to reactor design calculations for multi-region and multi-group diffusion in thermal and heterogenous reactors

Course Code	**:**	EN638
Course Title	**:**	OPTIMIZATION TECHNIQUES
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamentals of process optimization
CLO2	Learn optimization techniques for one-dimensional functions
CLO3	Explore unconstrained and constrained multi-variable optimization
CLO4	Apply optimization methods to complex processes using optimization techniques such as dynamic programming, and mixed-integer programming and advanced optimization techniques

Course Content

Introduction to Process Optimization; Formulation of Various Process Optimization Problems and their classification.

Basic Concepts of Optimization-Convex and Concave Functions, Necessary and sufficient conditions for Stationary Points; Optimization of one-dimensional Functions.

Unconstrained Multivariable Optimization- Direct Search Methods. Indirect First Order and Second Order Methods; Linear Programming and its Applications.

Constrained Multivariable Optimization-Necessary and Sufficient Conditions for Constrained Optimum, Quadratic Programming, Generalized Reduced Gradient Method, Successive Linear and Quadratic Programming, Optimization of Staged and Discrete Processes, Dynamic Programming, Integer and Mixed Integer Programming.

Advanced Optimization Techniques.

References

1.	*S.Singh, S.Dalal, Optimization Techniques and Associated Applications, CRC press, 2025.*
2.	*T.F. Edgar and D.M. Himmelblau, Optimization of Chemical Processes, McGraw Hill International Editions, Chemical Engineering Series (1989)*
3.	*G.S. Beveridge and R.S. Schechter, Optimization Theory and Practice, McGraw Hill, New York 1970*
4.	*G.V. Rekllaitis, A. Ravindran, and K.M. Ragsdell, "Engineering Optimization-Methods and Applications", John Wiley, New York (1983)*
5.	*P. R. Adby, M. A. H. Dempster, "Introduction to Optimization Methods", Springer, 1970*
6.	*Andreas Antoniou and Wu-Sheng Lu; Practical Optimization: Algorithms and Engineering Applications; Springer, 2007*
7.	*S. S. Rao; Engineering Optimization: Theory and Practice; 4th Ed., John Wiley and Sons, 2009*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Formulate and classify optimization problem based on its characteristics using the concepts and properties of concave and convex functions
CO2	Perform optimization calculations for one-dimensional functions by applying necessary and sufficient conditions using appropriate optimization technique.
CO3	Solve unconstrained and constrained optimization problems by applying concepts of search methods, linear programing, and quadratic programming
CO4	Perform optimization of staged and discrete engineering processes using advanced optimization techniques such as dynamic programming.

Course Code	**:**	EN639
Course Title	**:**	POWER SOURCES FOR ELECTRIC VEHICLES
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the primary energy sources and secondary energy sources used for transportation.
CLO2	To learn the principles and operation of Aqueous Electrolyte Batteries and Non Aqueous Electrolyte Batteries.
CLO3	To learn the performance of batteries and fuel cell.
CLO4	To learn the differences between Combustion Engine, electric vehicle and Hybrid Electric Vehicles

Course Content

The Electric Vehicle Debate, Primary Energy Sources and Alternative Fuels for Transportation, History of Electric Vehicles, Electrochemical Power Sources – Secondary

Batteries and Fuel Cells Sources- Aqueous Electrolyte Batteries –Lead Acid, Nickel – Iron, Nickel – Zinc, Metal – Air Zinc – Halogen Non Aqueous Electrolyte Batteries- High Temperature Batteries, Organo Electrolyte and
Solid State Batteries

Overview of Performances of Candidate Secondary Battery Systems-Fuel Cells – Acid Systems, Direct Methanol / Air Systems, Alkaline Systems-Overview of Performances of candidate Fuel Cell Systems, Battery / Fuel cell / Internal

.Combustion Engine, Hybrid Electric Vehicles, Laboratory Test of Electric Vehicle Batteries, Vehicle tests with Electric Vehicle Batteries, Future of Electric Vehicles

References

1.	*Power Sources for Electric Vehicles, Edited by B.D. McNicol and D.A.J. Rand, ElsevierPublications.1998Lithium Batteries for Hybrid Cars By John Voelcker, IEEE Spectrum, 1990.*
2.	*Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas.B. Reddy, McGraw Hill Book Company, N.Y. 2002.*
3.	*Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M,Universities Press, 2006.*

4	*The Essential Hybrid Car Handbook: A Buyer's Guide (Paperback) by Nick Yost, TheLyons Press, N.Y. 2006.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To summarizes the primary energy sources and secondary energy sources.
CO2	To explain the principles and operation of Aqueous Electrolyte Batteries and Non-Aqueous Electrolyte Batteries.
CO3	To analyze the performance of batteries and fuel cell.
CO4	To distinguish Combustion Engine and electric vehicles.

