M.Tech.

IN

ENERGY ENGINEERING AND MANAGEMENT

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

Department of Mechanical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech.in Energy Engineering and Management

PEO1	Impart the graduates with in-depth and advanced knowledge to become professionals in the areas of energy engineering and related fields capable of identifying, analysing and solving practical engineering problems.
PEO2	Enable graduates to carry out innovative and independent research work in academia/industry to develop energy efficient systems and processes and to disseminate the knowledge.
PEO3	Prepare the graduates to exhibit a high level of professionalism, integrity, environmental and social responsibility, and life-long independent learning ability.

Programme Outcomes (POs) of M.Tech. in Energy Engineering and Management

PO1	Independently carry out research/investigation and development work to solve practical problems
PO2	Write and present a substantial technical report/document
PO3	Demonstrate a degree of mastery in energy engineering and management at a level higher than the requirements in the appropriate bachelor program.
PO4	Acquire and share in-depth knowledge in the area of energy engineering and management.
PO5	Analyse complex problems in the field of energy engineering critically and arrive at optimal solution
PO6	Use modern computer/software tools to model and analyse problems related to energy engineering and management

CURRICULUM

Total credits for completing M.Tech. in Energy Engineering and Management is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	26
2.	Program Electives (PE)	12
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA6002E	Mathematical Methods for Thermal and Energy Systems	3	1	0	5	3	PC
2.	ME6401E	Fluid Flow and Heat Transfer in Energy Systems	3	0	0	6	3	PC
3.	ME6402E	Alternative Energy Technologies	3	0	0	6	3	PC
4.	ME6491E	Computational Lab for Energy Engineering	1	0	3	5	3	PC
5.		Elective-1	3	0	0	6	3	PE
6.		Elective-2	3	0	0	6	3	PE
7.		Institute Elective	2	0	0	4	2	IE
		Total	**18**	**1**	**3**	**38**	**20**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME6411E	Advanced Energy Conversion Systems	3	1	0	8	4	PC
2.	ME6412E	Design and Analysis of Energy Systems	3	0	0	6	3	PC
3.	ME6413E	Industrial Energy Conservation and Audit	3	1	0	8	4	PC
4.		Elective 3	3	0	0	6	3	PE
5.		Elective 4	3	0	0	6	3	PE
6.	ME6492E	Energy Engineering Lab	1	0	3	5	3	PC
7.	ME6493E	Project Phase I	0	0	0	6	2	PC
		Total	**16**	**2**	**3**	**45**	**22**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME7494E	Project Phase II	0	0	0	9	3	PC
2.	ME7495E	Project Phase III	0	0	0	45	15	PC
		Total	**0**	**0**	**0**	**54**	**18**	**--**

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME7496E	Project Phase IV	0	0	0	45	15	PC
		Total	**0**	**0**	**0**	**45**	**15**	**--**

List of Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	ME6421E	Direct Energy Conversion Systems	3	0	0	6	3
2	ME6422E	Energy and Environment	3	0	0	6	3
3	ME6423E	Integrated Energy Systems	3	0	0	6	3
4	ME6424E	Energy Policies for Sustainable Development	3	0	0	6	3
5	ME6425E	Machine Learning for Thermal and Energy Systems	3	0	0	6	3
6	ME6426E	Battery Management Systems for Electrical Vehicles	3	0	0	6	3
7	ME6427E	Heat Pump Technology	3	0	0	6	3
8	ME6428E	Design of Solar Thermal Systems	3	0	0	6	3
9	ME6429E	Energy Efficient Buildings	3	0	0	6	3
10	ME6430E	Alternative Fuels- Production and Applications	3	0	0	6	3
11	ME6431E	Computational Methods for Heat Transfer and Fluid Flow	3	0	0	6	3
12	ME6432E	Industrial Combustion and Pollution Control	3	0	0	6	3
13	ME6433E	Hydrogen-Production, Storage and Utilization	3	0	0	6	3
14	ME6434E	Energy Modelin g, Economics and Project Management	3	0	0	6	3
15	ME6435E	Hydropower Systems	3	0	0	6	3
16	ME6436E	Wind Energy Technology	3	0	0	6	3
17	ME6437E	Thermodynamic Property Relations and Exergy Analysis	3	0	0	6	3

List of Institute Electives

Sl. No.	Code	Course Name	L	T	P	O	C
1	IE6001E	Entrepreneurship Development	2	0	0	4	2
2	ZZ6002E	Research Methodology	2	0	0	4	2
3	MS6174E	Technical Communication and Writing	2	1	0	3	2

MA6002E MATHEMATICAL METHODS FOR THERMAL AND ENERGY SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the concepts of vector calculus
CO2: Develop the analytic approach for solving differential equations for thermal and energy systems
CO3: Apply the finite difference and finite volume methods for differential equations
CO4: Implement the analytical and computational techniques in thermal and energy systems

Vector Calculus
Gradient, Divergence, Curl operators and their interpretation, Line Integrals, Surface Integrals, Volume Integral, Gauss-Divergence theorem, Green's Theorem, and Stokes' theorem with applications.

ODE and PDE-Analytical solutions to ordinary and partial differential equations
First-order differential equations: Initial value problem, Solution techniques and applications, Second-order differential equations: homogeneous and nonhomogeneous cases. Boundary value problem: Shooting methods, Applications of second-order differential equations, series solutions, Frobenius method, Sturm-Liouville problems, Bessel and Legendre equations; Systems of first-order differential equations, Partial differential equations: Cauchy problem, Method of characteristics, classification of second-order PDEs, Solution to one-dimensional unsteady heat conduction equation, Solution to one-dimensional wave equation using variable separable methods, d'Alembert's solution, Solution to two-dimensional Laplace equation

Numerical solutions to ordinary and partial differential equations
First and higher-order numerical methods for solving first-order differential equations, Implementation of higher-order ordinary differential equations: boundary value problem: Finite difference and shooting method, Data-fitting, Interpolation, Least-squares, Numerical methods for scalar transport equation, Finite difference methods for heat, wave, and Laplace equations. Introduction of finite volume method.

Case studies: Solution for liquid flat plate collector with steady or variable heat flux, Solution for liquid parabolic collector with steady or variable heat flux, Energy storage system, Wind energy system, Fuel cell, Droplet combustion, Application of Bessel function for 2-D heat conduction problem

References:

[1] Kreyszig, E, 2011, *Advanced Engineering Mathematics*, Wiley.

[2] Simmons, G.F., 2017, *Differential Equations with Applications and Historical Notes*, McGraw Hill.

[3] Ross, S. L., 2004, *Differential Equations*, John Wiley & Sons, Inc.

[4] Buchanan, J R and Shoude, Z, 2017, *A First Course in Partial Differential Equations*, World Scientific.

[5] Butcher, J C, 2003, *Numerical Methods for Ordinary Differential Equations*, Wiley.

[6] Thomas, J W, 2013, *Numerical Partial Differential Equations: Finite Difference Methods*, Springer.

[7] Versteeg, H K and Malalasekera, W, 2007, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, Pearson Ed. Ltd.

ME6401E FLUID FLOW AND HEAT TRANSFER IN ENERGY SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate the conservation equations in different frames of reference and in different approaches
CO2: Model the conduction heat transfer in different practical situations and rate evaluation
CO3: Model the convective heat transfer in different practical situations and rate evaluation
CO4: Model the radiation heat transfer in different practical situations and rate evaluation

Review of fundamentals: continuum, Eulerian and Lagrangian methods, kinematics of fluid flow; Reynolds transport theorem; Integral and differential forms of continuity, momentum, and energy equations; Navier-Stokes equation; Boundary conditions; Analytical solutions to Couette flow, Couette-Poiseuille flow, Hagen-Poiseuille flow, flow through annulus, flow between rotating cylinders; Order of magnitude analysis; Analytical solution to creeping flow; Integral and similarity solutions to boundary layer flows.

Differential formulation of heat conduction; initial and boundary conditions; Solutions to one dimensional and two dimensional steady state conduction with reference to standard geometries; Solution to one dimensional unsteady state conduction, lumped system, mixed boundary conditions, infinite and semi-infinite solids; Differential formulation of convective heat transfer; Solutions to external forced convective heat transfer; Internal forced convection; Solutions to fully developed internal forced convective heat transfer; Natural convection; Conductive heat transfer in energy systems; Convective heat transfer in energy systems.

