भारतीय प्रौद्योगिकी संस्थान जोधपुर
Indian Institute of Technology Jodhpur

Curriculum of

M.Tech

in

Energy Engineering

ऊर्जा एवं स्वचालितयंत्र अभियांत्रिकी विभाग
Department of Energy and Automotive Engineering

1. Background and Rationale

The global energy sector is undergoing a rapid transformation driven by climate change mitigation targets, the large-scale deployment of renewable energy, the electrification of transportation, and the emergence of digital energy technologies. India has committed to achieving Net-Zero emissions by 2070, while simultaneously expanding renewable energy capacity, advancing the National Green Hydrogen Mission, and modernizing its power infrastructure. These developments require a new generation of engineers trained in integrated energy systems, including renewable generation, energy storage, smart grids, hydrogen technologies, and digital energy management. Traditional energy engineering programs often treat these domains independently, whereas modern energy systems require holistic and interdisciplinary expertise. The proposed M.Tech. in Energy Engineering at IIT Jodhpur aims to address these challenges by providing advanced training in Renewable and Conventional power generation systems; Hydrogen and alternative energy carriers; Energy storage technologies; Distributed energy systems; Digital energy systems, and AI/ML-enabled Data Analytics. Through interdisciplinary coursework, computational modelling, experimental laboratory exposure, and industry-linked research, the programme will prepare graduates to contribute to energy transition, sustainable infrastructure, and next-generation power systems in India and globally. Furthermore, thesis projects will originate from real industrial problems, enabling students to develop solutions directly relevant to industry. This model significantly improves innovation transfer, industry collaboration, and employability.

2. Objectives of the Programme

The objectives of the program are:

1. To provide a comprehensive understanding of modern energy systems, including generation, storage, distribution, and intelligent energy management.
2. To develop advanced analytical and modelling capabilities for integrated energy infrastructure and emerging technologies, including AI, IoT, and advanced analytics, for intelligent monitoring and control of energy systems.
3. To train students for leadership roles in key areas relevant to industry, such as renewable energy, hydrogen systems, energy storage, smart grids, and energy analytics.
4. To translate industry problem statements into practical engineering solutions, prototypes, and technology demonstrations that address contemporary challenges in the energy sector.
5. To foster innovation and entrepreneurship by enabling students to carry out independent research addressing real-world energy challenges through product engineering, scalable technologies of high technology readiness level.

3. Graduate Attributes

Graduates of the programme are expected to:

1. Possess strong fundamentals and specialized expertise in renewable energy systems, energy storage technologies, power systems, and hydrogen energy.
2. Demonstrate the ability to analyze and design complex energy systems integrating generation, storage, and digital control.
3. Apply advanced computational tools for modelling, simulation, and optimization of energy infrastructure.
4. Exhibit sustainability-oriented engineering thinking in addressing energy transition challenges.
5. Be prepared for careers in industry, research organizations, energy utilities, government agencies, academia as well as entrepreneurs.

4. Learning Outcomes

On successful completion of the programme, students will be able to:

1. Design and evaluate renewable and conventional energy systems for improved efficiency and sustainability.
2. Analyze energy storage technologies including batteries, hydrogen systems, and thermal energy storage.
3. Model and simulate integrated energy systems including renewable power plants, smart grids, and distributed energy networks.
4. Apply optimization and data-driven techniques for energy management and system planning.
5. Undertake independent research in advanced areas of energy systems engineering and pursue doctoral studies.

5. Programme Structure

Course Category	**Credits**
Compulsory Courses	14
Electives	12
Summer Term Thesis	08
M.Tech. Thesis – I	16
M.Tech. Thesis – II	16
Total Credits	**66**

6. Semester wise distribution of credits

Cat.	Course No, Course Title	L-T-P	Credits	Cat.	Course No, Course Title	L-T-P	Credits
I Semester				**II Semester**			
C	MEL7XXX, Engineering Mathematics	3-0-0	3	C	EAL7XXX, Machine Learning in Energy Systems	3-0-0	3
C	EAL7XXX, Energy Conversion Technologies	3-0-0	3	C	EAL7XXX, Energy Storage Technologies	3-0-0	3
C	EAP7XXX, Energy Engineering Laboratory -I	0-0-2	1	C	EAP7XXX, Energy Engineering Laboratory-II	0-0-2	1
E	Elective Course-1	3-0-0	3	E	Elective Course-3	3-0-0	3
E	Elective Course-2	3-0-0	3	E	Elective Course-4	3-0-0	3
NG	Technical Communications	1-0-0	S/U	NG	Innovation and IP Management	1-0-0	S/U
		Total	**13**			Total	**13**
Summer Term							
T	EAT7XX0, Thesis*		**08**				
III Semester				**IV Semester**			
T	EAT7XX0, Thesis*		16	T	EAT7XX0, Thesis*		16
		Total	**16**			Total	**16**

**The thesis work must be aligned with the objectives of the enrolled program as stated in the concept note.*

List of Elective Courses

S.No.	Course Code	Course name	L-T-P	Credits
1.	EAL7XXX	Solar Energy and Applications	3-0-0	3
2.	MEL7XXX	Non-Conventional Sources of Energy and Emerging Technologies	3-0-0	3
3.	EAL7XXX	Life Cycle Analysis and Sustainable Engineering Concepts	3-0-0	3
4.	EAL7XXX	Internal Combustion Engine	3-0-0	3
5.	EAL7XXX	Alternate Fuels and Advances in IC Engines	3-0-0	3
6.	PHL7XXX	Energy Harvesting	3-0-0	3
7.	EAL7XXX	Smart Grid	3-0-0	3
8.	CHL7XXX	Principles of Electrochemical Engineering	3-0-0	3
9	EAL7XXX	Selected Topics in Energy Engineering*	3-0-0	3

**This course may be offered by a new faculty on a selected topic in Energy Engineering for one time only.*

7. Course Content of Compulsory Course (C)

Title	**Engineering Mathematics**	Number	MELXXX
Department	Mechanical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech. and Ph.D.	Type	Compulsory
Prerequisite	None		

Course Objectives

1. Equip students with a comprehensive understanding of advanced mathematical tools (vector calculus, linear algebra, differential equations) and their application in modeling and solving complex physical and engineering systems using ordinary and partial differential equations.
2. Introduce foundational concepts in probability and statistics to enable students to interpret data and analyze uncertainty in engineering processes.

Learning Outcomes

1. Students will proficiently apply vector calculus, tensor analysis, matrix operations, and both analytical and numerical methods for solving ODEs and PDEs to address engineering problems involving multivariable systems, transformations, and physical contexts like vibrations and heat transfer.
2. Students will effectively use statistical methods to analyze experimental data, conduct hypothesis testing, and develop simple predictive models for engineering applications.