Course Code	**:**	EN640
Course Title	**:**	IPR, STARTUP AND ENTREPRENEURSHIP
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn types of IPR and Concept Of Entrepreneurship.
CLO2	To learn methodology of project identification.
CLO3	To learn sale strategies, implement business ethics, and utilize knowledge management.
CLO4	To learn Accounting Principles-Accounting principles - conventions and concepts

Course Content

Introduction to IPR and Types of IPR

Concept Of Entrepreneurship-Definition and concept of enterprising - profile of an entrepreneur - need scope and characteristics of entrepreneurs

Project Identification-Methodology of project identification - short listing and zeroing on product/service - problems in project evaluation

Marketing-Market share - distribution - sale strategies - certification agencies - term finance -source and management working capital

Assistance To Entrepreneur-Small industries development in India and its concept - ancillary industries - starting a small scale industry

Accounting Principles-Accounting principles - conventions and concepts - balance sheet - profit and loss account - accounting rate of return, pay back period, SSI duty practice.

References

1.	*Wright, Peter, Kroll, Mark J. and Parnell, John A: Strategic Management Concepts andCases, Prentice – Hall, N. J. 1996.*
2.	*Coates, V.T.:"A Handbook of Technology Assessment", U.S. Department of Energy,Washington D.C., 1988.*
3.	*Ayres, Robert U: "Technologies forecasting and Long Range planning".*
4.	*Intellectual Property Protection in India: A Practical Guide for Scientists, Technologies and Other Users, Delhi, TIFAC / CSIR, 1993.*
5.	*H. Ansoff "Implementing Strategic Management" by Englewood Cliffs, New Jersey*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To understand IPR and Concept Of Entrepreneurship.
CO2	To implement methodology of project identification.
CO3	To apply sale strategies, implement business ethics, and utilize knowledge management.
CO4	To apply Accounting Principles-Accounting principles - conventions and concepts

Course Code	**:**	EN641
Course Title	**:**	CARBON SEQUESTRATION TECHNIQUES
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Get an overview of importance of carbon abatement and its impacts
CLO2	Understand the various carbon sequestration technologies
CLO3	Detailed comparison of CO_2 removal technologies
CLO4	Gain an overview on carbon reduction systems, carbon taxes and carbon credit

Course Content

Introduction to Negative Emissions; Paris climate summit on limiting average global temperature rise; Future projected concentration of Carbon dioxide (CO_2) in atmosphere and consequences of Climate change and global warming; Carbon budget; Overview of CO_2 emission from industrial sectors, transport sectors, power generating sectors.

Formation mechanism of CO_2 emission in combustion engines; Radiative forcing of climate change; Global warming potential (GWP); Stabilization of CO_2 emission in the atmosphere by renewable energy systems; Renewable energy system with carbon sequestration technologies.

Different methods / technologies of Carbon dioxide removal from the atmosphere: Ocean Liming; Enhanced Weathering; Ocean Fertilization; Forestation; Soil Carbon Management; Direct Air Capture; Artificial trees; Bioenergy with Carbon Capture & Storage; Pyrolysis process and Biochar;

CO2 emission reduction through Energy efficiency improvement in energy devices / power plants**;** Integration of different renewable energy systems (solar photo-voltaic, solar thermal, wind, bioenergy, geothermal, tidal) with the carbon sequestration technologies.

Analysis of energy intensity of carbon dioxide removal system; Different scenario of CO2 emission reduction; Exploration of possible Sequestration of CO2 at source level in industries; Issues and control measures of CO2 removal system; Carbon tax and credit; Case studies

References

1.	*Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, The National Academies Press, (2018).*
2.	*Pachauri R. K. and Meyer L., Climate Change 2014 Synthesis Report, IPCC (2018).*
3.	*Dincer I. and Zamfirescu C., Sustainable Energy Systems and Applications, Springer (2011).*

4.	*Ryan B. and Anderson D., Carbon Sequestration: Technology, Measurement Techniques, and Environmental Effects, Nova Publishers (2012)*
5.	*Goel M., Sudhakar M., Shahi R., Carbon Capture Storage and Utilization, TERI Press (2014)*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Give an overview of importance of carbon abatement and its impacts
CO2	Explain different carbon sequestration techniques
CO3	Compare various CO_2 removal technologies
CO4	Choose carbon reduction systems based on carbon taxes and carbon credits

Course Code	**:**	EN642
Course Title	**:**	DESIGN OF HEAT TRANSFER EQUIPMENT
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Develop understanding of different design methodologies and fundamentals of heat transfer equipment design
CLO2	Analyse and design various types of heat transfer equipment such as shell and tube heat exchangers, double pipe heat exchangers, etc.
CLO3	Apply concepts of extended surfaces and compact heat exchangers
CLO4	Evaluate and select different heat exchanger configurations according to various applications

Course Content

Types – Details – Specifications for heat exchangers – Standards of heat exchangers Study of different methods used for design of heat exchangers, classification, design methodology, LMTD and NTU methods.

