ANNA UNIVERSITY, CHENNAI

NON- AUTONOMOUS COLLEGES

AFFILIATED TO ANNA UNIVERSITY

M.E. ENERGY ENGINEERING

REGULATIONS 2025

PROGRAMME OUTCOMES (POs):

PO	Programme Outcomes
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 over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PROGRAMME SPECIFIC OUTCOMES (PSOS)

PSO	Programme Specific Outcomes
PSO1	Demonstrate versatility in using modern tools, software, and techniques for improving the efficiency of energy systems, and managing projects effectively from both technical and financial perspectives.
PSO2	Design and develop energy products and processes with environmental consciousness and sustainability, while working independently or in teams, fostering lifelong learning, industry collaboration, and professional ethics.

ANNA UNIVERSITY, CHENNAI

POSTGRADUATE CURRICULUM (NON-AUTONOMOUS AFFILIATED INSTITUTIONS)

Programme: M.E., Energy Engineering **Regulations:** 2025

Abbreviations:

BS– Basic Science (Mathematics, Physics, Chemistry)

ES – Engineering Science (General (**G**), Programme Core (**PC**), Programme Elective (**PE**) & Emerging Technology (**ET**))

SD – Skill Development

OE – Open Elective

L –Laboratory Course

T – Theory

LIT –Laboratory Integrated Theory

PW – Project Work

TCP –Total Contact Period(s)

Semester I

S. No.	Course Code	Course Title	Type	Periods Per Week			TCP	Credits	Category
				L	T	P			
1.	MA25C06	Applied Mathematical and Statistical Modelling	T	3	1	0	4	4	BS
2.	TE25C01	Advanced Thermodynamics	LIT	3	0	2	5	4	ES (PC)
3.	TE25C02	Advanced Fluid Mechanics and Heat Transfer	LIT	3	0	2	5	4	ES (PC)
4.	TE25C03	Instrumentation and Control for Thermal Systems	T	3	0	0	3	3	ES (PC)
5.	EY25101	Sustainable Energy Systems	LIT	3	0	2	5	4	ES (PC)
6.	EY25C01	Energy Storage Technologies	T	3	0	0	3	3	ES (PC)
7.	EY25102	Technical Seminar	-	0	0	2	2	1	SD
						Total Credits	**27**	**23**	

Semester II

S. No.	Course Code	Course Title	Type	Periods Per Week			TCP	Credits	Category
				L	T	P			
1.		Energy Conservation and Management	LIT	3	0	2	5	4	ES (PC)
2.		Computational Fluid Dynamics	LIT	3	0	2	5	4	ES (PC)
3.		Fuels and Combustion	LIT	3	0	2	5	4	ES (PC)
4.		Programme Elective I	T	3	0	0	3	3	ES (PE)
5.		Programme Elective II	T	3	0	0	3	3	ES (PE)
6.		Industry Oriented Course I	---	1	0	0	1	1	SD
7.		Self-Learning Course	---	-	-	-	-	1	-
						Total Credits	**22**	**20**	

Semester III

S. No.	Course Code	Course Title	Type	Periods Per Week			TCP	Credits	Category
				L	T	P			
1.		AI & ML in Energy Systems	T	2	0	2	3	3	ES (PC)
2.		Programme Elective III	T	3	0	0	3	3	ES (PE)
3.		Programme Elective IV	T	3	0	0	3	3	ES (PE)
4.		Open Elective	T	3	0	0	3	3	---
5.		Industrial Training	-	-	-	-	-	2	SD
6.		Industry Oriented Course II	-	1	0	0	1	1	SD
7.		Project Work I		0	0	12	12	6	SD
Total Credits							**25**	**21**	

Semester IV

S. No.	Course Code	Course Title	Type	Periods Per Week			TCP	Credits	Category
				L	T	P			
1.		Project Work II	---	0	0	24	24	12	SD
Total Credits							**24**	**12**	

PROGRAMME ELECTIVE COURSES (PE)