Course Content

1. Vectors & Tensors - Vector Algebra; Functions of several variables; Curves and surfaces; Multiple integrals; Gauss (divergence), Stokes and Green's theorems; Tensor notation, transformation and operations. [9 lectures]
2. Linear Algebra - Matrix operations; LU factorization; Reduced row echelon form and rank; Independence, basis & dimension; Orthogonality, projection and least square approximation; Basis Vectors; Determinant properties; condition number; Eigenvalues and Eigenvectors - including examples; Singular Value decomposition. [8 lectures]
3. ODEs - First order ODEs; second order linear ODEs; system of ODEs; phase-plane relationship; series solutions of ODEs; Laplace transforms; Fourier series; Sturm-Liouville problems; Fourier transforms; Examples - mass-spring-damper system, multi-degree of freedom discrete vibration systems. [8 Lectures]
4. Numerical ODE - Initial value problem using Euler's Method, Runge-Kutta Method, Integrating Higher order ODE using system of ODEs, stiff problems, Boundary value problem using shooting method. [4 Lectures]
5. PDEs - Characterization of PDEs, Separation of Variables, Examples - Unsteady heat conduction equation, string vibrations - Eigen modes etc, Cauchy equilibrium equation-applied on thin elastic plate. [4 Lectures]
6. Probability and Statistics - Experiments, outcomes, events, central limit theorem, random variables, probability distributions, distributions of several random variables, random sampling, point estimation, confidence intervals, Testing

hypotheses, Goodness of fit, regression, correlations. Examples from thermofluids - temperature data in Jodhpur, rainfall data. [6 Lectures]

Reference Books/Reading Material

Textbook:

1. Kreyszig, E. (2011). Advanced engineering mathematics (10th ed.). John Wiley & Sons.

Reference Books:

1. Abeyratne, R. (2021). Volume 1. A brief review of some mathematical preliminaries (Version 1.0: 2 Dec 2006; updated 09 Jul 2021) URL: https://web.mit.edu/abeyaratne/lecture_notes.html
2. Strang, Gilbert. Introduction to Linear Algebra. 5th ed., Wellesley-Cambridge Press, 2016.
3. Borisenko, A. I., and I. E. Tarapov. Vector and Tensor Analysis with Applications. Translated by Richard A. Silverman, Dover Publications, 1979.
4. Chapra, S. C., & Canale, R. P. (2021). Numerical methods for engineers (8th ed.). McGraw-Hill Education

Title	**Energy Conversion Technologies**	Number	EALXXX
Department	Energy and Automotive Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech./M.Sc./M.Tech./Ph.D.	Type	Compulsory
Prerequisite	None		

Course Objectives

1. Develop a comprehensive understanding of energy conversion principles across thermal, mechanical, electrical, and electrochemical systems.
2. Introduce conventional and emerging energy conversion technologies, including thermal power plants, gas turbines, fuel cells, hydrogen systems, batteries, solar thermal, photovoltaic, wind, biomass, and hybrid energy systems.
3. Enable students to analyze and design energy systems with efficiency, sustainability, and system integration perspectives.
4. Provide exposure to automotive energy systems, including IC engines, electric vehicles, and hybrid systems.

Learning Outcomes

Students will be able to:

1. Analyze and compare different energy conversion technologies based on thermodynamic efficiency, exergy, and sustainability metrics.
2. Evaluate energy conversion devices such as turbines, compressors, boilers, fuel cells, batteries, photovoltaic systems, and wind turbines.
3. Perform efficiency, exergy, economic, and environmental assessments of integrated energy systems.
4. Compare conventional fossil-fuel-based systems with emerging low-carbon technologies including hydrogen and renewable energy systems.
5. Apply basic computational and modeling approaches for performance prediction and optimization of energy conversion systems.

Course Contents

1. *Fundamentals of Energy Conversion and Thermodynamics*: Global energy scenario, energy demand, sustainability challenges; Forms of energy and energy conversion pathways; First and second laws of thermodynamics; Energy efficiency and entropy generation; Exergy analysis and irreversibility in energy systems [5 lectures]
2. *Conventional Thermal Power Generation Systems*: Steam power plants and Rankine cycle; Reheat and regenerative cycles; Supercritical and ultra-supercritical systems; Gas turbine systems and Brayton cycle; Combined cycle power plants; Boilers, condensers, and cooling systems; Performance analysis and efficiency enhancement methods [7 lectures]
3. *Internal Combustion Engines and Combustion Systems*: SI and CI engine fundamentals; Otto, Diesel, and Dual cycles; Combustion chemistry and flame propagation; Alternative fuels and biofuels; Engine emissions, after-treatment, and waste heat recovery [5 Lectures]
4. *Solar Energy Conversion Technologies:* Solar radiation fundamentals and resource assessment; Solar thermal collectors and concentrating solar power systems; Photovoltaic principles and solar cell technologies; MPPT and PV system integration; Hybrid solar energy systems and applications [5 Lectures]

5. *Wind, Hydro, and Ocean Energy Systems*: Wind resource assessment and aerodynamics of wind turbines; Horizontal and vertical axis wind turbines; Hydropower systems and hydraulic turbines; Tidal, wave, and ocean thermal energy conversion systems [4 Lectures]
6. *Biomass and Bioenergy Conversion*: Biomass resources and characterization; Thermochemical conversion: combustion, gasification, pyrolysis; Biochemical conversion: anaerobic digestion and biofuels [3 Lectures]
7. *Electrochemical Energy Conversion and Storage*: Electrochemical fundamentals and fuel cells; PEMFC, SOFC, AFC, and MCFC systems; Hydrogen production, storage, and utilization; Battery technologies: Li-ion, solid-state, sodium-ion batteries; Supercapacitors and grid-scale energy storage systems [5 Lectures]
8. *Emerging Energy Conversion Technologies*: Thermoelectric and thermionic conversion; Organic Rankine cycle systems and waste heat recovery; Piezoelectric energy harvesting and micro-energy systems [3 Lectures]
9. *Energy System Analysis, Economics, and Sustainability*: Energy auditing and performance assessment; Techno-economic analysis and life cycle assessment; Carbon emissions, environmental impact, and energy policy [3 Lectures]

Text Books

1. Çengel, Y. A., & Boles, M. A. Thermodynamics: An Engineering Approach (9th Edition). McGraw-Hill Education, 2019.
2. Boyle, G. (Ed.) Renewable Energy: Power for a Sustainable Future (4th Edition). Oxford University Press, 2012.
3. Boyce, M. P. Gas Turbine Engineering Handbook. Elsevier.
4. Kalogirou, S. Solar Energy Engineering: Processes and Systems. Academic Press.
5. Masters, G. M. Renewable and Efficient Electric Power Systems. Wiley.

Reference Books

1. Dincer, I., & Rosen, M. A. Exergy: Energy, Environment and Sustainable Development (3rd Edition). Elsevier, 2020.
2. Larminie, J., & Dicks, A. Fuel Cell Systems Explained (2nd Edition). John Wiley & Sons, 2003.
3. Linden, D., & Reddy, T. B. Handbook of Batteries (4th Edition). McGraw-Hill, 2011.
4. Heywood, J. B. Internal Combustion Engine Fundamentals (2nd Edition). McGraw-Hill Education, 2018.
5. Kalogirou, S. A. Solar Energy Engineering: Processes and Systems (2nd Edition). Academic Press, 2014.