Design of double pipe heat exchanger-study and performance - Design of shell and tube heat exchanger. Air preheaters and economizers.

Extended surfaces, fin design, longitudinal and transverse fins.

Regenerators - Plate type heat exchangers - Compact heat exchangers- Cross flow heat exchangers

References

1.	*D. G. Kern: “Process Heat Transfer,” McGraw-Hill Book Co., N.Y. 1997.*
2.	*W.L. McCabe, J.C. Smith, P. Harriott, “Unit Operations of Chemical Engineering Sixth Edition, McGraw Hill Company, 2001.*
3.	*M. Necati Ozisik “Heat Transfer A Basic Approach”, International Edition, McGraw Hill Company, 1985*
4.	*S. Kakac, A.E.Bergles, F.Maylinger: “Heat Exchangers: Thermal, Hydraulic Fundamentals and Design”, McGraw Hill Company, 1982*
5.	*J.P. Gupta: “Heat Exchanger Design: A Practical Look”, C.S. Enterprises, 1979*
6.	*A Heat Transfer Textbook, by J.H. Lienhard IV and J.H. Lienhard V, Phlogiston Press, Cambridge, Massachusetts, 2005*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Elaborate on fundamentals of heat transfer equipment design
CO2	Perform the sizing calculations for the equipment by analyzing the system thermal behavior
CO3	Design heat exchanger for a given application considering the particular purpose and standards

Course Code	**:**	EN643
Course Title	**:**	WASTE MANAGEMENT AND ENERGY GENERATION TECHNOLOGY
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To teach the different types of waste, their characterization and collection strategies
CLO2	To know more on handling Medical and Industrial waste and EIA
CLO3	To give a detailed hazardous waste management and associated techniques
CLO4	To present a overview agro-residue conversion techniques and its environmental benefits.

Course Content

Sources, Types, Compositions, Properties Physical, Chemical and Biological - Collection - Transfer Stations – Waste minimization and recycling of Municipal Waste.

Size Reduction - Aerobic Composting - Incineration for Medical /Pharmaceutical Waste - Environmental Impacts -Environmental Effects due to Incineration.

Land Fill Method- Types, Methods & Siting Consideration - Composition, Characteristics, generation, Control of Landfill Leachate & Gases – Environmental monitoring System for Land Fill Gases.

Sources and Nature of Hazardous Waste - Impact on Environment - Hazardous Waste - Disposal of Hazardous Waste, Underground Storage Tanks Construction, Installation & Closure

Biochemical Conversion - Industrial, Agro Residues - Anaerobic Digestion – Biogas Production Types of Biogas Plant-Thermochemical Conversion -Gasification - Types – Briquetting Industrial Applications of Gasifiers - Environment Benefits

References

1.	*Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, PrinticeHall, 2000*
2.	*Parker, Colin, & Roberts, Energy from Waste - An Evaluation of ConversionTechnologies, Elsevier Applied Science, London, 1985*
3.	*Syed E Hasan, Introduction To Waste Management - A Textbook, Wiley-Blackwell; 1st edition (1 September 2022)*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain and understand about different types and characterization of waste
CO2	To apply strategies to collect and handle bio-medical waste and MSW
CO3	To demonstrate knowledge hazardous waste management
CO4	To do detailed studies agro-residue based conversion techniques and its environmental assessment.

Course Code	**:**	EN644
Course Title	**:**	BLOCKCHAIN TECHNOLOGIES
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamental concepts and technologies behind blockchain and its cryptographic foundations.
CLO2	Explore the functionalities and scripting capabilities of Bitcoin Blockchain and its applications.
CLO3	Develop and deploy decentralized applications (DApps) on Ethereum and understand the scaling solutions.
CLO4	Analyze the use of blockchain in various sectors including e-governance, and learn about Hyperledger Fabric and its implementations.

Course Content

Basics of Blockchain Technology, how it is changing the landscape of digitalization, introduction to cryptographic concepts required, Hashing, public key cryptosystems, private vs public blockchain and use cases, Hash Puzzles.

Introduction to Bitcoin Blockchain, Bitcoin Blockchain and scripts, Use cases of Bitcoin Blockchain scripting language in micropayment, escrow etc. Downside of Bitcoin – mining .

Building Ethereum Applications, Enterprise Ethereum, DApp development, DApp example, advanced development, Scaling Ethereum: State channels, and Sidechains and Serenity

Decentralized Identity Management, Uses of Blockchain in E-Governance, Land Registration, Medical Information Systems, and others, Hyperledger Fabric, Hyperledger Powered Project, Capstone Project.