S. No.	Course Code	Course Title	Periods Per Week			Total Contact Periods	Credits
			L	T	P		
1.		Bio Energy Technologies	3	0	0	3	3
2.		Wind Energy Systems	3	0	0	3	3
3.		Solar Energy Systems	3	0	0	3	3
4.		Polygeneration Systems	3	0	0	3	3
5.		Waste to Energy	3	0	0	3	3
6.		Sustainability in Buildings	3	0	0	3	3
7.		Modern Power Plants	3	0	0	3	3
8.		Energy Modelling and Project Management	3	0	0	3	3
9.		Energy Policy, Economics, and Regulatory Frameworks	3	0	0	3	3
10.		Modelling and Analysis of Thermal Systems	3	0	0	3	3
11.		Carbon Sequestration and Utilisation	3	0	0	3	3
12.		Hydrogen Energy and Fuel Cell Technology	3	0	0	3	3
13.		Smart Grid Technology	3	0	0	3	3
14.		Nanomaterial for Energy Systems and Environmental Applications	3	0	0	3	3
15.		Nuclear Power Engineering	3	0	0	3	3
16.		Smart Energy Management Systems	3	0	0	3	3
17.		Thermal Management in Electronics and Batteries	3	0	0	3	3

Semester I

MA25C06	Applied Mathematical and Statistical Modelling	L	T	P	C
		3	1	0	4

Course Objectives:

- To equip students with advanced mathematical techniques, specifically Fourier Transforms, for formulating and solving partial differential equations that model fundamental mechanical engineering phenomena such as heat transfer, vibrations, and fluid flow.
- To provide a strong foundation in statistical inference, enabling students to estimate population parameters (like material properties and process capabilities) from experimental data and assess the quality and reliability of these estimators.
- To enable students to design efficient, structured experiments and apply appropriate statistical tests to make valid, data-driven decisions for comparing processes, optimizing designs, and solving complex engineering problems.

Fourier Transform: Definitions, Properties, Transform of elementary functions, Dirac delta function, Convolution theorem, Parseval's identity, Solutions to partial differential equations: Heat equation, Wave equation, Laplace and Poison's equations.

Estimation Theory: Unbiasedness, Consistency, Efficiency and sufficiency, Maximum likelihood estimation, Method of moments.

Testing of Hypothesis: Sampling distributions, Small and large samples, Tests based on Normal, t, Chi square, and F distributions for testing of means, variance and proportions, Analysis of r x c tables, Goodness of fit, independent of attributes.

Design of Experiments: Analysis of variance, One way and two-way classifications, Completely randomized design, Randomized block design, Latin square design, 2^2 Factorial design.

Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%.

References:

1. Andrews, L. C., & Shivamoggi, B. K. (2003). Integral transforms for engineers. Prentice Hall of India.
2. Devore, J. L. (2014). Probability and statistics for engineering and the sciences, Cengage Learning.
3. Johnson, R. A., Miller, I., & Freund, J. (2015). Miller and Freund's probability and statistics for engineers, Pearson Education Asia.

E-resources:

1. https://www.edx.org/learn/probability-and-statistics/massachusetts-institute-of-technology-probability-the-science-of-uncertainty-and-data
2. https://www.itl.nist.gov/div898/handbook/
3. https://ocw.mit.edu/courses/2-830j-control-of-manufacturing-processes-sma-6303-spring-2008

TE25C01	Advanced Thermodynamics	L	T	P	C
		3	0	2	4

Course Objectives:

To develop the ability to apply thermodynamic principles for analyzing energy systems and cycles using theoretical, experimental, and simulation approaches.

Thermodynamic Laws and Systems: Thermodynamics Laws and processes, Closed & Open Systems, Steady-state operations, Second Law efficiency.

Practical: Verification of First Law using Calorimeter, Experiment on Heat Work Interaction in Closed System (P-V diagram plotting)

Availability: Available Work: Non-flow and steady flow processes, Entropy Generation Mechanisms, Entropy Minimization Techniques, Exergy of fuels, Combustion Process and Exergy, Exergy Analysis in Heat exchangers, Boilers, Heat pumps, Turbomachines, Internal combustion Engines.