Learning Material

1. NPTEL Course on Energy Conversion Technologies (Biomass and Coal) https://nptel.ac.in/courses/103103222
2. NPTEL Course on Wind Energy https://nptel.ac.in/courses/101104546
3. NPTEL Course on Renewable Energy Engineering: Solar, Wind And Biomass Energy Systems https://nptel.ac.in/courses/103103206

Title	**Energy Storage Technologies**	Number	EALXXX
Department	Energy and Automotive Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech./M.Sc./M.Tech./Ph.D.	Type	Compulsory
Prerequisite	None		

Course Objectives

The Instructor will:

1. Provide students with fundamental understanding of various energy storage technologies and their role in modern energy systems.
2. Introduce principles, design, operation, and performance analysis of electrochemical, thermal, mechanical, and hydrogen-based energy storage systems.
3. Enable students to evaluate energy storage solutions for renewable integration, electric mobility, and grid applications.
4. Familiarize students with emerging trends, techno-economic analysis, and sustainability aspects of energy storage technologies.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the operating principles and characteristics of different energy storage systems.
2. Analyze and compare performance parameters such as energy density, power density, efficiency, and lifecycle of storage technologies.
3. Design and evaluate suitable energy storage systems for renewable energy, transportation, and industrial applications.
4. Assess techno-economic and environmental aspects of energy storage deployment.
5. Understand recent advancements and research challenges in advanced energy storage technologies.

Course Contents

1. Introduction to Energy Storage Systems: Need for energy storage, role in renewable energy integration and smart grids, classification of energy storage technologies, energy and power density, storage characteristics, efficiency, lifecycle, safety, and sustainability considerations. (4 lectures)

2. Electrochemical Energy Storage: Fundamentals of electrochemical storage, batteries and working principles, lead-acid batteries, nickel-cadmium and nickel-metal hydride batteries, lithium-ion batteries, sodium-ion batteries, solid-state batteries, flow batteries, battery management systems, charging/discharging characteristics, degradation mechanisms, recycling and safety. (10 lectures)

3. Thermal Energy Storage: Principles of thermal energy storage, sensible heat storage, latent heat storage, phase change materials (PCM), thermochemical storage, packed-bed thermal energy storage, high-temperature thermal storage systems, materials selection, thermal performance analysis, applications in solar thermal and industrial waste heat recovery. (10 lectures)

4. Mechanical Energy Storage: Pumped hydro energy storage, compressed air energy storage, flywheel energy storage, gravity-based storage systems, working

principles, performance analysis, system integration, advantages and limitations. (6 lectures)

5. Hydrogen and Chemical Energy Storage:Hydrogen production methods, electrolysis, hydrogen storage techniques, fuel cells, power-to-gas concept, synthetic fuels, ammonia-based energy storage, hydrogen economy and infrastructure challenges. (8 lectures)

6. Supercapacitors and Hybrid Storage Systems: Electrochemical capacitors, supercapacitor fundamentals, electrode materials, hybrid energy storage systems, battery-supercapacitor integration, applications in electric vehicles and grid support. (5 lectures)

7. Applications and System Integration: Energy storage for renewable energy integration, electric vehicles, microgrids, smart grids, industrial applications, energy management strategies, policy and regulatory aspects, techno-economic analysis, environmental impact assessment, recent trends and future prospects. (5 lectures)

Text Books/Reference Books

1. Luo, X., Wang, J., Dooner, M., Clarke, J., 2015, Overview of Current Development in Electrical Energy Storage Technologies and the Application Potential in Power System Operation, Applied Energy.
2. Ibrahim, H., Ilinca, A., Perron, J., 2008, Energy Storage Systems-Characteristics and Comparisons, Renewable and Sustainable Energy Reviews.
3. Cabeza, L. F., 2015, Advances in Thermal Energy Storage Systems, Woodhead Publishing.
4. Dincer, I., & Rosen, M. A. (2021). Thermal Energy Storage: Systems and Applications (3rd ed.). Wiley.
5. Linden, D., & Reddy, T. B. Handbook of Batteries (4th Edition). McGraw-Hill, 2011.
6. M Hirscher, Katsuhiko Hirose, Handbook of Hydrogen Storage, Wiley-VCN, 2010

Learning Material

1. NPTEL Course on Electrochemical Energy Storage, IIT Kharagpur; https://nptel.ac.in/courses/113105102
2. NPTEL Course on Hydrogen Energy: Production, Storage, Transportation and Safety, https://nptel.ac.in/courses/103101215

Title	Machine Learning in Energy Systems	Number	EALXXX
Department	Energy and Automotive Engineering Department	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech./M.Sc./M.Tech./Ph.D.	Type	Compulsory
Prerequisite	Basic Programming and Engineering Mathematics		

Course Objectives:

- To provide fundamental understanding of machine learning techniques and workflows.
- To introduce data-driven modeling approaches for energy systems.
- To develop competency in handling energy datasets and implementing ML models.
- To apply machine learning for forecasting, optimization, diagnostics, and control in energy applications.
- To expose students to neural networks and deep learning for advanced energy analytics.
- To familiarize students with Python-based ML tools and deployment workflows.

Learning Outcomes:

- Understand the role of machine learning in modern energy systems.
- Perform preprocessing and analysis of energy-related datasets.
- Develop ML models for energy forecasting and demand prediction.
- Apply ML techniques for fault diagnosis and predictive maintenance of energy systems.
- Design neural-network-based models for advanced energy analytics.
- Evaluate ML models using appropriate engineering performance metrics.

Course Contents:

Fundamentals of Machine Learning, Data Analytics and Preprocessing [Lecture 13]: The topics covered include introduction to Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL); role of machine learning in modern energy systems; types of machine learning including supervised, unsupervised, and reinforcement learning; machine learning workflow; energy datasets and data acquisition systems; data cleaning and preprocessing; feature engineering; data normalization and scaling; train-test-validation split; cross-validation techniques; exploratory data analysis and visualization; challenges in energy data such as sensor uncertainty, missing values, and noisy measurements; and ethics, sustainability, and responsible AI.

Classical Machine Learning for Energy Applications [13 Lectures]: The topics covered include linear regression; polynomial regression; cost functions and gradient descent optimization; regularization methods including Ridge and Lasso regression; bias-variance trade-off; overfitting and underfitting; performance metrics such as RMSE, MAE, and R^2 score; logistic regression; confusion matrix, precision, recall, and F1-score; Support Vector Machines (SVM) and kernel methods; decision trees and random forests; ensemble learning techniques; clustering methods including K-means and DBSCAN; dimensionality reduction techniques including Principal Component Analysis (PCA); and applications in solar irradiance prediction, wind energy forecasting, building energy demand prediction, fault diagnosis in engines and batteries, smart grid analytics, and predictive maintenance.

Deep Learning and Advanced Energy Analytics [13 Lectures]: The topics covered include fundamentals of neural networks and multilayer perceptrons (MLP); activation functions and backpropagation; hyperparameter tuning and optimization techniques; overfitting prevention and regularization methods; deep learning architectures; PINNs (Physics Informed Neural Networks), MLOps, GenAI for data, recurrent neural networks (RNN); Long Short-Term Memory (LSTM) networks; sequence modeling and time-series forecasting; renewable energy forecasting using deep learning; grid load forecasting; electric vehicle energy consumption prediction; battery degradation modeling; physics-informed machine learning; digital twins in energy systems; reinforcement learning for smart energy management; explainable AI; and emerging AI applications for sustainable and intelligent energy systems.