References

1.	*Daniel Drescher, “Blockchain Basics: A Non-Technical Introduction in 25 Steps”, Apress, 2017.*
2.	*Arshdeep Bahga and Vijay Madisetti, "Blockchain Technology and Applications", VPT, 2017.*
3.	*Andreas M. Antonopoulos and Gavin Wood, "Mastering Ethereum: Building Smart Contracts and DApps", O'Reilly Media, 2018.*
4.	*Jai Singh Arun, Jerry Cuomo, and Nitin Gaur, "Blockchain for Business: A Hands-On Guide to Developing, Implementing, and Monitoring Blockchain Applications", Pearson Education, 2019.*
5.	*Ashwani Kumar, "Hyperledger Fabric In-Depth: Learn, Build, and Deploy Blockchain Applications Using Hyperledger Fabric", BPB Publications, 2020.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand the core concepts and cryptographic foundations of blockchain technology.
CO2	Gain practical experience with Bitcoin Blockchain and its scripting applications.
CO3	Develop and deploy Ethereum-based decentralized applications (DApps).
CO4	Apply blockchain technology to various sectors, including identity management and e-governance, through a capstone project.

Course Code	**:**	EN645
Course Title	**:**	HEAT AND MASS TRANSFER
Type of Course	**:**	PE
Prerequisites	**:**	Nil
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand and explain the fundamental modes of heat transfer (conduction, convection, and radiation) and the governing laws for each.
CLO2	Analyze and solve steady and unsteady heat conduction problems in various geometries using analytical and approximate methods.
CLO3	Apply heat and mass transfer principles to practical energy engineering systems
CLO4	Interpret and evaluate mass transfer phenomena and combined heat and mass transfer processes

Course Content

Introduction to Heat Transfer, Modes of heat transfer: conduction, convection, and radiation.

Conduction, One-dimensional and multi-dimensional conduction, Steady and unsteady state, Thermal resistance and insulation.

Convection, Natural and forced convection, Heat transfer in laminar and turbulent flows, Heat exchangers.

Radiation, Basic radiation laws, Blackbody and gray body concepts.

Mass transfer: Basic concepts and types of mass transfer, Diffusion and convective mass transfer, Mass transfer across.

References

1.	*Sachdeva R.C,. Principles of Heat and Mass Transfer, New Age International Publishers (2017)*
2.	*D.S. Kumar. Fundamentals of Heat and Mass Transfer, S.K. Kataria & Sons (2013)*
3.	*J.P.Holman, A Textbook on Heat and Mass Transfer, Tata McGraw Hill (2020)*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Analyze heat conduction problems in various geometries and apply appropriate boundary conditions and solution techniques.
CO2	Evaluate convective heat transfer in both natural and forced convection systems, including laminar and turbulent flows.
CO3	Apply radiation heat transfer principles to calculate heat exchange between surfaces and understand radiation shielding.
CO4	Solve basic mass transfer problems involving diffusion and convection, and analyze combined heat and mass transfer scenarios relevant to energy systems.

MICROCREDITS (MC)

Course Code	**:**	EN680
Course Title	**:**	BUIDLING ENERGY MANAGEMENT USING IoT
Type of Course	**:**	Micro Credit
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn Energy Management and Conservation techniques in Buildings.
CLO2	To learn Concepts of IoT and Communication Technologies related to IoT.

Course Content

Energy Management in Buildings
Fundamentals, Types of energy sources used in Building, Significance of Thermal Comfort, IoT in building design.

IoT-Introduction:
IoT Devices and Applications in Buildings, Communication Technologies related to IoT, Energy Efficiency through IoT.

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain Energy Management and Energy Conservation strategies in Buildings.
CO2	To illustrate concepts of IoT and communication technologies related to IoT.

Course Code	**:**	EN681
Course Title	**:**	CARBON MARKETS
Type of Course	**:**	Micro Credit (MC)
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the concept of carbon markets and their role in climate change mitigation strategies.
CLO2	Analyze the different types of carbon markets (cap-and-trade, carbon offsets) and their respective functionalities.
CLO3	Evaluate the economic and environmental effectiveness of carbon pricing mechanisms.
CLO4	Critically assess the challenges and opportunities associated with carbon markets in the global context.