Practical: Entropy Generation in Flow through Pipe (Friction Loss Measurement),Entropy Change during Heat Transfer using Heat Exchanger Setup, Exergy Analysis of a Heat Exchanger (Shell & Tube setup), Fuel Combustion Calorific Value Analysis using Bomb Calorimeter, Software Simulation: Exergy analysis using Software.

Ideal & Real Gas Mixtures: Van der Waals Equation of state, Virial Equations, Maxwell Relations, Joule–Thomson Coefficient, Thermodynamic Relations, Real gas mixtures

Practical: Joule-Thomson Expansion Experiment (Throttle Valve Setup, P-V-T Data Analysis using Real Gas Equations (Van der Waals/Virial),

Thermodynamic Cycles: Rankine, Kalina, Supercritical and Gas Cycles, Refrigeration & Heat Pump Cycles, Combined Cycle and Cogeneration Systems.

Practical: Performance Test on a Vapour Compression Refrigeration Unit, Analysis of Rankine Cycle using a Mini Steam Power Plant Setup, Gas Power Cycle Demonstration using Internal Combustion Engine Setup, Simulation: Rankine/Kalina Cycle analysis using Software.

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Project (10%), Assignment (10%), Practical (25%), Review of Question papers (IES, SSC, GATE) (20%), Internal Examinations (30%)

References:

1. Bejan, A. (2016). Advanced engineering thermodynamics. John Wiley & Sons.
2. Annamalai, K., Puri, I. K., & Jog, M. A. (2011). Advanced thermodynamics engineering. CRC Press.
3. Kuo, K. K. (2005). Principles of combustion. John Wiley & Sons.

4. Wark, K., Jr. (1995). Advanced thermodynamics for engineers. McGraw-Hill.
5. Borel, L., &Favrat, D. (2010). Thermodynamics and energy systems analysis: From energy to exergy. CRC Press.

E-Resources:

https://ocw.mit.edu/courses/mechanical-engineering/2-05-thermodynamics-fall-2003/
https://www.youtube.com/@LearnEngineering
https://nptel.ac.in/courses/112/105/112105275
https://ocw.tudelft.nl/courses/thermodynamics/
https://nptel.ac.in/courses/112/103/112103231
https://www.coursera.org/learn/energy-systems
https://dwsim.org/

Other Resources:

Interactive simulation platforms:
https://direns.mines-paristech.fr/Sites/ThermoptimEN
https://www.tlk-thermo.com/
https://www.grc.nasa.gov/www/k-12/airplane/
Interactive learning:
https://www.energyquest.ca.gov/games/energy_island/index.html
https://phet.colorado.edu/en/simulation/energy-skate-park

	Description of CO	Mapped POs	PSO1	PSO2
CO1	Apply the fundamental laws of thermodynamics to analyze energy interactions in closed and open systems.	PO3 (3)	3	–
CO2	Evaluate entropy generation, exergy, and availability in energy systems and combustion processes.	PO1 (3), PO3 (3)	3	3
CO3	Analyze real gas behavior, thermodynamic relations, and validate concepts through experimental studies.	PO1 (2), PO2 (3), PO3 (3)	3	–
CO4	Simulate and assess the performance of advanced thermodynamic cycles and energy conversion systems using theoretical, practical, and software-based approaches.	PO1 (3), PO2 (3), PO3 (3)	3	3

TE25C02	Advanced Fluid Mechanics Heat Transfer	L	T	P	C
		3	0	2	4

Course Objectives:
To provide knowledge and skills to analyze and apply principles of fluid mechanics and heat transfer, including conduction, convection, phase change, and advanced applications, through theoretical study, experimental investigation, and computational techniques.

Fluid Kinematics and Boundary Layer Theory: 3D Governing Equations: Mass, momentum and applications, Rotational & irrotational flows, stream & potential functions, Vorticity, flow visualization concepts, Velocity Boundary layer theory: displacement, momentum & energy thickness, Laminar and turbulent boundary layers (flat plate & circular pipe)

Practical: Measurement of boundary layer thickness over a flat plate in a wind tunnel, Determination of velocity profile for laminar/turbulent flow using Pitot tube.