Reading Materials

1. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow by Aurelien Geron, O'Reilly Publications.
2. Pattern Recognition and Machine Learning by Christopher Bishop, Springer.
3. Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press.
4. Machine Learning: A Probabilistic Perspective by Kevin Murphy, MIT Press.
5. Artificial Intelligence in Renewable Energetic Systems by Ahmed F. Zobaa and Trevor J. Bihl.
6. Renewable Energy Forecasting: From Models to Applications edited by Georges Kariniotakis, Woodhead Publishing.
7. Artificial Intelligence Techniques in Smart Grid and Renewable Energy Systems for applications in intelligent power and smart grid systems.

Title	**Energy Engineering Laboratory – I**	Number	EAP3XX0
Department	Energy And Automotive Engineering	L-T-P [C]	0-0-2 [1]
Offered for	M.Tech. in Energy Engineering	Type	PC
Prerequisite	Thermodynamics, Fluid Mechanics		

Objective:

1. To provide hands-on understanding of fundamental energy conversion systems and thermal energy management principles through experiments involving thermodynamics, heat transfer, fluid flow, refrigeration, and power generation systems.
2. To develop practical knowledge of energy measurement, thermal performance evaluation, efficiency analysis, and sustainable energy utilization.

Learning Outcomes:

The students are expected to have the ability to:

1. Relate thermodynamic and heat transfer principles with experimental observations.
2. Understand the operation and performance of various energy conversion devices.
3. Measure thermal and fluid parameters using engineering instrumentation.
4. Evaluate efficiencies and energy losses in thermal systems.
5. Analyse heat transfer and fluid flow characteristics in practical systems.
6. Understand basic concepts of energy conservation and management.
7. Interpret experimental data and prepare technical reports.

Lab Contents

1. Introduction to Energy Conversion Systems and Instrumentation: Familiarization with temperature, pressure, flow, and energy measurement devices used in thermal engineering systems.
2. Thermal Conductivity Measurement: Determination of thermal conductivity of different materials using steady-state heat conduction apparatus.
3. Heat Transfer through Extended Surfaces: Study of heat transfer enhancement and fin efficiency under natural and forced convection conditions.
4. Natural and Forced Convection Experiments: Determination of convective heat transfer coefficients and thermal performance characteristics.
5. Heat Exchanger Performance Analysis: Experimental analysis of parallel-flow and counter-flow heat exchangers including effectiveness and NTU evaluation.
6. Radiation Heat Transfer and Emissivity Measurement: To verify and investigate the radiation laws using thermal radiations.
7. Refrigeration System Performance Test: Performance evaluation of vapor compression refrigeration systems and determination of coefficient of performance.

8. Air Conditioning System Analysis: Study of psychrometric processes and thermal comfort analysis in air conditioning systems.
9. Boiler and Steam Generation Experiment: Determination of boiler efficiency and analysis of steam generation systems.
10. Pump and Hydraulic Turbine Performance Test: Measurement of pump characteristics, hydraulic efficiency, and turbine performance.
11. Flow Measurement and Energy Loss Analysis: Calibration and application of venturimeter, orifice meter, and pipe friction analysis.
12. Energy Audit and Thermal Efficiency Evaluation: Experimental estimation of energy consumption, thermal losses, and efficiency improvement opportunities in engineering systems.

Title	**Energy Engineering Laboratory – II**	Number	EAP3XX0
Department	Energy And Automotive Engineering	L-T-P [C]	0-0-2 [1]
Offered for	M.Tech. in Energy Engineering	Type	PC
Prerequisite	Thermodynamics, Fluid Mechanics		

Objective:

1. To provide hands-on exposure to advanced energy conversion systems, internal combustion engines, renewable energy systems, combustion analysis, emissions measurement, and energy management techniques.
2. To develop understanding of energy efficiency, sustainability, environmental impact, and modern energy conversion technologies.

Learning Outcomes:

1. The students are expected to have the ability to:
2. Understand the working principles of conventional and renewable energy conversion systems.
3. Conduct experimental performance evaluation of IC engines and energy systems.
4. Measure fuel properties and combustion characteristics.
5. Analyse thermal efficiency, heat balance, and energy distribution.
6. Understand emission formation and environmental impacts of energy systems.
7. Evaluate renewable energy system performance.
8. Develop practical skills in energy management and sustainability analysis.
9. Interpret experimental results and prepare technical reports.

Lab Contents

1. Overview of Energy Conversion Systems: Study of conventional and renewable energy conversion technologies.
2. Internal Combustion Engine Performance Test: Determination of brake power, fuel consumption, brake thermal efficiency, and specific fuel consumption under varying operating conditions.
3. Heat Balance Test on IC Engine: Analysis of energy distribution in operating engines including brake power, cooling water losses, exhaust losses, and unaccounted heat losses.
4. Fuel Property Measurement: Determination of calorific value, flash point, viscosity, and density of fuels used in energy systems.
5. Morse Test on Multi-Cylinder Engine: Estimation of indicated power, brake power, friction power, and mechanical efficiency.
6. Combustion and Air-Fuel Ratio Analysis: Experimental investigation of combustion processes and combustion efficiency.
7. Exhaust Emission Analysis: Measurement of CO, CO_2, HC, NOx, and smoke opacity under different engine operating conditions.

8. Variable Compression Ratio (VCR) Engine Study: Investigation of the effects of compression ratio on engine efficiency and emissions.
9. Solar Thermal Energy System Experiment: Performance analysis of solar collectors and estimation of solar thermal efficiency.
10. Photovoltaic (PV) System Performance Analysis: Measurement of electrical characteristics and efficiency of photovoltaic systems under varying conditions.
11. Wind Energy System Demonstration and Analysis: Study of wind turbine characteristics and power generation behavior.
12. Energy Management Analysis: To investigate energy flow balance, energy transport via different media and charging and discharging of an ice store; Edge AI Demo: Smart Energy Monitoring & Fault Detection.

Course Content of Elective Courses (PE)

Title	**Solar Energy and Applications**	Number	MEL7560
Department	Mechanical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech./M.Sc./M.Tech./Ph.D.	Type	Elective
Prerequisite	None		

Objectives

This course has objectives-
1. to familiarize students with the potential of solar energy to meet the growing energy demands of society in a sustainable way,
2. to elaborate students, the concepts of solar energy applications in architecture and infrastructure, and
3. to illustrate solar technologies of producing power and cooling/heating in buildings.

Learning Outcomes

The students will acquire-
1. knowledge of various means of solar energy utilization technologies and their applications.
2. ability to model, design and evaluate solar energy systems and their applications from the fundamental principles and methods.
3. practical exposer to various measurement experiments and simulation of applications.

Course Contents

Solar Radiation: Introduction to Solar Radiation, distribution, measurement and data, Sun motion, Introduction to Detectors, Radiation on Sloped Surfaces, Principle of conversion of solar radiation into heat, Thermal comfort, Introduction to Concentrated Solar Power (CSP) Technologies. [Lectures 14]

Photovoltaics: Photovoltaic (PV) Effect, PV cells, The electrical model of PV cells, effect of shading, converters for grid integration of solar PV: DC-DC boost converter and inverter, control of boost converter and inverter, MPPT techniques and implementation. Mounting of solar panels, design and analysis of solar trees. [Lectures 14]

Energy Efficient Buildings: Building orientation and design, passive heating and cooling concepts, thumb rules, heat transfer in buildings: Thermal modeling of passive concepts, Evaporative cooling, Energy efficient windows and daylighting, Earth air tunnel and heat exchanger, Zero energy building concept and rating systems, Energy conservation building codes, Software for Building Simulation, Automation and Energy Management of Buildings. [Lectures 14]

Reference Books/Reading Material

1. Solar Engineering of Thermal Processes. John A. Duffie, William A. Beckman. John, Fourth Edition, Wiley & Sons, Inc., 2013.