Review of concepts and laws of blackbody radiation; Radiation properties for real bodies and Kirchoff's law; Shape factor algebra; Modeling of enclosure; Radiation between blackbodies; Radiation between real bodies, surface and space resistances, direct and network methods; Radiation shields; Gas radiation and Beer's law; Network method and chart solutions to gas radiation.

References:

[1] Muralidhar, K. and Biswas, G., 2015, Advanced *Engineering Fluid Mechanics*, Narosa.

[2] Poulikakos, D., 1994, Conduction *Heat Transfer,* Prentice Hall.

[3] Arpaci, V.S., 1996, *Conduction Heat Transfer,* Addison Wesley.

[4] Carslaw, H.S. and Jaeger, J.C., 1959, *Conduction of Heat in Solids*, Oxford University Press.

[5] Bejan, A., 2013, Convection *Heat Transfer*, J. Wiley.

[6] Modest M.F., 2021, *Radiative Heat Transfer,* Academic Press.

ME6402E ALTERNATIVE ENERGY TECHNOLOGIES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the nature and availability of different alternative energy sources
CO2: Describe the different energy conversion systems based on alternative energy
CO3: Model the energy conversion and evaluate useful energy from alternative energy conversion devices
CO4: Analyse the performance of alternative energy conversion devices

Solar energy
The Sun- Production and transfer-Availability and limitations-Sun-Earth angles-Sun path diagram- Solar radiation- Extraterrestrial solar radiation- Terrestrial irradiation- solar radiation on horizontal and inclined planes- Measuring techniques and estimation of solar radiation- Solar energy collectors: stationary collectors-Flat plate collectors- Compound parabolic collectors-Evacuated tube collector- Sun tracking concentrating collectors-Parabolic trough collectors- Fresnel collectors- Parabolic dish collectors- Heliostat field collectors- Thermal analysis of flat plate collectors: Absorbed solar radiation- Collector energy analysis- Temperature distribution- Collector efficiency factor- Thermal analysis of air collector-Other Applications – Solar cooker, Building heating and cooling, Solar cooling – Absorption cooling, desiccant cooling, and mechanical cooling.

Solar energy systems
Passive systems- Active systems- Energy storage: Sensible heat storage- Liquid media storage- Solid media storage- Dual media storage- Phase change energy storage- Storage Capacity-Other storage methods- Solar dehumidification: Design- performance and applications- Combined solar heating and cooling systems- Special topics on solar energy – Solar industrial process heating. Energy from biomass: Sources of biomass- Different species- Conversion of biomass into fuels- Energy through fermentation: Pyrolysis- gasification- combustion- Aerobic and anaerobic bio-conversion: Types of biogas plants: Design and operation.

Other renewable energy systems
Wind energy-Availability- Turbine types: Horizontal axis machines- vertical axis machines- Concentrators- Linear momentum and basic theory: Energy extraction- Axial force- Torque- Drag machines- Dynamic matching: optimal rotation rate- tip speed ratio- Extensions for linear momentum theory- Blade elementary theory. Geothermal energy – Availability- system development and limitations – Ocean thermal energy conversion – Wave and tidal energy – Scope and economics – Introduction to integrated energy systems. Economic and life cycle analysis of solar and wind energy systems.

References:

[1] Duffie, J. A. and Beckman, W.A., 2013, *Solar Engineering of Thermal Processes*, J. Wiley.
[2] Saigh, A. A. M. (Ed), 1977, *Solar Energy Engineering*, Academic Press.
[3] Kreith, F. and Kreider, J.F., 1978, *Principles of Solar Engineering*, McGraw Hill.
[4] Tiwari, G. N., 2002, *Solar Energy-Fundamentals- Design- Modelling and Applications*, Narosa Publishers.
[5] Kalogirou, S. A., 2009, *Solar Energy Engineering Processes and Systems*, Elsevier.
[6] Twidell, J. and Weir, T., 2006, *Renewable Energy Resources*, Taylor& Francis.
[7] Mittal, K. M., 1997, Non-*conventional Energy Systems-Principles- Progress and Prospects*, Wheeler Publications.
[8] Rai, G. D., 2003, *Non-conventional Energy Sources*, Khanna Publishers.

ME6491E COMPUTATIONAL LAB FOR ENERGY ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
1	0	3	5	3

Total Sessions: 9L + 30P

Course Outcomes:

CO1: Solve complex fluid flow and heat transfer in energy systems using the software.
CO2: Numerical discretization of ODEs and PDEs using state-of-the-art algorithms and development of coding skills.
CO3: Model the fluid flow and heat transfer in energy systems.
CO4: Numerically predict and analyze the data, with meaningful physical insights, of various problems.

Lecture Sessions:

Introduction to numerical method; algorithms; numerical schemes; explicit and implicit methods; initial value problem; boundary value problem; numerical integration and differentiation; application in energy systems (for instance, heat exchangers, fluid flow and heat transfer in flat plate collector, cooling of battery pack using fins, etc.) - fluid flow or heat transfer in internal or external flows.

Practical Sessions:

List of Computational Experiments

1. Fluid flow and heat transfer in a mixing elbow-pipe and comparison of accuracies of discretization schemes (using a software).
2. Flow past a cylinder and comparison with the analytical data (using software).
3. Heat transfer in a concentric pipe and comparison with the experimental data (using software).
4. Velocity boundary layer flow over a flat plate using software and comparison with the analytical data (using software).
5. Unsteady heat transfer from suddenly dropped hot square plate or slab in cold water (using software).
6. A computer program for finding roots of a given algebraic or transcendental equation (for instance, using the Newton-Raphson Method, Bisection Method, etc.).
7. A computer program for solving ODE (for instance, using the Euler method, RK method, etc.).
8. Computer implementation of numerical integration for one or two dimensions.
9. Computer program for solving 1D transient heat conduction using the explicit method.
10. Solution of simultaneous algebraic equations: A computer program to solve unsteady 1D heat conduction using TDMA.

References:

[1] Press, W., Flannery, B.P., Teukolsky, S.A., Vetterling, W. T., 2007, *Numerical Recipes in C: The Art of Scientific Computing*, Cambridge University Press
.

[2] Ozisik, N., 2017, *Finite Difference Methods in Heat Transfer*, CRC Press.

[3] Jaluria, Y., 2017, *Computational Heat Transfer*, Taylor and Francis group.

[4] Jaluria, Y., 2012, *Computer Methods for Engineering with MATLAB Applications*, Second ed, CRC Press.

[5] Chapra, S. C. and Canale, R. P., 2012, *Numerical Methods for Engineers*, McGraw-Hill.

[6] Chapra, S. C., 2017, *Applied Numerical Methods with MATLAB for Engineers and Scientists* McGraw-Hill Education.

[7] Griffith, D. V. and Smith, I. M., 2019, *Numerical Methods for Engineers: A Programming Approach*, CRC Press.

ME6411E ADVANCED ENERGY CONVERSION SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	8	4

Total Lecture and Tutorial Sessions: 52

Course Outcomes:

CO1: Ability to assess different kinds of fuels and their properties, and write combustion reactions
CO2: Analyse the energy conversion techniques in different components of steam turbine power plants
CO3: Analyse the energy conversion techniques in different components of gas turbine power plants
CO4: Analyse nuclear reactions and to execute thermal design of nuclear reactors
CO5: Analyse heat removal from nuclear reactor core and ability to evolve strategies to protect the environment from nuclear emissions

Fuels and combustion
Combustion fundamentals: fossil fuels – solid/liquid/gaseous fuels, heating values; combustion thermodynamics – laws of thermodynamics, combustion stoichiometry, adiabatic flame temperature, chemical equilibrium; Introduction to combustion chemistry.

Steam power plants
Conventional thermal power plant design and operation - reheat and regeneration, Combined cycle power plants; Co-generation, Tri-generation; High-pressure boilers: Steam generator control; Other auxiliaries of thermal plant – steam drum, superheaters, reheaters, once-through boilers, economizers, preheaters; performance evaluation of boiler and its auxiliaries, Integrated Gasification Combined Cycle.

Gas turbine power plants
Gas turbine and combined cycle analysis – Intercooling, reheating and regeneration, gas turbine cooling; design for high temperature; combined cycles with heat recovery boiler, combined cycles with multi-pressure steam, STAG combined cycle power plant, influence of component efficiencies on cycle performance, gas turbine applications. Catalytic combustion systems.