Fluid Flow Analysis: Laminar flow: parallel plates and circular pipes, Friction factor, smooth vs rough pipes, Moody diagram, Minor and major losses, pipes in series/parallel, Power transmission through pipes,1D compressible flow in variable area ducts, Nozzles and diffusers, choking and flow regimes

Practical: Flow rate measurement in pipes using venturi/mass flow meters, Determination of friction factor using Moody's chart, Losses in pipe systems (major & minor losses), experimental setup

Conduction: Boundary Conditions, Thermal Conductivity, Conduction equation, Fin Design, analytical solutions ,Multi-dimensional steady state heat conduction, Transient Heat conduction, Lumped Capacitance Method, Semi-Infinite Media Method

Practical:
Thermal conductivity of solids & liquids and effect of temperature, Thermal analysis of fins, Lumped heat method for analysis of different geometries

Convection: Energy & Momentum equations, Laminar & Turbulent Boundary Layers, Entry length, Reynolds-Colburn Analogy, Heat transfer coefficient for flow over a flat surface, circular & non-circular ducts

Practical: Thermal & hydraulic boundary layer development through fluid, Free & Forced convective heat transfer coefficient studies.

Two-Phase Heat Transfer: Pool & Convective boiling, critical heat flux, Dropwise &filmwise condensation, Melting & Solidification, Heat transfer enhancement methods.

Practical: Plotting of boiling & condensation curves, T-t plots during melting & solidification

Thrust Areas: Thermoregulation, Laser Generated Heat Transfer, Tissue Thermal Properties and Perfusion, Thermal Damage and Rate Processes in Biologic Tissues, Thermal Injury, Mathematical models of bio-heat transfer

Machine Learning in Heat Transfer, Linear regression and Neural networks, Practical considerations & Applications.

Practical: Irradiation studies & heat generation from lasers

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Project (10%), Assignment (10%), Practical (25%), Review of Question papers (IES, SSC, GATE) (20%), Internal Examinations (30%)

References:

1. Çengel, Y. A., &Cimbala, J. M. (2018). Fluid mechanics: Fundamentals and applications. McGraw-Hill.
2. White, F. M. (2016). Fluid mechanics. McGraw-Hill Education.
3. Lienhard, J. H., IV, & Lienhard, J. H., V. (2020). A heat transfer textbook. Phlogiston Press.
4. Bejan, A. (2013). Convection heat transfer. Wiley.
5. Holman, J. P. (2002). Heat transfer. Tata McGraw-Hill.
6. Çengel, Y. A. (2020). Heat and mass transfer: Fundamentals and applications. McGraw-Hill.
7. Brennen, C. E. (2005). Fundamentals of multiphase flow. Cambridge University Press.
8. Collier, J. G., & Thome, J. R. (n.d.). Convective boiling and condensation. Oxford University Press.
9. Incropera, F. P., & DeWitt, D. P. (2002). Fundamentals of heat and mass transfer. John Wiley & Sons.
10. Welch, A. J., & van Gemert, M. J. C. (2011). Optical-thermal response of laser-irradiated tissue. Springer Dordrecht.
11. Prakash, P., &Srimathveeravalli, G. (2021). Principles and technologies for electromagnetic energy-based therapies. Academic Press.

E-Resources:

https://nptel.ac.in/courses/112105269?utm_
https://www.youtube.com/playlist?list=PLbMVogVj5nJTZJHsH6uLCO00I-ffGyBEm&utm
https://onlinecourses.nptel.ac.in/noc25_me171/preview?utm
https://onlinecourses.nptel.ac.in/noc23_ch32/preview?utm

Other Resources:
Interactive simulation platforms:
Interactive learning:

	Description of CO	Mapped POs	PSO1	PSO2
CO1	Apply principles of fluid mechanics to analyze flow behavior, boundary layers, and pressure/velocity variations in internal and external flows.	PO3 (3)	3	–
CO2	Evaluate fluid flow parameters, frictional losses, and compressible flow behavior in ducts, nozzles, and diffusers through theoretical and experimental studies.	PO1 (2), PO3 (3)	3	–
CO3	Analyze heat transfer by conduction, convection, and phase change, and validate models using experimental investigations.	PO1 (3), PO2 (2), PO3 (3)	3	3
CO4	Utilize computational and modern techniques, including machine learning, to simulate advanced heat transfer and bio-heat transfer processes for sustainable applications.	PO1 (3), PO2 (3), PO3 (3)	3	3

TE25C03	Instrumentation and Control for Thermal Systems	L	T	P	C
		3	0	0	3

Course Objectives:

To provide knowledge and skills in experimental methods, measurement systems, and industrial automation for accurate data acquisition, analysis, and process control.