2. Renewable Energy Resources: Basic Principles and Applications. G. N. Tiwari, M K. Ghosal, Narosa Publishing House, New Delhi, 2004.
3. M.S. Sodha, N.K. Bansal, P.K. Bansal, A. Kumar, and M.A.S.Malik, Solar Passive Building, Science and Design, Pergamon Press, 1986.
4. Masters,G.M., (2004), Renewable and Efficient Electric Power Systems, John Wiley & Sons, Inc.

Learning Material

1. Solar Energy Technology https://nptel.ac.in/courses/112105050
2. Solar Photovoltaics Fundamentals, Technology And Applications https://nptel.ac.in/courses/115107116

Title	**Non-Conventional Sources of Energy and Emerging Technologies**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech./M.Sc./M.Tech./Ph.D.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

Deliver knowledge of fundamental principles of non-conventional sources of energy and their utilization.

Teach important technologies of producing power from non-conventional and alternative energy sources.

Learning Outcomes

The students are expected to have the ability to:

Understand various energy sources such as solar, wind, hydropower, biomass, geothermal, and emerging technologies.

Utilize the potential of non-conventional energy sources and their applications.

Contents

(Fractal 1) *MEL7XX1 Principles of Non-Conventional Sources and Solar Energy (1-0-0)*

Introduction to non-conventional energy sources; Availability and form of delivery; Energy consumption and conservation; Sustainable development; Standards and Regulations. (4 Lectures)

Solar radiation, Distribution, measurement and data; Solar energy collectors; Photovoltaic cell; Parabolic trough; Parabolic dish; Central receiver system; Solar energy storage; Solar Pond; Applications of solar energy- Solar distillation, Solar cooker, Solar drying, Solar greenhouse, Solar water heating, Solar heating and cooling of buildings. (10 Lectures)

(Fractal 2) *MEL7XX2 Wind and Hydro Energy (1-0-0)*

Wind data, Estimation and site selection; Principle of wind energy conversion- system and its components; Wind turbine and estimation of power output; Energy storage; Application of wind energy; Environmental Aspects. (7 Lectures)

Hydro-electric power and its classification; Typical components of micro/mini hydropower station; Water turbine; Pelton wheel turbine; Working principle, Performance and limitations; Ocean wave energy- Working principle, Performance and limitations. (7 Lectures)

(Fractal 3) *MEL7XX3 Geothermal, Biomass and Emerging Technologies (1-0-0)*

Geothermal sources and resources; Geothermal system and technologies; Ground-source heat pumps; Social and environmental aspects; Applications. (4 Lectures)

Biomass conversion technologies, Classification, Advantages, and disadvantages; Production of biomass, Photosynthesis; Biogas generation; Properties of biogas and its purification; Applications. (4 Lectures)

Fuel cell, Working principle, Performance and limitations; Hydrogen Energy, Production methods, Storage and Transportation, hydrogen as an alternative fuel for vehicles. (6 Lectures)

Textbook

1. J. Twidell, T. Weir, *Renewable Energy Resources*. 3rd Ed., Taylor & Francis Group, London, 2015.

2. J. A. Duffie, W. A. Beckman, *Solar Engineering of Thermal Processes*. 4th Ed., Wiley & Sons, Inc., 2013.
3. B.H.Khan, *Non-Conventional Energy Resources*. Tata McGraw-Hill Education, New Delhi, 2009.

Self-Learning Material

Dr. P. Haridoss, *Non-Conventional Energy Resources*, NPTEL Course Material, IIT Madras. https://nptel.ac.in/courses/121/106/121106014/

Title	**Hydropower**	Number	
Department	Mechanical Engineering	L-T-P [C]	**3–0–0 [3]**
Offered for	**M.Tech., Ph.D.**	Type	**Elective**
Prerequisite			

Objectives:
The Instructor will:

1. Describe the role of the hydropower and working principles of small- and large-scale hydropower plants.
2. Provide overview of the practical design of hydropower structures including mechanical and electrical equipment.
3. Introduce students to geotechnical, mechanical, and electrical engineering aspects of conventional large dams.

Learning Outcomes:
The students are expected to have the ability to:

1. Formulate and analyze technical solutions for design, and operation of hydropower plants.
2. Analyze a technical problems connected to the hydroelectric power industry.
3. Compare the design of dams, mechanical, electric and electronic equipment.
4. Implement design details of embankment dam, components of face rockfill dams and concrete gravity dam, and basis of dam foundation design.

Fractal 1 (ME)

- *Introduction*: Hydropower resource, potential and market, Hydropower sites, Types of hydropower plants. (2 Lectures)
- *Large hydropower*: Run-of-River Hydropower, Dams and Barrages, Dam types (3 Lectures)
- Hydropower turbines, Classification and working principles, Impulse and reaction turbines; Propeller and Kaplan Turbines, Deriaz turbine. (5 Lectures)
- *Tidal power*: Tidal barrage power plant, operation and design, Tidal lagoons, Barrage construction techniques, Turbine speed regulation. (4 Lectures)

Fractal 2 (EE)

- *Hydro Power Generators:* Generator poles and rotational speed, orientation, types (2 lectures)
- *Small Hydro Power*: Small, mini, and micro hydropower plant, generators for small hydro power plants (3 lectures)
- *Electronic Control of Hydro Power*: Phase angle control, relay switched on loads, Mark-Space ratio controller (3 lectures)
- *Pumped Storage Hydro power*: Pumped storage hydro power plant, turbines, motors (3 lectures)
- *Hydro Power House:* Classification, equipment, accessories, layout, components, sizing (3 lectures)

Fractal 2 (CIE)

- *Site investigation techniques:* Geological environments: rocks and soils; Geological, geotechnical, and geophysical investigation; Trenching and drilling *(Lectures: 2)*
- *Design of embankment dams:* freeboard; Slope protection; Embankment crest details; Dimensioning and tolerances; Conduits through embankments; Flood control structures; Seismic stability analysis of embankments; Liquefaction of dam embankments and foundations. *(Lectures: 4)*

- *Concrete face rockfill dams and Concrete gravity dams:* Selection of dam types; Rockfill zones; Concrete face; Construction aspects; Settlements, and displacements of the face slab, and joints; Leakage; Strength and compressibility of rock foundations; Strength of concrete in the dam; Strength of the concrete-rock contact; Silt and ice load *(Lectures: 4)*
- *Foundation preparation:* General foundation preparation for embankment dams; Cutoff foundation for embankment dams; Width and batter slopes; Slope modification; Foundation preparation for concrete gravity dams. *(Lectures: 4)*

Textbook

- Breeze,P., (2018), *Hydropower*, Academic Press
- Pandey,B., Karki,A., (2017), *HYDROELECTRIC ENERGY Renewable Energy and the Environment*, CRC Press
- Robin Fell, Patrick MacGregor, David Stapledon, Graeme Bell (2005) *Geotechnical Engineering of Dams*. A. A. Balkema publishers. ISBN 04 1536 440 x.