Nuclear fuel, power plants and safety
Nuclear energy conversion: Chemical and nuclear equations, nuclear reactions, Fission and fusion, Energy from fission and fuel burn-up, Radioactivity, Neutron energies, fission reactor types; Nuclear power plants – Fast breeder reactor and power plants; Production of nuclear fuels. Fuel rod design – Steam cycles for nuclear power plants, reactor heat removal, Coolant channel orificing, Core thermal design, Thermal shields, Fins in nuclear plants, Core thermal hydraulics, Safety analysis, LOCA, Time scales of transient flow and heat transfer processes.

References:

[1] Mishra, D.P., 2008, *Fundamentals of Combustion*, PHI.
[2] Mukunda, H.S., 2009, *Understanding Combustion*, University Press.
[3] Irvin Glassman, Richard, A. Yetter, Nick, G. Glumac, 2014, *Combustion*, Elsevier.
[4] El-Wakil, M. M., 1985, *Power Plant Technology*, McGraw Hill.
[5] Culp Jr, A. W., 2001, *Principles of Energy Conversion*, McGraw Hill.
[6] Sorensen, H. A., 1983, *Energy Conversion Systems*, J. Wiley.
[7] Morse, T. F., 1978, *Power Plant Engineering*, Affiliated East West Press.
[8] El-Wakil, M. M., 1962, *Nuclear Power Engineering*, McGraw Hill.
[9] Winterton, R. H. S., 1981, *Thermal Design of Nuclear Reactors*, Pergamon Press.
[10] Raymond Murray, Keith E Holbert, 2019, *Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes*, Butterworth-Heinemann.

ME6412E DESIGN AND ANALYSIS OF ENERGY SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design energy systems for engineering applications and model their performance (like turbo machines, heat exchangers, HVAC systems, etc.).
CO2: Analyze systems (particularly, energy systems) as a whole under design and off-design operating conditions.
CO3: Improve and optimize the system performance, especially, with respect to energy systems.

Fundamentals of System Design
Engineering design fundamentals - Designing a workable system - Economic evaluation - Fitting data and solving equations - Heat exchanger design calculations – Evaporators, cooling towers, and condensers temperature concentration - pressure characteristics of binary solutions - Rectifiers - Cooling towers -Pressure drop and pumping power.

Applications of System Design
Pump characteristics - Manufacturer's specifications - Relations among performance characteristics -Pump system operation - Cavitation prevention - Other system considerations, Fans and nozzles – Basics of second law analysis in heat and fluid flow - Applications in thermal design.

Modeling and Optimization
Modeling and simulation principles - Hardy-Cross method - Multivariable, Newton-Raphson simulation method - Simulation of a gas turbine system - Simulation of a vapor absorption refrigeration system - Simulation using differential equations - Mathematical modeling of thermodynamic properties - Steady state simulation of large systems – Simulation of dynamic systems - Design optimization – Component optimization for maximum efficiency, energy storage optimization - Knowledge based system design.

References:

[1] Bejan, A., 1995, *Thermal Design and Optimization*, John Wiley.

[2] Jaluria, Y., 2008, *Design and Optimization of Thermal Systems*, CRC Press.

[3] Stoeker, W.F., 1989, *Design of Thermal Systems*, McGraw Hill.

[4] Hodge, B.K., 1990, *Analysis and Design of Energy Systems*, Prentice Hall.

[5] Boehm, R.F., 1987, *Design Analysis of Thermal systems*, John Wiley.

[6] Yunus A. Cengel, 1994, *Thermodynamics: An Engineering approach*, McGraw Hill.

[7] Taha, H. A., 2007, *Operations Research: An Introduction*, Prentice-Hall of India Pvt. Ltd.

[8] Sastry, S. S., 1988, *Introductory Methods in Numerical Analysis*, Prentice-Hall.

ME6413E INDUSTRIAL ENERGY CONSERVATION AND AUDIT

Pre-requisites: NIL

L	T	P	O	C
3	1	0	8	4

Total Lecture and Tutorial Sessions: 52

Course Outcomes:

CO1: Ability to perform energy audit of industrial systems
CO2: Analyze the energy conversion efficiencies and specific energy consumption of industrial systems
CO3: Analyze the performance of industrial energy systems based on exergy
CO4: Perform techno-economic analysis of industrial energy systems

Efficiency and sustainability in industrial energy systems, current scenario; energy auditing: methodology, instruments for energy audit, analysis of plant data and systematic reporting, application of mass and energy balance; supply and demand side management, DSM measures; steam systems: steam generator performance, excess air control, steam distribution and use of steam traps; thermal Insulation and refractories, energy conservation in furnaces; waste heat recovery options, case studies.

Cogeneration: different schemes, performance assessment; energy conservation in the built environment and HVAC systems, thermal energy storage systems and applications in energy conservation, case studies; exergy analysis of thermal systems: reversible work and exergy destruction, exergy transfer and exergy balance; exergy efficiency of thermal systems; thermo-economics and pricing of utilities; heat exchanger networking: concept of pinch, energy targeting, composite curves, problem table algorithm.

Electrical energy management: overall structure of electrical systems, economic operation; reactive power, power factor correction and capacitor sizing; transformer loading and efficiency analysis; feeder loss evaluation; energy efficient lighting schemes.

Electric motors: types and operating characteristics of electric motors, energy efficient control and starting, load matching, motor selection; industrial drives and control schemes, variable speed drives and energy conservation options; energy conservation in pumps and fans; case studies.

References:

[1] Thumann, A., Niehus, T., and Younger, W. J., 2013, *Handbook of Energy Audits*, CRC Press.

[2] Doty, S. and Turner, W. C., 2007, *Energy Management Handbook*, Fairmont Press.

[3] Chiogioji, M. H., 1979, *Industrial Energy Conservation*, Marcel Dekker.

[4] Kenney, W. F., 1984, *Energy Conservation in the Process Industries*, Academic Press.

[5] Morvay, Z. K. and Gvozdenac, D. D., 2008, *Applied Industrial Energy and Environmental Management*, Wiley.

[6] Kanoglu, M., Cengel, Y. A., and Dincer, I., 2012, *Efficiency Evaluation of Energy Systems*, Springer.

[7] Kemp, I. C., 2007, *Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy*, Elsevier.

[8] IEEE, 1996, *IEEE Bronze Book: IEEE Standard 739-1984-Recommended Practice for Energy Conservation and Cost-Effective Planning in Industrial Facilities,* IEEE Publications.

ME6492E ENERGY ENGINEERING LABORATORY

Pre-requisites: NIL

L	T	P	O	C
1	0	3	5	3

Total Sessions: 39

Course Outcomes:

CO1: Ability to develop rectifying solutions for existing energy systems
CO2: Design and fabricate energy systems as per the requirement based on the theory and principles learnt.
CO3: Analyze the performance of existing energy systems and improve the design and operation using the various tools learnt.

List of Suggested Experiments on Energy Systems:

1. Performance study on Heat Exchangers
2. Performance study on Refrigeration Systems
3. Performance study on Heat Pumps
4. Experiment on Wind Energy System
5. Experiment on Solar PV System
6. Performance of Solar Water Heater.
7. Experimentation on Solar Air Heaters
8. Performance of Solar Still
9. Performance Study on Biomass Gasifiers
10. Experiment on Fluidized Bed System
11. Experiment on Waste Heat Recovery Systems
12. Performance study of PV/T Heat Pump-based Water Heater
13. Experiment on Indoor Solar Air Heater with Dryer
14. Experiment on Exhaust Gas Recirculation in Diesel Engine
15. Experiment on Dual Fuel Engine
16. Experiment on Fluidized Bed Combustor

References:

[1] Sukhatme, S. P. and Nayak, J. K., 2017, *Solar Energy*, McGraw Hill Publications.

[2] Stoecker, W. F., 1987, *Refrigeration & Air conditioning*, McGraw-Hill.

[3] Arora, C. P., 2000, *Refrigeration & Air conditioning*, McGraw-Hill.

[4] Holman, J. P. and Bhattacharya, S., 2002, *Heat Transfer*, McGraw Hill Education.

[5] Howard, J.R., 1989, *Fluidized Bed Technology, Principles and Applications*, CRC Press.

[6] Thummann, A.P.E.,1984, *Fundamentals of Energy Engineering*, Prentice Hall.

[7] Prabir Basu, 2006, *Combustion and Gasification in Fluidized Beds*, CRC Press.

[8] Garg, H. P. and Kandpal, T. C., 1999, *Laboratory Manual on Solar thermal Experiments*.

ME6493E PROJECT PHASE I

L	T	P	O	C
0	0	0	6	2

Pre-requisite: NIL

Course Outcomes:

CO1: Understand the process of reviewing and recording the literature
CO2: Understand the process of identification of the project problem
CO3: Apply the learning to define the problem and problem environment/boundary conditions
CO4: Develop a focused research learning, presentation and communication

Project Phase I is normally an initiation into the project.