Experimental Methods: Statistical and regression analysis, uncertainty and data reduction, experimental design, basics of data analytics and machine learning.

Activities: Mini-project on regression and uncertainty analysis using software, Design of Experiments (DoE) simulation using Taguchi method, Introduction to Python/R for basic data analytics.

Sensors, Transducers and Calibration: LVDT, strain gauge, capacitive, piezoelectric, optical and magnetic transducers; thermocouple, RTD, thermistor; calibration of sensors; electronic, fibre-optic and pneumatic transmitters; telemetry.

Activities: Lab experiments using LVDT, strain gauge, and thermocouples, Sensor signal acquisition and visualization via DAQ systems, Calibration experiments with standard temperature and pressure instruments

Measurements in Thermal Systems: Temperature, pressure, and flow measurements, Measurement of: Thermal conductivity, Specific heat, Viscosity, Rheological analysis of Newtonian and non-Newtonian fluids, Humidity, Solar irradiation, Differential Scanning Calorimetry, Calorific values of fuels (solid, liquid, gas)

Activities: Measurement of temperature, pressure, flow using industrial instruments, Determination of thermal conductivity and specific heat in the lab, Analysis using Differential Scanning Calorimetry (DSC)

Control Systems and Industrial Automation: Open/closed loop systems, transfer functions, feedback, signal conditioning, DAQ, PID and PLC controllers, regulators, thermostats, drives, SCADA, DCS, IIoT, and system optimisation.

Activities: Simulation of PID control using software, PLC programming using ladder logic (e.g., Siemens, Allen-Bradley), Hands-on with SCADA/DCS platforms (demo setups or software simulators), Virtual labs on IIoT and remote monitoring systems

Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%

Assessment Methodology: Quiz (5%), Project (10%), Assignment (10%), Practical (25%), Review of Question papers (IES, SSC, GATE) (20%), Internal Examinations (30%)

References:

1. Holman, J. P. (2011). Experimental methods for engineers. Tata McGraw-Hill.
2. Doebelin, E. O. (2004). Measurement systems: Application and design. McGraw-Hill.
3. Kirkup, L. (2019). Experimental methods for science and engineering students. Cambridge University Press.
4. Morris, A. S., &Langari, R. (2015). Measurement and instrumentation: Theory and application. Elsevier.
5. Anderson, N. A. (2017). Instrumentation for process measurement and control. CRC

Press.
6. Datta, A., & Goel, P. (2023). Practical guide to instrumentation, automation and robotics. Elsevier.
7. Lipták, B. G. (Ed.). (2018). Instrument engineers’ handbook: Process measurement and analysis. CRC Press.

E-resources and Other Resources:

https://nptel.ac.in/courses/106/106/106106179/
https://nptel.ac.in/courses/108/105/108105062/
https://nptel.ac.in/courses/112/104/112104906/
https://nptel.ac.in/courses/108/101/108101037/
https://nptel.ac.in/courses/108/105/108105062/

Other Resources:

Interactive simulation platforms:

Interactive learning:

	Description of CO	Mapped POs	PSO1	PSO2
CO1	Apply experimental methods, statistical analysis, and data analytics for accurate investigation of thermal systems.	PO1 (3), PO2 (2)	3	–
CO2	Demonstrate the use of sensors, transducers, and advanced measurement systems for thermal parameters.	PO3 (3)	3	–
CO3	Design and implement control and automation strategies (PID, PLC, SCADA, IIoT) for efficient and sustainable thermal system operations.	PO1 (3), PO2 (3), PO3 (3)	3	3

EY25101	Sustainable Energy Systems	L	T	P	C
		3	0	2	4

Course Objectives:

To provide foundational knowledge and technical understanding of sustainable energy sources like solar, wind, biomass, hydro, and geothermal and to emphasize their practical applications and evaluates their design, performance, and sustainability in real-world contexts.