Title	**Energy Harvesting**	Number	PHL6XX0
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech../M.Tech./Ph.D.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide the student with an extended knowledge of the basic principles and recent advances in Energy harvesting technologies for low-power applications including self-powered or autonomous systems.
2. Provide the students with the role of materials in energy harvesting technologies with a focus on miniaturized and microfabricated devices.

Learning Outcomes

The students will:

1. Develop an understanding of basic principle, concept, working mechanism and applications of various energy harvesting devices.
2. Develop an understanding to design new energy harvesting systems.

Contents

- *Micro Photovoltaic Module Energy Harvesting*: *p-n* Junction and Crystalline Si Solar Cells, Amorphous Silicon Solar Cell, CIGS and CdTe Solar Cell Development, Polymer Solar Cell, Dye-Sensitized Solar Cells (DSSC), Perovskite Solar Cells, Monolithically Integration of Solar Cells with IC, Low-Power Micro Photovoltaic Systems, Maximum Power Point Tracking (*Lectures : 14*)
- *Mechanical Energy Harvesting*: Energy Harvesting from Macro to Micro to Nano, Piezoelectric MEMS Energy Harvesters, Nano-Piezoelectric Generator, Piezoelectric Cantilever Generator, Piezoelectric Transducers. New-generation Triboelectric Nanogenerators. (*Lectures: 8*)
- *Thermal Energy Harvesting:* Overview of Nanoscale Heat Conduction and the Seebeck Effect, Thermoelectric energy harvesting and Power Generation, Thermoelectric figures of merit, Novel nanostructured Thermoelectric materials and devices, Thermal energy harvesting using pyroelectric materials, Thermodynamic cycles for Pyroelectric energy harvesting, Nanostructured and micro-scale materials and devices. (*Lectures: 14*)

Textbook

1. Briand, D., Yeatman, E., Roundy, S., *Micro Energy Harvesting* Wiley, 2015.
2. Shashank, P., Inman, D. J., *Energy Harvesting Technologies*, Springer, 2009.

Self-Learning Material

1. Elvin, N., Erturk, A., *Advances in Energy Harvesting Methods*, Springer, 2013.
2. Jaffe, R., and Taylor, W., *Physics of Energy*, MIT open course, https://ocw.mit.edu/courses/physics/8-21-the-physics-of-energy-fall-2009/

Preparatory Course Material

3. Pal, K., Selection of Nanomaterials for Energy harvesting and Energy Storage Applications, https://nptel.ac.in/courses/112107283/

Title	**Principles of Electrochemical Engineering**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech.., Ph.D.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
1. Provide the student with the essential knowledge needed to understand electrochemical engineering and technology.
2. Illustrate the basic principles of electrochemistry, electrokinetic phenomena required for modelling and design of electrochemical processes and devices.

Learning Outcomes
The students are expected to have the ability to:
1. Understand the principles of electrochemistry processes and electro-analytical methods.
2. Correlate the principles of electrochemistry to electrochemical processes and suggest design solutions to engineering problems.

Contents
Basic Principles: Introduction to electrochemistry and fundamentals, Nernst equation, Electrode kinetics, Volta and Galvani potentials, electrochemical potential, electrochemical equilibrium, Enthalpy and Gibbs free energy calculation, solvation energy, ionic equilibrium. (5 lectures)

Cell potential: Electrochemical cell, standard electrode potential, Butler-Volmer formulation, Tafel equation, Pourbaix diagram, Activity Coefficients, Donnan potential, reversible electrode, Born model for ion-solvation energy, Batteries and Cell Chemistries. (6 lectures)

Ion-ion interactions and ionic transport: Debye-Huckel theory, activity coefficient of ionic solution, ion pair, Bjerrum theory and Fuoss theory, migration, extended Nernst-Planck equation, electrochemical mobility and its relation with diffusivity, Stokes-Einstein equation, ionic conductivity, transport number, Kohlrausch law. (11 lectures)

Charged interface: surface excess quantity, Lippmann equation, Gouy-Chapman model, Stern layer, internal and external Helmholtz layer, zeta potential, electric double layer. (8 lectures)

Electrochemical Kinetics: Nonequilibrium formulation, diffusion potential, junction potential, Planck-Henderson equation, pH electrode, electro-osmosis, electrophoresis, streaming potential, sedimentation potential. (7 lectures)

Application: Electro-chemical Processes, Fuel Cells. (2 lectures)

Text Book
1. Prentice ,G., 1991, Electrochemical Engineering Principles, Prentice Hall.
2. Girault, H., 2004, Analytical and Physical Electrochemistry, EPFL Press, 1st Edition.

Reference Book
1. Allen J. Bard, Larry R. Faulkner, 2005, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd Edition.
2. Fuller,T.F., Harb, J. N., 2018, Electrochemical Engineering, Wiley.

Online Course Material
https://nptel.ac.in/courses/104106105/

Title	**Power Plant Engineering**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-2 [4]
Offered for	B.Tech./M.Tech./Ph.D.	Type	Compulsory
Prerequisite	B.Tech.		

Objectives

This course is designed-

1. to introduce different aspects of power plant engineering such as power plant layout, operation and safety principles
2. to provide knowledge of the working principle of conversion of different energy resources into electrical power generation.

Learning Outcomes

The students will acquire,

1. ability to select an appropriate type of power plant for given requirements under different situations
2. skills for optimization of energy efficiency of power plants with respect to available resources and energy requirements.
3. ability to analyze the working and layout of power plants and the various components comprising the plant.

Content:

Introduction to power plant engineering: Sources of energy, National and International status on power generation.

Thermal Power Plant: Plant layout, Thermal power plant equipment, Types of boilers, the performance of boilers, supercritical steam generator, the performance of condensers, types of steam turbines, draught system.

Gas Turbine Power Plant: Classification and construction layout, Principles of closed and open cycle gas turbines.

Combined cycle power plants: Load type and calculation, Load variation, Use of internal combustion engine plant, Plant layout and design calculation, combined cycle efficiency.

Nuclear power plant: Principles of nuclear energy, Elements of nuclear power plants, Types of nuclear fuel, nuclear reactor, Boiling Water Reactor, Pressurised Water Reactor, Pressurised Heavy Water Reactor, Fast breeder reactors, Next generation nuclear plant.

Hydroelectric power plant: Plant layout, water turbine, plant operation, water storage and flow duration, hydrographs, Low, medium and high head plants, pumped storage plants, Penstock, water hammer, surge tanks, gates and valves, power house.

Site selection: Selection of for power station, load estimation, load duration curve, load factor, capacity factor, use factor, diversity factor, demand factor, Effect of variable load on power plant, selection of the number and size of units.

Economics and Environmental Considerations: Capital cost, Cost of energy production, Operational cost of power plants, tariffs for electrical energy, Environmental impact, different types of pollution, fuel availability.
Electrical components of power plants: generator, transformer, speed governing systems, generator excitation systems, switchyard.

Laboratory Classes [12-13 Classes]
Steam Power Plant: Start-up, Operation and maintenance, Shut down of Steam Power Plant, Control and monitoring.
Boilers: Efficiency of a steam generator, Analysis of exhaust gas from boiler, Determination of the heat flux density and the overall heat transfer coefficient in boilers.
Steam Turbine: Demonstration of the function of a steam turbine, Operating Characteristics of Steam turbine.
Cooling tower: Determination of cooling capacity, Operating Characteristics of Cooling tower
Gas Turbine: Determination of specific fuel consumption, Determination of Shaft power and System efficiency.