Each student shall identify a topic of interest related to energy engineering and management. He/she shall get the topic approved by the project guide in the concerned area of specialization. The student is expected to conduct a literature survey. A mid semester evaluation shall be done by the duly constituted evaluation committee. At the end of the semester the student shall present the project problem and the related literature in the presence of the evaluation committee. Grade will be awarded on the basis of the student’s work and presentation.

ME7494E PROJECT PHASE II

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem
CO2: Analyze and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop algorithms and solve the problem.
CO4: Analyze and interpret the results using tables and figures for visualization
CO5: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis
CO6: Publish the findings in reputed journals, conferences or apply for patents

Project Phase II can be an extension of Phase I or internship outside during the summer semester break. Students shall continue to work on the problem identified in the project phase I or undergo internship outside. Students shall identify the methodology, apply for a preliminary work. The work should be suitable for communicating to a conference. The student shall submit a report. All the projects will be evaluated by a duly constituted committee.

ME7495E PROJECT PHASE III

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Analyze and Identify a suitable research methodology for solving the problem identified.
CO2: Apply the methods/tools learned to develop algorithms and solve the problem.
CO3: Analyze and interpret the results using tables and figures for visualization
CO4: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis
CO5: Publish the findings in reputed journals, conferences or apply for patents

The project work can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project work in an industry or in other organizations have to fulfil the requirements as specified in the "Ordinances and Regulations for M. Tech." The student is expected to complete the pilot study, redefine the project based on pilot study, decide on the appropriate research design, generate data/collect data, develop the algorithm and code, and obtain preliminary results in the third semester. There shall be evaluations of the project work during and at the end of the third semester by a committee constituted by the department.

ME7496E PROJECT PHASE IV

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L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Analyze and Identify a suitable research methodology for solving the problem identified.
CO2: Apply the methods/tools learned to develop algorithms and solve the problem.
CO3: Analyze and interpret the results using tables and figures for visualization
CO4: Compile and construct a report by employing the techniques of academic writing critical analysis, and defend the thesis
CO5: Publish the findings in reputed journals, conferences or apply for patents

The project work will be extended to the end of the fourth semester. There shall be evaluations of the project work by a committee constituted by the department during the fourth semester. The student shall submit the thesis based on the recommendation of the departmental evaluation committee. There shall be viva-voce examination conducted by an evaluationcommittee with an external examiner.

“The project work/thesis will be considered for awarding Grade ‘S’ only if a paper, based on whether the project work is published/accepted for presentation at least in a Scopus indexed conference or a software copyright is granted. However, in exceptional cases, where the student and the guide want to submit a journal/conference publication at a later stage and if the student is able to submit the draft version of the journal/conference paper to the evaluation committee at the time of final presentation of the project work, the student may be considered for awarding ‘S’ grade if the committee finds the work to be excellent and guide ensures the submission of the work for journal/conference publication”

ELECTIVE COURSES

ME6421E DIRECT ENERGY CONVERSION SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Impart knowledge of the underlying principles of direct energy conversion and the technological options for its utilization in various end use applications.
CO2: Apply the principles of thermodynamics for the performance assessment of different direct energy conversion systems.
CO3: Design energy conversion systems based on the principles of direct energy conversion incorporating futuristic technologies like MHD generators and fuel cells.
CO4: Analysis of working principle and design concepts of different PV Cells

Introduction to Direct Energy Conversion- Basic concepts and definitions, Classification of direct energy conversion system, Overview of energy sources and their availability. Thermoelectric Conversion- Introduction to thermoelectricity, Seebeck effect, Peltier effect, Thomson effect, Thermoelectric generators- Thermo electric materials and applications, Thermoelectric figure of merit. Thermionic power conversion- Introduction to Thermionic Effect, Thermionic Materials, Richardson's equation - Analysis of high vacuum thermionic converter - Gaseous converter.

Fuel cells - Definition, general description, types, design and construction - Thermodynamics of ideal fuel cells - Practical considerations - Present status. Introduction to MHD generators - Seeding and ionization in MHD generators - Analysis of MHD engines and MHD equations - Conversion efficiency and electrical losses in MHD power generation systems. Hybrid Energy Systems- Overview of hybrid energy systems, Integrated renewable energy systems, Optimal design of hybrid energy systems, Control strategies for hybrid energy systems

Fundamentals of solar photovoltaic cells - Production of solar cells –Thin film solar cell technologies - Design concept of PV cell systems - Solar cells connected in series and parallel - Voltage regulation and energy storage - Centralized and decentralized PV System design and applications–Concentrator PV cells and systems - Maintenance of PV systems - Current developments.

References:

[1] Chang, S. S. L., 1963, *Energy Conversion*, Prentice Hall.

[2] Angrist, S. W.,1982, *Direct Energy Conversion*, Pearson.

[3] Rosa, R. J., 1987, *Magneto hydrodynamic Energy Conversion*, Springer.

[4] Bagotsky, V. S., 2009, *Fuel Cell Problems and Solutions*, John Wiley & Sons.

[5] Chetan Singh Solanki, 2015, *Solar photovoltaics: Fundamentals, Technologies and Applications*, PHI learning.

[6] Rakosh Das Begamudre, 2000, *Energy Conversion Systems*, Newage International(P) limited.

ME6422E ENERGY AND ENVIRONMENT

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Classify components of the environment.
CO2: Analyse the biogeochemical cycles
CO3: Assess different techniques for the control and management of pollution of air and water
CO4: Explain environmental impact assessment, regulatory steps in environmental sector

Fundamentals
Energy Overview: Basics of energy - Types of energy and its utilization - Energy characteristics – Energy Measures- global energy scenario - India energy scenario- Fundamentals of environment – Nutrient cycles - Water cycle - Oxygen cycle - Carbon cycle -Nitrogen cycle - Phosphorus cycle – Rock cycle - Bio-diversity - Environmental aspects of energy utilization - Public health issues related to environmental Pollution.

Environmental Pollution
Air Pollution: Classification of air pollutants, sources of emission and air quality standards - Physical and chemical characteristics - Meteorological aspects of air pollutant dispersion - Temperature lapse rate and stability - Factors influencing dispersal of air pollutant - Air pollution dispersion models - Air pollution sampling and measurement - types - Ambient air sampling - Gaseous air pollutants - Particulate air pollutants - Analysis of air pollutants – e-waste pollution.

Pollution Control
Air Pollution Control methods, Types of controls – Particulate emission control - Gaseous emission control - Water Pollution Control methods: Sources and classification of water pollutants - Wastewater sampling and analysis - Basic process of wastewater treatment - Primary treatment – Secondary treatment - Advanced treatment Methods of feed water treatment. Biological effects of radiation, heat and radioactivity disposal, Environmental impact assessment: Air quality and water quality standards – Pollution prevention and control acts - Principles and methodology of Environmental impact assessment, Air and water quality impacts by project type.

References:

[1] Rao, C. S., 1992, *Environmental Pollution Control Engineering*, Wiley Eastern.

[2] Anjaneyulu, Y., 2002, *Air Pollution and Control Technologies*, Allied Publishers.

[3] Rau, J. and Wooten, D.C., 1980, *Environmental Impact analysis Handbook*, McGraw Hill.

[4] Liu, D.H.T, 1997, *Environmental Engineers Handbook*,Lewis.

[5] Masters, G. M. and Ela, W. P., 2007, *Introduction to Environmental Engineering and Science*,Prentice-Hall.

[6] Miller, G. T. and Spoolman, S., 2010, *Environmental Science,* Yolanda Cossio.

ME6423E INTEGRATED ENERGY SYSTEMS

Pre-requisites: ME6402D

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Ability to evaluate different options of hybrid systems for a given location/application
CO2: Ability to model and simulate the hybrid system operation
CO3: Evaluate the performance of the integrated/hybrid system
CO4: Ability to evaluate the economic feasibility of hybrid systems

Introduction to hybrid and integrated energy systems; various options of integration, system architecture; energy storage opportunities in hybrid energy systems; assessing the consumer load demand, renewable energy resource assessment; feasibility analysis; environmental factors and regulatory requirements.

Modeling of integrated energy systems; load matching and scheduling; system operation, choice of generators, selection of diesel generator set and renewable energy-based generators, dump or auxiliary heat loads, storage selection; system control, electrical safety; operational issues associated with integrated energy systems; installation and monitoring; performance analysis.