Course Content

Introduction to carbon markets:
Climate Change and Carbon Emissions, Carbon Pricing as a policy tool, Fundamentals of carbon markets, History and evolution of carbon markets, Types of carbon markets: Compliance markets and voluntary markets, Key terminologies: Carbon credits, carbon offsets, cap-and-trade

Types and Mechanisms of Carbon Markets:
Cap-and-trade systems: Design and implementation, Carbon offset projects: types, development mechanisms, carbon credits, verification and validation processes, and certification, Clean Development Mechanism (CDM) and Joint Implementation (JI), Market-based instruments: Carbon taxes vs. carbon trading
Global Carbon Market Structures and Their Effectiveness:
Major carbon markets: EU Emissions Trading System (EU ETS), California Cap-and-Trade Program, Regional Greenhouse Gas Initiative (RGGI); Emerging carbon markets: China, India, and other regions; Role of international organizations: UNFCCC, World Bank, and others; Challenges and opportunities in global carbon markets;

Ensuring Equity and Transparency: Considerations for developing countries and ensuring transparency in carbon market transactions

The Future of Carbon Markets:
Linking Carbon Markets: Importance of international cooperation and harmonization of carbon pricing mechanisms; Emerging Trends: Role of technology in carbon market monitoring, verification, and market development; The Role of Carbon Markets in Energy Transition: Promoting clean energy investments and accelerating decarbonization

References

1.	*G. Bryant, Carbon Markets in a Climate-Changing Capitalism, Cambridge University Press, 2019*
2.	*G. Singh, Understanding Carbon Credits, Aditya Books Pvt. Ltd., 2009*
3.	*S. Rudolph, E. Aydos, Carbon Markets Around the Globe: Sustainability and Political Feasibility, Edward Elgar Publishing, 2021*
4.	*F. Yamin, Climate Change and Carbon Markets A Handbook of Emissions Reduction Mechanisms, 1st Edition, Routledge (Taylor and Francis), 2005*
5.	*A. Brohe, N. Eyre, N. Howarth, Carbon Markets: An International Business Guide, Earthscan Publishing, 2009*
6.	*G. Dufrasne, Carbon Markets 101: The Ultimate Guide to Global Offsetting Mechanisms, 2nd Edition, Carbon Market Watch, 2020*
7.	*C. Streck, M. Dyck, D. Trouwloon, The Voluntary Carbon Market Explained, VCM Primer, 2021*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the fundamental principles and functionalities of carbon markets in addressing climate change.
CO2	Differentiate between various types of carbon markets and their applicability in different contexts.
CO3	Critically analyze the effectiveness of carbon pricing mechanisms in driving emissions reduction and economic efficiency.
CO4	Identify and discuss the challenges and opportunities associated with carbon markets in the transition towards a low-carbon future.

Course Code	**:**	EN682
Course Title	**:**	CARBON CAPTURE AND UTILIZATION, SEQUESTRATION
Type of Course	**:**	MC
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the need for CCUS technologies in mitigating climate change and achieving net-zero emissions goals.
CLO2	Analyze the different methods for capturing CO_2 emissions from power plants and industrial facilities.
CLO3	Evaluate the potential applications of captured CO_2 for utilization in various sectors and their environmental benefits.
CLO4	Critically assess the geological considerations and safety aspects of CO_2 sequestration for long-term storage.

Course Content

Introduction to CCUS and Climate Change:
The Urgency of Climate Action, Rising CO_2 emissions, limitations of renewable energy penetration alone, and the role of CCUS in achieving net-zero; Overview of CCUS chain, potential applications, and economic considerations, Role of government policies and carbon pricing in promoting CCUS technologies.

CO_2 Capture Technologies:
Pre-combustion capture (oxy-fuel combustion, integrated gasification combined cycle); post-combustion capture (amine scrubbing, membrane separation); Oxy-fuel technology and its advantages for high capture efficiency; Techno-economic analysis and selection of capture technologies for specific applications

CO_2 Utilization Pathways:
Enhanced oil recovery (EOL) in crude oil production; conversion of CO_2 into fuels (synthetic methane, methanol, etc.) and chemicals (plastics, fertilizers, etc.); Mineralization of CO_2 for permanent storage in form of stable carbonites; LCA of different utilization pathways.

CO_2 Sequestration and Safety:
Geological formations suitable for CO_2 storage: Site selection and characterization for safe and permanent CO_2 storage, monitoring and verification techniques to ensure secure storage with no leaks, Environmental considerations and potential risks associated with CO_2 sequestration.