Energy Scenario: Indian and global energy scenario, renewable vs. non-renewable energy sources, renewable energy integration and smart grid, energy demand and supply trends, energy pricing and energy substitution

Practical: Study of India's energy mix using data sets (MNRE, IEA), analysis of energy consumption trends and fuel substitution, study of energy policy framing

Environmental Impact & Policy: Greenhouse gases and global warming, Ozone depletion and climate change, UNFCCC, Kyoto protocol, Paris agreement, environmental sustainability in energy, environmental impact assessment, role of energy in achieving SDGs.

Practical: Carbon footprint calculator, Case study: UNFCCC, Kyoto protocol, India's INDC, Environmental impact analysis using LCA software or spreadsheet.

Solar Energy Systems: Solar radiation and measurement, solar thermal collectors: flat plate, concentrating, solar thermal applications and storage, solar PV system design, PV/T, CPV, BIPVand its applications.

Practical: Measurement of solar radiation, testing of flat plate and concentrating solar collectors, I-V characteristics of solar PV panels under varying intensity

Wind Energy Technology: Wind characteristics and site selection, wind energy estimation and Betz limit, wind turbines, materials and components, wind farm layout and performance, hybrid systems, wind turbine recycling, environmental impact and applications.

Practical: Wind speed measurement, Estimation of power from a wind turbine

Bio-Energy Conversion Technologies: Biomass resources and classification, Thermochemical conversion: gasification, pyrolysis, combustion, Biochemical conversion: fermentation, biomethanation, Physicochemical: biodiesel production, briquetting, bioenergy applications, hybrid systems.

Practical: Study of a biomass gasifier/biogas plant (demo or visit), Transesterification process for biodiesel production, Solid fuel briquette manufacturing (demo or visit).

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Project (10%), Assignment (10%), Practical (25%), Review of Question papers (IES, SSC, GATE) (20%), Internal Examinations (30%)
References: 1. Boyle, G. (2017). Renewable energy: Power for a sustainable future. Oxford University Press. 2. Khan, B. H. (2016). Non-conventional resources. McGraw Hill. 3. Nayak, J. K., &Sukhatme, S. P. (2017). Solar energy. McGraw Hill. 4. Rai, G. D. (2014). Non-conventional energy sources. Khanna Publishers. 5. Twidell, J. (2022). Renewable energy resources. Routledge.
E-Resources: https://mnre.gov.in https://unfccc.int https://www.solarenergy.org https://nptel.ac.in/courses/112105051 https://nptel.ac.in/courses/121106014 https://www.fao.org/bioenergy https://www.hydroworld.com
Other Resources: Interactive simulation platforms: https://pvlib-python.readthedocs.io https://www.mathworks.com/matlabcentral/fileexchange/128213-hybrid-renewable-energy-system https://www.renewables.ninja https://qblade.org https://www.renewables.ninja

	Description of CO	**Mapped POs**	**PSO1**	**PSO2**
CO1	Analyze the global and Indian energy scenario, energy mix, demand–supply trends, and role of renewable integration in sustainable development.	PO1 (3), PO2 (2)	3	2
CO2	Evaluate the environmental impacts of energy systems and interpret policies, protocols, and sustainability frameworks (UNFCCC, Kyoto, Paris, SDGs).	PO6 (3), PO7 (3)	–	3
CO3	Apply theoretical and practical knowledge of solar, wind, biomass, and other renewable systems to design and assess performance of sustainable energy technologies.	PO1 (3), PO2 (3), PO3 (2)	3	–
CO4	Demonstrate hands-on skills in measurement, testing, and analysis of renewable energy systems and technologies through laboratory/practical activities.	PO4 (3), PO5 (2)	2	–
CO5	Develop competence to analyze hybrid energy systems and propose sustainable energy solutions with technical, environmental, and policy considerations.	PO2 (3), PO3 (3), PO7 (2)	3	3

EY25C01	Energy Storage Technologies	L	T	P	C
		3	0	0	3

Course Objectives:

To provide foundational knowledge of various energy storage methods thermal, electrical, chemical, and mechanical and analyse the performance of modern systems like batteries and hydrogen storage, explores emerging technologies, safety challenges

Overview of Energy Storage Systems: Classification, key performance parameters, comparison of technologies, energy storage prediction and system optimization using software.