Cost parameters, indirect financial considerations of total environmental and social cost, direct financial considerations, economic appraisal methodology; recent developments, integration of biomass-based systems, wind-hydropower systems, systems capable of meeting electrical and thermal loads, building integration; case studies.

References:

[1] Hunter, R. and Elliot, G., 1994, *Wind Diesel Systems: A Guide to the Technology and its Implementation, Cambridge University Press*.

[2] Kaldellis, J. K., 2010, *Stand-alone and Hybrid Wind Energy Systems Technology, Energy Storage and Applications*, Woodhead Publishing Limited.

[3] Murthy, W. R. and McKay, G., 2001, *Energy Management*, Butherworth Heinemann.

[4] Rao, S. S., 1996, *Textbook on Engineering Optimization – Theory and Practice*, J. Wiley.

ME6424E ENERGY POLICIES FOR SUSTAINABLE DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze energy policies, their need and significance, and the implications in energy utilization.
CO2: Analyze diverse scenarios linking energy utilization and environmental issues with due consideration of the prevailing energy policies.
CO3: Apply mathematical modeling techniques for energy planning and energy policy simulation.

Energy policies, Supply focus approach and its limitations, Energy paradigms, DEFENDUS approach, End use orientation; Energy policies and development: Case studies on the effect of governmental policies on the consumption and wastage of energy, Critical analysis, Need for renewable energy policies in India, Energy and environment, Greenhouse effect, Global warming, Global scenario, Indian environmental degradation, Environmental laws, Sustainable Development Goals.

Water (prevention & control of pollution) act 1974; The environmental protection act 1986; Effluent standards and ambient air quality standards; Latest development in climate change policies and CDM; Energy conservation schemes: Statutory requirements of energy audit, Economic aspects of energy audit, Capital investments in energy saving equipment, Tax rebates, Advantages of 100% depreciation, India's plan for a domestic energy cap and trade scheme.

Social cost benefit analysis: Computation of IRR and ERR; Advance models in energy planning, Dynamic programming models in integrated energy planning, Energy planning case studies; Development of energy management systems, Decision support systems for energy planning and energy policy simulation.

References:

[1] Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., 1990, *Energy for a Sustainable World*, Wiley Eastern.

[2] Reddy, A.K.N. and Bhalla, A.S., 1997, *The Technological Transformation of Rural India*, UN Publications.

[3] Reddy, A.K.N., Williams, R.H. and Johanson, J.B., 1997, *Energy After Rio-Prospects and Challenges*, UN Publications.

[4] Meier, P. and Munasinghe, M., 1993, *Energy Policy Analysis & Modeling*, Cambridge University Press.

[5] Pindyck, R.S and Rubinfeld, D.L., 1998, *Economic Models and Energy Forecasts*, McGraw Hill.

ME6425E MACHINE LEARNING FOR THERMAL AND ENERGY SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO 1: Ability to apply basic machine learning algorithms.
CO 2: Ability to apply data-driven techniques to thermal-energy problems
CO 3: Apply neural networks for dynamical systems.
CO 4: Ability to apply physics informed machine learning

Introduction to Machine learning: Regression and Model Selection-classic curve fitting, nonlinear regression and gradient descent, cross validation, information criteria. Clustering and Classification-feature selection and data mining, supervised versus unsupervised learning, k-means clustering, Dendrogram, mixture model and expectation, Support Vector Machines, classification trees and random forest; Neural networks and deep learning- single layer, multiplayer and activation function, back-propagation algorithm, stochastic gradient descent algorithm, Deep convolutional neural networks.

Introduction to thermal and energy systems as dynamic systems: Overview, patterns, models and control, various examples. Data driven dynamical systems: Overview motivation and challenges, proper orthogonal decomposition (POD), Dynamic Mode decomposition (DMD), Sparse Identification of Nonlinear Dynamics (SINDy), Koopman operator theory, data-driven Koopman analysis, Reduced order Modeling (ROM).

Neural networks for Dynamical systems: Recurrent neural networks, Autoencoders, Generative Adversarial Networks (GANs), diversity of neural networks. Dimensionality reduction and Transforms: singular value decomposition (SVD), Principle Component Analysis (PCA), Fourier and wavelet transforms-FFT; sparsity and compressed sensing. Physics informed machine learning: mathematical foundations, SINDy Auto-encoders, Physics informed neural networks (PINNs).

References:

[1] Mendez, M. A., Ianiro, A., Noack, B.R., and Brunton, S. L., 2022, *Data-Driven Fluid Mechanics: Combining First Principles and Machine Learning*, Cambridge University Press.
[2] Brunton, S. L., Kutz, N., 2022, *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Contro*l, Cambridge University Press.
[3] Kutz, N., Brunton, S. L., Brunton, B. W., Proctor, J. L., 2016, *Dynamic mode decomposition-data driven modeling of complex systems*, SIAM.
[4] Gene, H.G., Charles, F. V. L., 2013, Matrix *Computations*, Johns Hopkins University Press.
[5] Hastie, T., Tibshirani, R., Friedman, J., 2009, The Elements of Statistical Learning: Data Mining, Inference, And Prediction, Springer.
[6] Nocedal, J., and Wright, S. J., 1999, *Numerical Optimization*, Springer-Verlag, New York, Inc.
[7] Bishop, C. M., 2011, *Pattern Recognition and Machine Learning*, Springer.
[8] Albon, C., 2018, Machine *Learning with Python Cookbook: Practical Solutions from Preprocessing to Deep Learning*, O'Reilly Media.

ME6426E BATTERY MANAGEMENT SYSTEMS FOR ELECTRICAL VEHICLES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analysis of heat transfer in battery applications
CO2: Ability to apply electrochemistry principles for battery applications
CO3: Analysis of applications of battery management in electric vehicles

Introduction to energy storage systems and devices, Components of a Battery Energy Storage System, Rechargeable batteries and their Fundamental electrochemistry. Introduction to electrical vehicles, - Basics of electric motors, the drive torque, power and energy, source of energy.

Battery Chemistry Types: Lead–Acid (PbA) Battery, Nickel–Cadmium (Ni–Cd) Battery, Nickel–Metal Hydride (Ni–MH) Battery, Lithium-Ion (Li-Ion) Battery, Sodium–Sulfur (Na–S) Battery, Redox Flow Battery (RFB), Lithium batteries, Nickel metal hydride battery, Lead-acid battery, The fundamental of BTMS: Liquid cooling and Air cooling, Thermoelectric cooling, Heat Transfer Fluids in phase change materials, High temperature batteries for back-up applications, Flow batteries for load leveling and large scale grid application, Ni-Hydrogen batteries for space and marine applications, Sustainable design of batteries, Grid applications of battery energy storage systems.

Hybridization of battery, Battery recycling technologies, Battery applications for stationary and secondary use, Battery chargers and battery testing procedures, Battery management, Modelling energy consumption, Charging Technology and Implementation, Regulations and safety aspects of high voltage batteries, Super capacitors, Case Study: Battery and Electrical Vehicle. Challenges and Risks

References:

[1] Andrea, D., 2010, *Battery management systems for large lithium-ion battery packs*, Artech house.

[2] Söffker, D., and Moulik, B., 2020, *Battery Management System for Future Electric Vehicles*. MDPI Multidisciplinary Digital Publishing Institute.

[3] Linden, D., and Reddy, T.S., 2002, Handbook *of Batteries*, McGraw-Hill.

[4] Aloui, F., Varuvel, G. E., and Sonthalia, A., 2023, Handbook *of Thermal Management Systems*, Elsevier

ME6427E HEAT PUMP TECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply thermodynamics for heat pump systems for specific applications.
CO2: Carry out the design of vapour compression and absorption heat pump systems.
CO3: Capability to carry out the performance assessment of different types of heat pumps.

Heat pump theory: Heat pump, refrigeration cycles, Vapour compression and vapour absorption heat pump systems, Heat pump circuits, Common sources used for heat pumps, Comparison of water-source and air-source heat pumps, Heat pump performance, Exergy analysis of heat pump.

Design of heat pump systems: components of heat pumps, compressor and prime mover types and performance, heat transfer components, condensers and evaporators, expansion and metering devices, reversing valves, filters, drier, receiver and accumulator, auxiliary heating elements; selection of working fluid; refrigerant piping and pipe insulation; various control and wiring circuits; Part-load performance of components.