References

1.	*M. Goel, M. Sudhakar, R V Shahi; Carbon Capture, Storage and Utilization: a possible climate change solution for energy industry; TERI Press; 2014*
2.	*J. Wilcox; Carbon Capture, 1st Edition, Springer New York Publishers, 2012*
3.	*H. J. Herzog; Carbon Capture, The MIT Press, 2018*
4.	*M. G. Faure, R. A. Partain; Carbon Capture and Storage: Efficient Legal Policies for Risk Governance and Compensation; The MIT Press, 2017*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Explain the importance of CCUS technologies as a mitigation strategy for climate change and achieving net-zero emissions.
CO2	Analyse the technical and economic feasibility of different CO2 capture methods for various emission sources.
CO3	Evaluate the environmental and economic benefits of CO2 utilization options compared to long-term storage.
CO4	Critically assess the geological suitability and safety considerations for CO2 sequestration as a permanent storage solution

Course Code	**:**	EN683
Course Title	**:**	LIFE CYCLE ASSESSMENT
Type of Course	**:**	MC
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students with LCA and the make them understand the need of LCA
CLO2	To provide methodology and inventory details to carry out and interpret the results obtained.

Course Content

Introduction to LCA; integral concepts; Life cycle inventory methods; stages and databases for generation and usage periods; raw materials, energy, transportation, production; production, use, end of life, recycling; impact assessment categories; – carbon foot printing, global warming; fossil fuel depletion , acidification, eutrophication, ozone, respiratory effects , ecotoxicity, land use, resource depletion; energy, water foot printing; uncertainty; social and consequential LCA; Product Declarations and Environmental Labeling.

References

1.	*Mary Ann Curran, Life Cycle Assessment Handbook [electronic resource]: A Guide for Environmentally Sustainable Products), First Edition, Wiley-Scrivener [Imprint] Oct. 2012 Hoboken : John Wiley & Sons, Inc*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To articulate the value of LCA and Outline the steps to conduct an attributional LCA.
CO2	To Conduct a life cycle assessment and interpret, critique, and communicate LCA results.

Course Code	**:**	EN684
Course Title	**:**	DECARBONISATION OF INDUSTRY
Type of Course	**:**	MC
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Familiarize students with the major carbon emitting sectors, current practices in use and quantum of emissions; focus will be on hard to decarbonise sectors
CLO2	Introduce the major decarbonisation technologies and their synergies between CCS and process industries.

Course Content

Introduction to major carbon emitting sectors – agriculture, power generation, cement, iron & steel making, chemicals and plastics and transportation; current practices and quantum of emissions from these activities with special focus on hard to decarbonise sectors. Major decarbonisation technologies - Rudimentary aspects of electrification including storage, efficiency enhancement, use of hydrogen, biomass and other low-carbon feed stock alternatives, and carbon capture, utilization and storage. Discussion of application of these methods to decarbonisation. Hydrogen and biomass - conventional and new low carbon sources of hydrogen. Strategies for introduction of hydrogen in cement, iron & steel making. Carbon capture, utilization and storage - post and pre-combustion capture, oxy-fuel combustion, direct air capture; absorption, adsorption and mineral carbonation processes for CO_2 capture; associated energy penalty; emerging technologies and their potential for deployment; synergies between CCS and cement and iron & steel industries. Basics of CO_2 utilization for synthesis of fuels and chemicals; basics of CO_2 storage

References

1.	*RACKLEY, Stephen A. "Carbon capture and storage. Stephen A. Rackley." (2010).*
2.	*Ramanathan, V., Aines, R., Auffhammer, M., Barth, M., Cole, J., Forman, F., & Zaelke, D. Bending the curve: Climate change solutions. (2019).*
3.	*Smil, Vaclav. Power density: a key to understanding energy sources and uses. MIT press, 2015.*
4.	*Gates, Bill. How to avoid a climate disaster: the solutions we have and the breakthroughs we need. Knopf, 2021*
5.	*Qingxu J., Xue C., Fan S., Shekhawat D. Industrial Decarbonisation: Materials, Methods, and Developments. CRC Press, 2025*
6.	*Sudaramurthy S., Sundaresan S., Swain S. Industrial Decarbonization and the Energy Transition: Innovative Solutions for a Carbon-Free, Sustainable, and Clean Environment. Elsevier, 2025*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Elucidate the rudimentary aspects of carbon cycle, greenhouse gas driven global warming and climate change and need for decarbonisation technologies in industries
CO2	Elaborate on various major decarbonisation technologies
CO3	Suggest and practice decarbonisation strategies possible in the industries through methodical approaches.

Course Code	**:**	EN685
Course Title	:	SAFETY MANAGEMENT IN ELECTRICAL VEHICLES
Type of Course	**:**	MC
Prerequisites	**:**	Nil
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Familiarize students with the Electric vehicle safety standards
CLO2	Introduce various safety aspects related to EV and procedures to test and certify EV safety

Course Content

Battery Safety Standards; Thermal management systems; Battery fire and explosion prevention; Crash Safety; Structural integrity of EVs in collisions; Impact of battery placement on crashworthiness; Emergency Response; Training for first responders on handling EV accidents; Guidelines for dealing with EV fires; Charging Safety; Safety standards for home and public charging stations; Protocols for safe charging practices Electrical Safety; Insulation and protection of high-voltage components; Prevention of electrical shock and short circuits; Autonomous Driving Safety; Safety regulations for self-driving EVs; Impact of autonomous technology on accident rates; Safety Testing and Certification; Procedures for testing EV safety.