Activities: Comparison of at least 6 energy storage technologies on key performance parameter, Case Study – Analyze a real-world energy storage project and present its technology, performance, and challenges, Debate - which energy storage technology will dominate in the next decade and justify your reasoning.

Thermal Energy Storage: Sensible heat storage systems, latent heat storage systems, Phase Change Materials (PCMs) and packed bed units, thermochemical storage systems, modern developments: solid-solid PCM and compact thermal storage systems.

Activities: Identify suitable PCMs for a solar water heating system based on melting point and thermal properties, Design a packed bed storage unit for a small-scale industrial heat recovery application.

Electrochemical and Electrical Storage: Lead-acid, NiCd, NiMH, Li-ion, zinc-air batteries, battery performance and safety, supercapacitors, ultracapacitors, SMES, emerging technologies: solid-state batteries, fast charging systems, Vehicle to Grid(V2G) technology, AI applications in battery health monitoring and predictive diagnostics.

Activities: Create a performance matrix for lead-acid, NiCd, NiMH, Li-ion, and zinc–air batteries, Analyze a vehicle-to-grid implementation and its impact on grid stability, Model charge–discharge cycles of different battery chemistries using softwares.

Hydrogen Energy Storage: Challenges in hydrogen storage, storage methods, storage protocols, hybrid storage systems.

Activities: Identify and explain key technical challenges in large-scale hydrogen storage, Summarize international standards and safety protocols for hydrogen storage and handling, Analyze a real-world hydrogen storage project and its operational performance.

Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%

Assessment Methodology: Quiz (5%), Project (10%), Assignment (10%), Practical (25%), Review of Question papers (IES, SSC, GATE) (20%), Internal Examinations (30%)
References: 1. Dincer, I., & Rosen, M. A. (2002). Thermal energy storage systems and applications. John Wiley & Sons. 2. Larminie, J., & Dicks, A. (2003). Fuel cell systems explained. Wiley Publications. 3. Cabeza, L. F. (Ed.). (2015). Advances in thermal energy storage systems: Methods and applications. Elsevier Woodhead Publishing. 4. Huggins, R. (2015). Energy storage: Fundamentals, materials and applications. Springer. 5. Liu, R., Zhang, L., & Sun, X. (2012). Electrochemical technologies for energy storage and conversion. Wiley Publications.
E-Resources: https://doi.org/10.21105/joss.06411 https://energyplus.net/MathWorks+2 https://globalwindatlas.info https://nptel.ac.in/courses/112107291 https://www.edx.org/course/energy-storage https://www.coursera.org/learn/batteries https://www.homerenergy.com
Other Resources: **Interactive simulation platforms:** https://www.calmac.com/energy-storage-video-energy-storage-simulator ASME Digital Collection+3 https://www.mathworks.com/matlabcentral/fileexchange/176408-thermal-energy-storage-design-with-simscape https://pvlib-python.readthedocs.io/en/stable/

	Description of CO	Mapped POs	PSO1	PSO2
CO1	Classify and compare different energy storage systems (thermal, electrochemical, electrical, hydrogen) on technical and economic bases.	PO1 (3), PO2 (2)	3	2
CO2	Analyze thermal energy storage methods (sensible, latent, thermochemical, PCM, packed bed) and assess their sustainable applications.	PO1 (3), PO2 (3), PO3 (2)	3	–
CO3	Evaluate electrochemical/electrical storage systems (batteries, capacitors, SMES) and hydrogen storage technologies with respect to safety, standards, and emerging developments.	PO1 (3), PO2 (3), PO3 (2)	3	3
CO4	Apply software tools, case studies, and system-level performance analysis to optimize and manage real-world energy storage projects.	PO2 (3), PO3 (3)	3	2