Heat pump performance evaluation**:** Seasonal performance factor, Comparison of solar assisted heat pumps; Applications of heat pump systems; Reliability and maintenance of heat pumps.
Advances in heat pumps: Improvements and innovations, Advanced cycles for vapor absorption heat pumps, Hybrid heat pumps, Peltier-effect heat pumps, Magnetic heat pumps, Heat transformers, Metal hydride heat pumps, Energy basis comparison of convention and advanced heating and cooling systems.

References:

[1] Billy, C. Langley, 2001, *Heat Pump Technology*, Pearson.

[2] Eugene Silberstein**,** 2015**,** *Heat Pumps***,** Delmar Cengage Learning.

[3] Lee Miles, 1993, *Heat Pumps: Theory and Service*, First Edition, Delmar Cengage Learning.

[4] Billy, C. Langley, 1989, *Heat Pump Technology: Systems Design, Installation, and Troubleshooting*, Second Edition, Pearson College Div.

[5] Randy F. Petit Sr., Turner L. Collins, 2011, *Heat Pumps: Operation, Installation, Service*, Esco Press.

ME6428E DESIGN OF SOLAR THERMAL SYSTEMS

Pre-requisites: ME6403E

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze solar thermal options based on the specified application
CO2: Estimate the process loads for the solar thermal application
CO3: Design the solar thermal system using characteristic equations
CO4: Analyze the techno-economics and arrive at optimum system design

Solar radiation and solar geometry; solar collector technologies: flat plate, evacuated tube and concentrators; options for thermal storage; typical solar thermal applications, modeling of thermal equipment and system simulation; elements of system optimization.

Flat plate collectors:collector characterization and design parameters; energy storage in solar process systems; solar process loads; system thermal calculations; estimation of building heating/cooling loads, passive, active and hybrid systems for building applications; design of active systems: f chart and utilizability methods.

Concentrator systems: optics for solar collectors, non-tracking and tracking concentrators, optical analysis and optimization of parabolic reflectors, concentrating solar power technology: Linear Fresnel Reflector receivers and thermal performance, design and analysis of parabolic-trough, central tower and parabolic dish systems, heliostat design issues, case studies on system design and optimization.

References:

[1] Duffie, J. A. and Beckman, W. A., 2013, *Solar Engineering of Thermal Processes*, Wiley.

[2] Rabl, A., 1985, *Active Solar Collectors and Their Applications*, Oxford University Press.

[3] Goswami, D. Y., Kreith, F., and Kreider, J. F., 2000, *Principles of Solar Engineering*, CRC Press.

[4] Lovegrove, K. and Stein, W., 2012, *Concentrating Solar Power Technology*, Woodhead Publishing Ltd.

ME6429E ENERGY EFFICIENT BUILDINGS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate comfort conditions for a given zone
CO2: Selection of energy-efficient technologies for the buildings
CO3: Modelling and simulation of building performance
CO4: Impart knowledge on recent advancements in this field

Introduction to energy efficient buildings, Different climate zones, Micro climate, Factors affecting human comfort, Human response to thermal environment, noise, visual environment, Comfort indices, Thermal comfort, Evaluation of comfort standards. Principles of energy-efficient building, Learnings from history, Energy performance metrics, indicators & measures. Design guidelines, Site planning, Solar architecture, Day lighting, Energy retrofit of existing buildings, Energy efficiency in new buildings, Concept of net-zero & green buildings

Energy demand for buildings: Estimation, Effect of thermal comfort and outdoor climatic conditions, Strategies to reduce energy demand, Measuring and implementing Energy efficiency. Passive technologies for cooling and heating: Building envelope, Thermal insulation materials, Phase change materials, Radiation shields, Ventilation techniques, and Moisture control. Active technologies: Heating ventilation and air conditioning (HVAC), Renewable energy-based systems. Recent technologies: Building integrated systems, Energy-efficient technologies, Energy generation technologies, Energy storage technologies, Intelligent buildings, Building management systems and automation for energy efficiency.

Building performance modelling and simulation tools: Software packages and coding. Energy efficient building standards: National and International Codes. Case studies: Historical and modern buildings, Residential and commercial buildings, Schools and hospitals etc. Course project: Designing an energy-efficient building.

References:

[1] Nayak, J. K. and Prajapati, J. A., 2006, *Handbook on Energy Conscious Buildings*, MNES.

[2] *User's Manual for The Energy Conservation Building Code 2017*, Bureau of Energy Efficiency.

[3] *Sustainable Building Design Manua*l, 2004, The Energy and Resource Institute.

[4] Givoni, B., 1994, *Passive and Low Energy Cooling of Buildings*, Van Nostrand Reinhold.

[5] Bradshaw, V., 2006, *Building Environment: Active and Passive Control Systems*, John Wiley.

[6] Clarke, J. A., 2001, *Energy Simulation in Building Design*, Butterworth.

[7] Morrison, I. B., 2020, *Fundamentals of Building Performance Simulation*, Routledge.

[8] Krishnan, A., 2004, *Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings*,Tata Mcgraw-Hill.

ME6430E ALTERNATIVE FUELS- PRODUCTION AND APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Ability to analyse various alternative fuels and their characteristics
CO2: Ability to analyse different alternative fuel production methods.
CO3. Analyze different alternative fuel conversion processes and predict the end-products.
CO4. Select suitable alternative-fuel for a particular application based on the economics and minimum environmental impact.

Alternative fuels: Introduction, types of alternative fuels: vegetable oils, biodiesel, methanol, ethanol, dimethyl ether, liquified petroleum gas, compressed natural gas, hydrogen—production, modeling and tests, material compatibility, economics, safety, pros and cons, their combustion qualities, combustion processes, combustion performance, fuel handling and storage. Energy perspective – Biomass prospects – Organic compounds – Chemistry of biomass materials – bio-renewable resources – herbaceous crops – woody crops – algae – thermodynamics of bioenergy—Compressed air an alternative fuel.

Energy production: Sources of production: Conventional and non-conventional resources, natural gas, plant material, biomass, electricity, Processes: Refining, Gasification, esterification, hydrogenation, gasification, electrolysis pyrolysis, steam reforming, compression. Conversion of biomass into heat, power and fuel – direct combustion – gasification – anaerobic digestion – Biomass into chemicals and fuels: sugars, biodiesel, thermochemical conversion, Fischer-Tropsch process.

Applications: Automobile and Aviation— Electric vehicles: principles, battery storage, charging, solar vehicles — fuel cell vehicles: operating principle, fueling options, manufacturers' developments, market—hybrid vehicles: configurations, operations. Environmental aspect of the alternative fuels - Land use – Pollution - Climate change – Economics and life-cycle analysis of alternative fuel.

References:

[1] Ramadhas, A.S., 2010, *Alternative Fuels for Tr*ansportation, CRC Press.
[2] Goodger, E. M., 1980, *Alternative Fuels: Chemical Energy Resources*, the MacMillan press ltd.
[3] Mousdale, D. M., 2017, *Introduction to Biofuels*, CRC Press.
[4] Riazi, M.R. and Chiaramonti, D. ed, 2017, *Biofuels Production and Processing Technology*, CRC Press.
[5] Love, J., Bryant, and J. A. ed, 2017, *Biofuels and Bioenergy*, Wiley-Blackwell.
[6] Ravindra, P. and Sarbatly, R. H. ed, 2013, *Advances in Biofuels*, Springer.
[7] Singh, R. S., Pandey, A. and Gnansounou, E. ed, 2016, *Biofuels: Production and Future Perspectives*, First Edition, CRC Press.
[8] Pandey, A., Editor, 2008, *Handbook of Plant-Based Biofuels*, CRC Press.

ME6431E COMPUTATIONAL METHODS FOR HEAT TRANSFER AND FLUID FLOW

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire knowledge of computational methods for heat transfer and fluid flow
CO2: Selection of a suitable computational method to solve a given problem
CO3: Attain the capability of solving partial differential equations numerically
CO4: Attain the ability to use computational methods, namely, FDM, FEM, and FVM

Classification of partial differential equations: elliptic, parabolic, and hyperbolic equations. Governing equations, boundary conditions and initial conditions for heat transfer and fluid flow. Introduction to computational methods, namely FDM, FEM, FVM and other methods.

Finite difference methods: derivation of finite difference equations, simple methods, general methods, higher order derivatives, multidimensional finite difference formulas, mixed derivatives, nonuniform mesh, higher order accuracy schemes, accuracy of finite difference solutions, finite difference formulations and solution methods for elliptic, parabolic, and hyperbolic equations, stability analysis, finite volume methods via finite difference methods.

Finite element methods: finite element formulations, definitions of errors, interpolation functions, one, two and three-dimensional elements, finite element formulations and solution methods for elliptic, parabolic, and hyperbolic equations, finite volume methods via finite element methods, grid generation techniques, computing techniques.