References

1.	*Chris Mi; M. Abul Masrur & David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, Wiley, 2011*
2.	*James Larminie and John Lowry, Electric Vehicle Technology, Wiley, 2012.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To explain the safety standards and management strategies of EV
CO2	To be familiar with testing and certification procedures of EV

Course Code	**:**	EN686
Course Title	**:**	INTRODUCTION TO BLOCKCHAIN
Type of Course	**:**	Microcredit
Prerequisites	**:**	NIL
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamental concepts and technologies behind blockchain and its cryptographic foundations.
CLO2	Explore the functionalities and scripting capabilities of Bitcoin Blockchain and its applications.

Course Content

Basics of Blockchain Technology, how it is changing the landscape of digitalization, introduction to cryptographic concepts required, Hashing, public key cryptosystems, private vs public blockchain and use cases, Hash Puzzles.

Introduction to Bitcoin Blockchain, Bitcoin Blockchain and scripts, Use cases of Bitcoin Blockchain scripting language in micropayment, escrow etc. Downside of Bitcoin – mining .

References

1.	*Daniel Drescher, "Blockchain Basics: A Non-Technical Introduction in 25 Steps", Apress, 2017.*
2.	*Arshdeep Bahga and Vijay Madisetti, "Blockchain Technology and Applications", VPT, 2017.*
3.	*Andreas M. Antonopoulos and Gavin Wood, "Mastering Ethereum: Building Smart Contracts and DApps", O'Reilly Media, 2018.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand the core concepts and cryptographic foundations of blockchain technology.
CO2	Gain practical experience with Bitcoin Blockchain and its scripting applications.

Course Code	:	EN687
Course Title	:	DIGITAL TWIN
Type of Course	:	PE
Prerequisites	:	NIL
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamental concepts and types of digital twins and their applications.
CLO2	Explore the computational tools and techniques used in developing digital twins, including physics-based and data-driven approaches.
CLO3	Learn advanced methods for digital twin implementation, such as Bayesian methods and multi-fidelity data integration.
CLO4	Investigate the role of deep learning in digital twin technology and identify future challenges and solutions.

Course Content

Introduction to Digital Twin, Types – Asset Twins, Component Twins, System Twins, Process Twins, Benefits and Applications of it. Computational tools in science and technology, from computational techniques to digital twins, Different tools in digital twin, Physics-based digital twin in dynamical systems - solution of ODEs and PDEs, Time-domain simulation of dynamical systems.

Digital twin for dynamical systems - frequency domain analysis, Digital twin for dynamical systems - time domain analysis, Data-driven digital twins.

Bayesian methods in digital twin technology – Kalman filter based approaches. Digital twin for multi-timescale dynamical systems - Mixture of Gaussian Process and Expectation maximization.

Digital twin from multi-fidelity data. Digital twin for systems with partially known physics. Deep learning in digital twin technology - GANS and VAEs. Way forward - challenges and possible wayouts.

References

1.	*Iserles, A. (2009). A first course in the numerical analysis of differential equations (No. 44). Cambridge university press.*
2.	*Rajesh Singh, Anita Gehlot, Bhupendra Singh, and Mahesh Bundele, "Digital Twin: Fundamental Concepts to Applications in Advanced Manufacturing", Wiley, 2022.*
3.	*Bishop, C.M. Pattern recognition and Machine learning, Springer, 2007.*
4.	*Murphy, K.P. Machine learning: A Probabilistic Perspective, MIT press, 2012.*
5.	*C. E. Rasmussen & C. K. I. Williams, Gaussian Processes for Machine Learning, MIT Press, 2006 (a free ebook is also available from the Gaussian Processes web site).*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Gain a comprehensive understanding of digital twin technology, its types, and benefits.
CO2	Develop proficiency in using computational tools and techniques for creating digital twins.
CO3	Apply advanced methods, including Bayesian approaches and multi-fidelity data integration, in digital twin development.
CO4	Utilize deep learning techniques in digital twin applications and understand the challenges and future directions in the field.

Course Code	**:**	EN688
Course Title	**:**	ENERGY ECONOMICS
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamental concepts and types of digital twins and their applications.
CLO2	Explore the computational tools and techniques used in developing digital twins, including physics-based and data-driven approaches.
CLO3	Learn advanced methods for digital twin implementation, such as Bayesian methods and multi-fidelity data integration.
CLO4	Investigate the role of deep learning in digital twin technology and identify future challenges and solutions.