Reference Books

1. M. M. Ei-Wakil, Power Plant Technology, Tata McGraw-Hill.
2. P. K. Nag, Power Plant Engineering, Tata McGraw-Hill.
3. F. T. Morse, Power Plant Engineering, D. Van Nostran, New York.

Learning Material

1. https://nptel.ac.in/courses/112107291/

Title	**Smart Grid**	Number	**EE7XX0**
Department	Electrical Engineering	L-T-P [C]	3–0–2 [4]
Offered for	B.Tech./M.Tech./Ph.D.	Type	SSE
Prerequisite	Power Engineering		

Objectives
The Instructor will:
1. Provide concepts and topics that are relevant to smart grid technologies to facilitate exploring research opportunities

Learning Outcomes
The students are expected to have the ability to:
1. Understand the basic concepts of smart grid development and the critical technologies that underpin such development, their basic principles, physical constraints, and technological potentials

Contents

- *Smart Grid Basics:* Evolution of Electric Power Grid and Smart Grid, Objectives, main features and challenges of smart grid (5 lectures)
- *Energy Resources:* Centralized vs. distributed generation (1 lecture); renewable energy: solar, wind, hydropower, biomass, geothermal, ocean wave; benefit, costs, and policies of renewable energy (5 lectures); renewable sources integration – overcoming intermittence; storage systems technology (4 lectures)
- *Plug-in Electric Vehicle (PEV):* History of EV; PEV challenges and potential solutions (1 lecture); EV and electric power grid; PEV charging infrastructure, challenges and solutions (4 lectures); PEV as an energy storage device and an energy source (V2G) (2 lectures)
- *Demand-side management:* Load profile of the power grid; market pricing (3 lectures); peak shaving and valley filling; load forecasting (4 lectures); regulations and policies (3 lectures)
- *Monitoring and Protection:* Wide-area monitoring system (WAMS), SCADA and PMU (4 lectures); advanced metering infrastructure (AMI); smart metering (3 lectures); communication infrastructure and technologies (3 lectures)
- *Laboratory:* Experiments related to the following topics will be conducted under laboratory component: Characteristics of solar PV, grid integration of renewable energy sources, effect of loads on power quality with renewable energy penetration, Inverter-based microgrid, virtual inertia in inverter-based sources, demand side management, contribution of energy storage systems to enhance power quality, ancillary services, smart metering, performance of PMU

Textbook
1. Bollean,M.H.J., Hasan,F., (2011), *Integration of Distributed Generation in the Power Systems*, Willey-IEEE India Press
2. Ehsani,M., Gao,Y., Gay,S.E., Emadi,A., (2005), *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design*, CRC Press

3. Bansal,R., (2019), *Power System Protection in Smart Grid Environment*, CRC Press

Self Learning Material

1. The Smart Grid: An Introduction, http://www.oe.energy.gov/SmartGridIntroduction.htm, Department of Energy, 2008.

Title	**Life Cycle Analysis and Sustainable Engineering Concepts**	**Number**	**EALXXX**
Department	Energy and Automotive Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech/MTech/PhD	Type	Elective
Prerequisite	None		

Course Objectives:

The course aims to:

- Introduce sustainability challenges associated with modern engineering systems.
- Develop a strong conceptual understanding of Life Cycle Assessment methodology.
- Apply LCA tools and indicators to evaluate engineering products and processes.
- Integrate sustainability principles into engineering design and decision-making.
- Examine case studies from multiple engineering disciplines to illustrate real-world applications.

Learning Outcomes:

After completing this course, students will be able to:

- Explain the concept of sustainability in engineering systems.
- Apply the LCA framework to analyze environmental impacts of products and technologies.
- Develop and interpret life cycle inventories and impact assessment results.
- Evaluate sustainability trade-offs in engineering design decisions.
- Critically assess environmental performance of engineering technologies across different sectors.

Course Contents:

Sustainability Concepts [13 Lectures]: Sustainable Engineering Concept; Understanding with International and National Sustainable Goals; Environmental Indicators; Carbon-water-food Nexus; Environmental Risk Assessment; Sustainability Challenges Across Engineering Sectors Including Manufacturing, Infrastructure, Material, Transportation, and Energy Systems; Introduction to Life Cycle Thinking; Stages of Life Cycle; Circularity, Cradle-to-Cradle and other sub-sets; Allocation Principles; Overview of International Standards for LCA.

LCA Methodology [Lecture 13]: System Modeling for Engineering Application; Functional Units and System Boundaries; Collection & Generation of Inventory Data; Data quality and Uncertainty; Inventory Analysis Methods; Environmental Impact Indicators; Impact Assessment Strategies; Midpoint and Endpoint Methods; Sensitivity Analysis; Scenario Assessment Methods; Interpretation of LCA Results; Limitations of LCA Studies; Introduction of the LCA tools. Example of Hard-to-Abate sectors like Steel, Power, Cement etc.

Sustainable Engineering Design [Lecture 13]: Material Releases in the Environment; Green and Sustainable Materials; Sustainable Product, Process, Services and Systems Design; Design for Resilience and Sustainability; Concept of ECO Design; Sustainable Engineering Design Principles, Introduction of Techno Economic Assessment; Socio Economic Trade-off, Environmental Risk, and End of Life Assessment; Engineering Case Studies in LCA, Policy Driven LCA.

Tutorial: Hands on LCA tool practices like GREET, Sima Pro, OpenLCA.

Reading Materials

1. Mary Ann Curran, 'Life Cycle Assessment Student Handbook', Wiley.
2. Krishna R. Reddy, Claudio Cameselle, Jeffrey A. Adams, 'Sustainable Engineering: Drivers, Metrics, Tools, and Applications', Wiley.
3. Martin A. Abraham, 'Sustainability Science and Engineering: Defining Principles', Elsevier.
4. Agarwal AK, Biswas S. LCA and TEA for Sustainable Development. Springer Nature Singapore, Imprint: Springer; 2025 Oct 9.

Online Materials:

1. https://www.sciencedirect.com/science/article/pii/S0016236126003492
2. https://legacy.sae.org/publications/technical-papers/content/13-06-02-0012/
3. https://www.sciencedirect.com/science/article/pii/S0016236125039390

Title	**Internal Combustion Engines**	**Number**	**EALXXX**
Department	Energy and Automotive Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech/MTech/PhD	Type	Elective
Prerequisite	Thermodynamics		

Course Objectives:

- To impart fundamentals of IC engines, thermodynamic cycles, and fuel–air chemistry.
- To cover combustion, ignition, cooling, and lubrication in SI and CI engines.
- To develop skills for performance analysis, including supercharging and turbocharging.
- To understand engine emission formation, control methods

Learning Outcomes:

- Understand IC engine cycles (Otto, Diesel, Dual) and combustion in SI/CI engines.
- Analyze performance parameters, effects of knocking, friction, and efficiency.
- Learn fuel injection, alternative fuels, and emission control.