References:

[1] Chung, T.J., 2010, *Computational Fluid Dynamics*, Cambridge University Press.

[2] Ozisik, M.N., 2017, *Finite Difference Methods in Heat Transfer*, CRC Press.

[3] Patankar, S.V., 1980, Numerical *Heat Transfer and Fluid Flow*, Hemisphere Publishing Co.

[4] Reddy, J.N., and Gartling, D., 2010, *The Finite Element Method in Heat Transfer and Fluid Dynamics*, CRC Press.

ME6432E INDUSTRIAL COMBUSTION AND POLLUTION CONTROL

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Ability to understand the importance of industrial combustion interaction with the environment.
CO2: Analyze, understand, and improve the combustion systems.
CO3: Demonstrate understanding of the thermodynamic, physics and chemistry aspects of flames.
CO4: Delineate the mechanics of formation of pollutants and apply control strategies.

Environmental pollution: Greenhouse gas and effect; Global warming; Ozone Depletion Acid rain; Biodiversity-Environmental legislations. Air pollution: air pollutants. Applications of combustion in industries: Chemical kinetics—reaction rate, pseudo-steady state, hydro-carbon pyrolysis kinetics; Mass and Heat Transfer—Equations, steady state mass transfer, heat transfer and characteristic times; Elementary Probability Theory—Concept of Random Variable; Properties and common Probability Distributions; Turbulent Mixing—Scales of Turbulence, Statistical properties of turbulence, the micro scale and Chemical Reactions.

Combustion Fundamentals: fuels, stoichiometry, combustion thermodynamics; combustion kinetics; flame propagation and structure- laminar and turbulent premixed and non-premixed (diffusion) flames; turbulent mixing; combustion of liquid and solid fuels.

Pollutant formation and control in combustion: Chemicals from combustion, Nitrogen Oxides-prompt, thermal and fuel NOx, control of nitrogen dioxide; carbon monoxide- oxidation quenching; hydrocarbon and sulfur oxides. Particle formation in combustion: Ash, charcoal, soot, aerosols; Quantification of emissions; Emission control strategies; removal strategies for solid and gaseous pollutants from the effluent stream; optimal control strategies—example, air pollution.

References:

[1] Richard C. Flagan, John H. Seinfeld, 2012, *Fundamentals of air Pollution Engineering*, Dover.

[2] Mishra, D.P, 2008, *Fundamentals of Combustion*, PHI.

[3] Mukunda, H.S., 2009, *Understanding Combustion*, University Press.

[4] Sara McAllister, Jyh-Yuan Chen, Carlos Fernandez-Pello, A., 2011, *Fundamentals of Combustion Processes*, Springer.

[5] Irvin Glassman, Richard A. Yetter, Nick G. Glumac, 2014, *Combustion*, Elsevier.

[6] Raghavan, V., 2021, *Combustion Technology--Essentials of Flames and Burners*, Springer.

[7] Date, A. W., 2020, *Analytic Combustion--With Thermodynamics, Chemical Kinetics and Mass Transfer*, Springer.

ME6433E HYDROGEN – PRODUCTION, STORAGE AND UTILIZATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the potential of hydrogen to fulfill the future energy requirements.
CO2: Select different hydrogen storage techniques for stationary and mobile applications.
CO3: Characterize materials suitable for hydrogen storage applications.
CO4: Analyze the performance of thermally driven sorption systems and fuel cells.

Hydrogen production
Introduction: Need for Hydrogen Energy, Global energy picture, Worldwide Energy Problems. Production of Molecular Hydrogen: From fossil fuels, synthetic fuels and nature's production. Electrolysis of water. Microbial photo electro chemical system, Reforming of Natural gas. Steam Reforming, Gas Separation: Gas Separation Processes, Membrane types and membrane development for gas separation, Membrane reactors, Gasification technology, Entrained-flow gasifier, Moving-bed gasifier, Fluidized-bed gasifier

Hydrogen storage and characterization
As Compressed gas storage, as Cryogenic liquid storage and as solid-state storage – Bulk absorption (Metal hydrides and Complex Hydrides) and Surface adsorption (Carbon Materials). Classification of hydrogen storage materials, Applications, Storage capacities, advantages and disadvantages. Phase transformation and thermodynamics of metal hydride formation.
XRD, SEM and EDX characterizations, Gravimetric and Volumetric analysis, Design of Sievert's apparatus and reactors, Pressure-concentration isotherms characterization, reaction kinetics measurements and thermodynamic properties measurements, Effective thermal conductivity, Effects of operating conditions on metal hydride properties, Van't Hoff plot analysis, static and dynamic characterization.

Hydrogen utilization and simulation
Hydrogen based thermally-driven refrigeration and air-conditioning systems, heat transformers, hydrogen compressors, hydrogen purification and thermochemical energy storage system – working principle, thermodynamics, selection of working pairs, performance evaluation, multi-staging of these systems. Conventional and sorption system comparison. Techno-economic analysis. Hydrogen based fuel cells for mobile applications, Lanthanum-Nickel Electrodes, Low-cost metal hydride electrodes. Integration of hydrogen compressor with fuel cells and internal combustion engines for power generation.
PCI simulation models, Reaction kinetics models. Thermodynamic simulations of hydrogen based thermodynamic systems. Heat and mass transfer analysis through finite volume approach, modelling of fuel cells. Design and analysis of hydrogen reactors

References:

[1] Paulo, E.V.D.M., 2018, *Science and Engineering of Hydrogen-Based Energy Technologies*, Elsevier.

[2] Viktor, H., and Shigenori, M., 2018, *Fuel Cells and Hydrogen*, Elsevier.

[3] Sastri, M.V.C., Viswanathan, B., and Murthy, S.S., 1998, *Metal Hydrides*, Narosa Publishing House.

[4] Viswanathan, B., and Aulice, S., 2006, *Fuel Cells Principle and Applications*, Universities Press, Hyderabad.

ME6434E ENERGY MODELING, ECONOMICS AND PROJECT MANAGEMENT

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Capability to analyze energy policies and suggest novel ideas on policies.
CO2: Apply quantitative techniques for analyzing energy resources and demand.
CO3: Apply the concepts of economics in the energy sector.
CO4: Systematic analysis of energy projects considering economic aspects.

Energy modeling: The energy imperative and patterns of use, planning and visioning the energy future; energy analysis and life-cycle assessment; demand forecasting, econometric approach to energy demand forecasting, common energy demand analysis models; integrated national energy planning; market transformation to sustainable energy; energy policy, role of modeling in energy policy analysis.

Energy economics: scope, energy and multidimensional interactions, energy data and energy balance; economic analysis of energy investments, economics of fossil fuel supply, economics of renewable energy supply; energy markets and principles of energy pricing, energy pricing and taxation; impact of high energy prices.

Project management: financial estimates and projections, project cash flows, time value of money; feasibility analysis, project appraisal criteria, risk analysis, project planning matrix; social cost benefit analysis; network analysis for project management, time estimation, critical path determination, PERT, CPM; Implementation and monitoring, performance indices; case studies in energy sector.

References:

[1] Randolph, J., and Masters, G.M., 2008, *Energy for sustainability: Technology, planning, policy*, Island Press.

[2] Munasinghe, M., and Meier, P., 1993, *Energy policy analysis and modelling*. Cambridge University Press.

[3] Bhattacharyya, S.C., 2019, *Energy economics: concepts, issues, markets and governance*, Springer Nature.

[4] Makridakis, S., Wheelwright, S.C., and Hyndman, R.J., 2008, *Forecasting methods and applications*, John Wiley & sons.

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ME6435E HYDROPOWER SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the concepts in the preliminary design of the various components of hydropower systems
CO2: Design hydraulic turbines for hydropower systems
CO3: Estimate the cost of power projects considering economic factors

Classification of hydro power plants, Run-of-river power plants and storage power plants, Classification based on power generation capacity - Overview of Small, Mini and Micro Hydropower systems and importance; Status of Hydropower Worldwide and India; Components of Hydropower Plants – Turbine, Electric generator, Transformer and Powerhouse, Upper and Lower Reservoir, Structural parts such as Dam and Spillway, Surge Chambers, Stilling Basins, Penstock, Intake structures etc.; Hydrological analysis for Hydro Power- Parameters to be analysed, Acquisition of Head and Flow Data, Flow Duration Analysis, Energy and Power Analysis using Flow Duration Approach.