Course Content

Review of the Basics of Supply, Demand and Price Formation in Competitive Markets, Energy Demand: Short Run and Long Run Price and Income Elasticities Energy Supply and the Economics of Depletable Resources, World Oil Markets and Energy Security

References

1.	*Pindyck, R., and D. Rubinfeld. Microeconomics. 6th ed. Upper Saddle River, NJ: Prentice Hall, 2005. ISBN: 0130084611.*
2.	*Stevens, P. An Introductionto Energy Economics. In Stevens, P.(ed.) The Economics of Energy, Vol.1, Edward Elgar, Cheltenham, UK. 2000*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand the basics of energy markets
CO2	Understand the energy demand, world oil markets, and energy security

Course Code	**:**	EN689
Course Title	**:**	ENERGY MARKETS AND CARBON TRADING
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide foundational understanding of energy market structures and pricing mechanisms in renewable and non-renewable sectors.
CLO2	To analyze causes of fluctuations in energy markets at national and international levels.
CLO3	To explain carbon trading mechanisms, including carbon credits and market instruments.
CLO4	To develop knowledge about the legal, regulatory, and governance frameworks related to energy markets and carbon trading.

Course Content

Energy Markets
Energy Markets Overview – Definitions, structure of energy markets - Key players, market clearing mechanisms - Differences in cost structures: renewable vs non-renewable energy economics - Energy Markets in India and Globally - Indian Energy Market: CERC, IEX, open access, RECs, UDAY, RPO - Global Market Trends: OPEC, LNG trade, RE integration, global price indexes - Price Fluctuations and Energy Transition Tools - Drivers of price fluctuations: fuel supply shocks, geopolitical risks, policy incentives - Levelized Cost of Energy (LCOE), externalities, subsidies, energy transition pathways.

Carbon Trading and Carbon Credit Mechanisms
Carbon Credit Fundamentals and CDM - Carbon Credit basics - Clean Development Mechanism (CDM) project cycle: Additionality, baselines, validation, MRV cycle - Scope of carbon trading: renewable energy, afforestation, waste-to-energy - International Carbon Market Frameworks - Kyoto Protocol, Paris Agreement, Article 6 mechanisms – Cap and Trade vs Carbon Tax: Market-based vs command-control approaches, real-world examples - Legal and Regulatory Aspects of Carbon Trading - Contractual risks, verification bodies, international vs domestic law - Indian Case Studies: Perform Achieve Trade (PAT), Indian voluntary carbon market trends, success/failure stories

References

1.	*Massimo Filippini & Suchita Srinivasan (2024), An Introduction to Energy Economics and Policy, Cambridge University Press.*
2.	*Subhes C. Bhattacharyya (2011), Energy Economics: Concepts, Issues, Markets and Governance, Springer.*
3.	*Thomas Tietenberg & Lynne Lewis (2023), Environmental and Natural Resource Economics, Routledge. ISBN: 978-1032101187*
4.	*Gurmit Singh (2009), Understanding Carbon Credits, Aditya Books Pvt. Ltd. ISBN:*

	978-8185353616
5.	*Scott D. Deatherage (2011), Carbon Trading Law and Practice, Oxford University Press. ISBN: 978-0199732210*
6.	*David Freestone & Charlotte Streck (2009), Legal Aspects of Carbon Trading, Oxford University Press. ISBN: 978-0199565931*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand the structure and dynamics of energy markets across renewable and non-renewable sectors, nationally and globally.
CO2	Analyze the causes of energy price fluctuations and their impact on market mechanisms.
CO3	Gain practical insight into carbon credit generation and trading under CDM and other mechanisms.
CO4	Understand the legal, policy, and governance frameworks governing carbon markets.

Course Code	**:**	EN690
Course Title	**:**	Solar PV systems – ON/OFF Grid
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	12
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Familiarize students with the PV cell operation and characteristics
CLO2	Familiarize students with the grid connected and standalone system designs

Course Content

Operation of PV cell, Characteristics of PV cell, MPPT Techniques, PV System to DC loads and AC loads-stand alone mode, PV System to grid, Power conditioning devices, Design of solar inverter, Design of DC-DC convertors, Sizing of the batteries

References

1.	*Peter Gevorkian, Large-Scale Solar Power System Design: An Engineering Guide for Grid-Connected Solar Power Generation, 2011 The McGraw-Hill Companies, Inc.*
2.	*Geoff Stapleton, Susan Neill, Grid-connected Solar Electric Systems The Earthscan Expert Handbook for Planning, Design and Installation, Routledge Home*
3.	*Chetan Singh Solanki, Solar Photovoltaics : Fundamentals, Technologies and applications, PHI Learning Pvt. Ltd.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	To illustrate working and operation of solar PV cell
CO2	To design grid connected and stand alone PV System