Course Contents:

Fundamentals of IC Engines, Thermodynamic Cycles and Fuels [Lecture 13]: Introduction, Heat Engine and Classification, IC engine components and basic Terminology, Basic working Principle, Engine Performance Parameters. Thermodynamic cycles, Effect of variables on engine performance, Actual Engine Cycles. Energy Scenario, Liquid Fuels and their Characteristics, Alternative Fuel Factors. Fossil Fuel Formation, various Sources, Drilling Arrangements, Crude Oil Composition, Petroleum Refining, Refined Petroleum Products, Fuels Properties. Stoichiometric Combustion of Fuels, Heat of Reaction, Adiabatic Flame Temperature.

Combustion in SI and CI Engines and Different Engine Systems [Lecture 13]: Examples of CI and SI engine, Engine Performance, Combustion in SI engines, Combustion in CI engine, Knocking in SI and CI engine, Effect of Engine Variables on Knock, Comparison of knocking in SI & CI engine, factors affecting Detonations. Different Ignition Systems and Working, Component of Battery Ignition System and working. Variation of Temperature and Parametric Affecting Engine Heat Transfer, Types of Cooling System, Diagnosis of Cooling Systems Problems, Engine Friction and Types, Factors affecting Mechanical Friction, Different Lubrication Systems (Mist, Wet Sump, Dry Sump). Properties of Lubricants. Boosting the Engine, Supercharging, Turbocharger, Turbocharger and Supercharger Configurations

Fuel Injection, Engine Design, Performance, and Emissions [Lecture 13]: Carburetor, Electronic Fuel Injection (EFI) System, Electronic control of engines, Types of Injection system for CI engine. Combustion Chambers in SI engines, Combustion Chamber Design, Direct Injection and Indirect Injection Chamber, Different Types of Swirl, Direct Injection Volumetric Combustion Chamber Illustrating Phases of Combustion. Engine performance characteristics for SI & CI engine, Variables affecting performance characteristics, Methods of improving engine performance, Performance Maps. Measurement of Speed, Fuel Consumption Measurement, Volumetric type flowmeters, Air consumption, Brake Power. Types of Dynamometer, Measurement of Frictional Power, Indicated Power. Effect of Various Parameters on Exhaust Emissions, Exhaust Emissions from SI & CI Engines, Gasoline and Diesel Engine Emission Control and Comparison.
Reading Materials: 1. Heywood, J. B. (1988). Internal combustion engine fundamentals. McGraw-Hill Education. 2. Gill, P. W., Smith, J. H., & Ziurys, E. J. (2017). Fundamentals of internal combustion engines (4th ed.). Oxford & IBH Publishing Co. 3. Stone, R. (1999). Introduction to internal combustion engines (4th ed.). SAE International. 4. Lakshminarayanan PA, Agarwal AK, Design and Development of Heavy Duty Diesel Engines Springer Nature Singapore, Imprint: Springer; 2019 5. Lakshminarayanan PA, Agarwal AK, Handbook of Thermal Management of Engines, Springer Nature Singapore, Imprint: Springer; 2022 **Online Materials:** **NPTEL:** https://www.youtube.com/playlist?list=PLjI7n73QrhzSPo_xrKmBLaz9DIL3XP2f6

Title	**Alternate Fuels and Advances in IC Engines**	**Number**	**EALXXX**
Department	Energy and Automotive Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech/MTech/PhD	Type	Elective
Prerequisite	IC Engines		

Course Objectives:

- To provide advanced knowledge of combustion and fuel refining for SI and CI engines.
- To analyze the viability and technical requirements of liquid and gaseous alternative fuels.
- To introduce modern engine technologies such as GDI, HCCI, and Turbocharging.
- To introduce advanced optical diagnostic techniques and emission control systems.

Learning Outcomes:

- Understand thermodynamic analysis of combustion & factors affecting knocking in engines.
- Evaluate the performance and tribological effects of biofuels, Hydrogen, CNG, and LPG.
- Gain knowledge of optical measurement tools like PIV and Laser diagnostics.
- Analyze emission standards & the functionality of after-treatment devices (DOC, SCR, DPF).

Course Contents:

Fundamental of IC Engine and Advanced Combustion Technologies [13 Lectures]: Renewable energy sources, pollutants (regulated and unregulated emissions), effect on human health, Alternative fuel for transportation sector, Fuel properties, Different phases of combustion, Thermodynamic analysis of SI engine combustion, combustion efficiency and various losses, Abnormal combustion in SI engines, Fuel factors responsible for knocking. Design of engine combustion chamber for IDI and DI engines, Characteristics of common rail diesel combustion systems, Ignition delay, chemical delay, factors affecting delay period, Swirl, Combustion DI engine and heat release analysis, comparison of DI and IDI engine combustion chambers. Exhaust gas recirculation (EGR), Classification of EGR systems, EGR ratio, Internal and external EGR systems, HCCI, Comparison with SI & CI, Combustion in HCCI.

Combustion of Alternative Fuels [13 Lectures]: Alternative fuels: environmental implication of using fossil fuels, Introduction to biofuels, Chemistry of vegetable oils, Advantages/ Disadvantages of vegetable oils as fuels, Transesterification for biodiesel production, Performance and emission test of biodiesel, emulsified fuels. CNG, Advantages/ Disadvantages, Properties, Various CNG induction techniques, CNG performance, emissions, maintenance, LNG, unregulated emissions, Storage systems, leak detection systems and safety instrumentation, Hydrogen fuelled vehicles, Hydrogen generation processes, Combustion properties & design of Hydrogen engines based on induction methods, LPG, Di-methyl ether, Hythane.

Advanced Fuel Induction, Diagnostics, and Emission Control Technologies [13 Lectures]: Fuel induction strategies, MPFI Systems, Speed density electronic multi point port fuel injection system (D-Jetronic), Air mass flow meter system (L-Jetronic) and K-Jetronic systems, Turbocharger, various systems and turbocharger controls, GDI engine, Key technical features, Two-stage mixing, Two-combustion modes, Compliance with emission standards. Optical diagnostic techniques: Fundamentals of PIV, types of lasers, PIV working principle, components and general aspects, applications, advantages, 3D and holographic PIV, Spray visualisation, Phase Doppler interferometry for spray characterisation, Optical engine and engine endoscopy. Exhaust gas emission analysis, FID and NDIR, Chemiluminescence technique, smoke opacity, Exhaust gas after-treatment, Three Way Catalysts, DOC, DPF, CRT, LNT and its working, LNT issues, Urea SCR catalyst system. 1-2 lab visits and a real-time demonstration may be planned if time permits.

Reading Materials:

6. Heywood, J. B. (1988). Internal combustion engine fundamentals. McGraw-Hill Education.
7. Gill, P. W., Smith, J. H., & Ziurys, E. J. (2017). Fundamentals of internal combustion engines (4th ed.). Oxford & IBH Publishing Co.
8. Stone, R. (1999). Introduction to internal combustion engines (4th ed.). SAE International.
9. Lakshminarayanan PA, Agarwal AK, Design and Development of Heavy Duty Diesel Engines Springer Nature Singapore, Imprint: Springer; 2019
10. Lakshminarayanan PA, Agarwal AK, Handbook of Thermal Management of Engines, Springer Nature Singapore, Imprint: Springer; 2022

Online Materials:

NPTEL: https://www.youtube.com/playlist?list=PLjI7n73QrhzSPo_xrKmBLaz9DIL3XP2f6