Classification and working principles of Hydraulic Turbines; Principles of modelling and similitude as applied to Turbomachines; Specific speed; Impulse and Reaction turbines; Design concepts of Pelton, Francis and Kaplan Turbines-Velocity triangles, Euler's turbine equation; Constructional features of Pelton, Francis and Kaplan turbines; Draft tube; Cavitation; Performance evaluation of turbines; Selection of a type of turbine.

Non-conventional hydro turbines, Pumped Storage Schemes, Pump as Turbine; Design and selection considerations for Micro and Mini Hydro Systems- Design aspects of various components; Water hammer and Surge Tanks; Speed Control and Governors; Elementary Electrical Considerations of Hydropower Plants, Types of Generators, Components of Transmission and Distribution Systems; Economic Analysis for Hydropower- Cost of Hydroelectric Power, Basic Economic Factors; Environmental Impact of Hydropower Systems; Case Studies.

References:

[1] Shepherd, D.G., 1956, *Principles of Turbomachinery*, Macmillan Company, New York.

[2] Dixon, S.L., Hall C., 2013, Fluid *mechanics and thermodynamics of turbomachinery*, Butterworth-Heinemann.

[3] Krevichenko, *Hydraulic Turbines*, MIR Publishers.

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[6] Alen, R., Inversin., 1986, *Micro Hydro Power Source Book*.

[7] Tyler, G.H., 1988, *Power Plant Evaluation and Design*.

ME6436E WIND ENERGY TECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the basic necessary components for the design of wind turbine
CO2: Employ the concepts of aerodynamics for efficient blade design
CO3: Design the wind turbines/farms in context with Indian wind scenario

Introduction to wind power; Wind power scenario in India; Wind characteristics – Extractable limits of wind power, Wind power potential, Gust/extreme wind speeds, Wind turbulence; Wind measurement and instrumentation; Horizontal/vertical axis wind turbines; Wind turbine topologies.

Wind turbines; Drag and lift in turbine blades; Orientation of rotor axis; Aerodynamics of horizontal axis wind turbines; Simple momentum theory and power coefficient; Betz limit; Rotor disc theory- Angular momentum theory and Maximum power; Blade geometry-a simple blade design; Optimal design at constant speed and variable speed operation; Losses in blades; Wind turbine performance curves; Performance measurements.

Components of horizontal axis wind turbines-Blades, Pitch bearings, Rotor hub, Gear box, Generator, Nacelle, Yaw drive, Tower; Wind turbine loads on wind turbine components; Conceptual design of horizontal axis wind turbines-blades – rating, rotational speed, number of blades; Teetering; Braking systems; Wind turbine materials; Wind turbine installations and wind farms in India; Off-shore wind turbines; Wind energy system economics; Small wind turbines.

References:

[1] Tony B., David S., Nick J., Ervin B., 2000, *Wind Energy Hand Book, Second Editio*n, John Wiley & Sons, Ltd.

[2] James F.M., Jon G.M.G., Anthony L.R., 2010, Wind *Energy Explained: Theory, Design and Application,* John Wiley & Sons, Ltd.

[3] Vaughn N., 2013, *Wind Energy: Renewable Energy and the Environment, Second Edition*, CRC Press.

[4] Jha A.R., 2011, Wind *Turbine Technology*, CRC Press.

ME6437E THERMODYNAMIC PROPERTY RELATIONS AND EXERGY ANALYSIS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse different thermodynamic processes based on the first and second laws
CO2: Evaluate the properties of single phase and two-phase thermodynamic systems
CO3: Exergy analysis of different thermodynamic cycles and engineering devices

Introduction to thermodynamics, energy, energy transfer, review of first law, properties of pure substances, second law applied to cyclic devices, entropy and entropy balance, practical applications; Thermodynamic property relations:Two constant and multi constant equations of state, relevant mathematical relations; Helmoltz and Gibbs functions; T-ds equations; Maxwell's relations; Difference in heat capacities; Ratio of heat capacities; Evaluation of change in internal energy, enthalpy and entropy; Energy equation; Joule-Thomson coefficient; Clausius-Clapeyron equation; Bridgman Tables for Thermodynamic relations; Evaluation of thermodynamic properties from an equation of state; Gas mixtures; Applications to ideal and real gasses.

Definition of exergy; forms of exergy; simple examples of calculation; the destruction of exergy. Exergy balance in thermodynamic systems, Exegetic efficiency, exergy and irreversibility, Exergy analysis of thermodynamic systems, Heat exchange - Expansion Pressure let down - Mixing - Distillation - Combustion air preheating – Systematic design method, closed and open systems.

Applications of exergy analysis of thermodynamic operations and cycles, Air standard cycles; Carnot, Otto, Diesel, Dual and Stirling cycles, p-v and T -s diagrams, description, efficiencies and mean effective pressures. Gas turbine (Brayton) cycle; description and analysis. Performance improvement of gas turbines; Regeneration cycle – conventional, alternative, Staged heat recovery

References:

[1] Bejan, A., 2016, Advanced *Engineering Thermodynamics*, John Wiley.

[2] Kennath, W., 1995, Advanced *Thermodynamics for Engineers*, McGraw Hill Inc
.
[3] Zemanzky, M.W., Dittman, R., 1998, *Heat and Thermodynamics*, McGraw Hill.

[4] Rao, Y.V.C., 1994, *Postulations and Statistical Thermodynamics*, Allied Publishers Ltd, New Delhi.

[5] Moran, M.J., Shaprio, H.N., 2006, *Fundamentals of Engineering thermodynamics*, Wiley.

[6] Holman, J.P., 1988, *Thermodynamics*, Fourth Edition, McGraw-Hill Inc.

[7] Cengal, Y.A., Boles, M.A., *Thermodynamics: An Engineering Approach*, McGraw Hill.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification
Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management. .

Business Planning and Execution
Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies
Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

[1] Kaplan, J. M., Warren, A. C., & Murthy V. (Indian Adoption), 2022, *Patterns of entrepreneurship management.* John Wiley & Sons.

[2] Kuratko, D. F., 2016, *Entrepreneurship: Theory, process, and practic*e. Cengage learning.

[3] Barringer, B. R. 2015, *Entrepreneurship: Successfully launching new ventures*. Pearson Education India.

[4] Shah Rajiv, Zhijie Gao, Harini Mittal, 2014, *Innovation, Entrepreneurship, and the Economy in the US, China, and India,* Academic Press.

[5] Sundar, K., 2022, *Entrepreneurship Developmen*t, Vijaya Nichkol Imprints, Chennai.

[6] Gordon, E., Natarajan, K., *Entrepreneurship Development*, Himalya Publishers, Delhi.

[7] Biswas Debasish, Dey Chanchal, 2021, *Enterpreneurship Development in India*, Taylor & Francis.

ZZ6002E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes
CO1: Explain the basic concepts and types of research.
CO2: Develop research design and techniques of data analysis
CO3: Present research to the scientific community
CO4**:** Develop an understanding of the ethical dimensions of conducting research

Exploring Research Inquisitiveness
Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis
Literature review :Tools and Techniques - Collection and presentation of data, processing and analysis of data - Descriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Probability distributions – Single population and two population hypothesis Testing - Parametric and non-parametric tests - Design and analysis of experiments: Analysis of Variance (ANOVA),completely randomized design – Measures of relationship: Correlation and regression, simple regression analysis, multiple regression – interpretation of results - Heuristics and simulation

Research writing and Ethics
Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.
The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey

References:

[1] Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., 2006, *Management Research Methodology, Pearson* Education.
[2] Leedy, P, D., 2018, *Practical Research: Planning and Design*, Pearson.
[3] Kothari, C.R., 2004, *Research Methodology – Methods and Techniques*, New Age International Publishers.
[4] Martin Mike, Schinzinger Roland, 2004, *Ethics in Engineering*, Mc Graw Hill Education.
[5] Sople, Vinod V., 2014, *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

[1] Foley, M., and Hall, D., 2018, *Longman advanced learner's grammar, a self-study reference & practice book with answers*, Pearson Education Limited.

[2] Gerson, S. J., and Gerson, S. M., 2009, *Technical writing: Process and product*, Pearson.

[3] Kirkwood, H. M. A., and M., M. C. M. I., 2013, *Hallidays introduction to functional grammar,* Hodder Education.

[4] Markel, M., 2012, *Technical Communication*, Palgrave Macmillan.

[5] Tuhovsky, I., 2019, *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills,* Rupa Publications India.

[6] Williams, R., 2014, *The Non-designer's Design Boo*k, Peachpit Press.