VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE
(VJTI)
MATUNGA, MUMBAI 400 019

(Autonomous Institute affiliated to University of Mumbai)

Curriculum
(Scheme of Instruction & Evaluation and Course contents)

For
Two Year Postgraduate Programme
Leading to Master of Technology
(M Tech) Degree in
Mechanical Engineering with specialization in
Thermal Science & Energy Systems
Implemented from the batch admitted in Academic Year 2025-26

Mechanical Engineering with specialization in Thermal Science & Energy Systems

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems in Thermal Science & Energy Systems.

PO2: An ability to write and present a substantial technical report/document in the area of Thermal Science & Energy Systems

PO3: Students should be able to demonstrate a degree of mastery in the area of Thermal Science & Energy Systems. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
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www.vjti.ac.in

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Curriculum
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For
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V J T I Veermata Jijabai Technological Institute
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M.Tech. in Mechanical Engineering (with specialization in Thermal Science & Energy Systems)

Scheme of Instruction and Evaluation

SEMESTER I

Scheme of Instruction					Scheme of Evaluation			
S. No	Course Code	Course Title	L-T-P	Credits	TA	MST	ESE	ESE hours
1	METS5001T	Computational Methods	3-0-0	3	20	30	50	3
2	METS5011S	Advanced Fluid Dynamics	3-0-0	3	20	30	50	3
3	METS5012S	Advanced Heat Transfer	3-0-0	3	20	30	50	3
4		Programme elective 1	3-1-0	4	20	30	50	3
5		Programme elective 2	3-1-0	4	20	30	50	3
6		Open elective 1	3-0-0	3	20	30	50	3
7	METS5071L	Laboratory 1 Computational Methods	0-0-2	1	60% CIE		40	-
8	METS5072L	Laboratory 2 Experimental Thermal Engineering	0-0-2	1	60% CIE		40	-
9	METS5073L	Laboratory 3 Modeling & Simulation of Thermal Systems	0-0-2	1	60% CIE		40	-
10		Liberal Learning	0-0-2	1	100% CIE			-
			28	24				

abbreviations **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **CIE** Continuous In-semester Evaluation

SEMESTER II

Scheme of Instruction					**Scheme of Evaluation**			
S. No	Course Code	Course Title	L-T-P	Credits	TA	MST	ESE	ESE hours
1	METS5002S	Research Methodology & IPR	3-0-0	3	20	30	50	3
2	METS5013S	Solar & Wind system design	3-0-0	3	20	30	50	3
3	METS5014T	Computational Fluid Dynamics	3-0-0	3	20	30	50	3
4		Programme elective 3	3-1-0	4	20	30	50	3
5		Programme elective 4	3-1-0	4	20	30	50	3
6		Open elective 2	3-0-0	3	20	30	50	3
7	METS5074L	Laboratory 4 Computational Fluid Dynamics	0-0-2	1	60% CIE		40	-
8	METS5077L	Laboratory 5 Solar Energy Lab	0-0-2	1	60% CIE		40	-
9	METS5078L	Laboratory 6 Cooling of Electronic System & Microfluidics Lab	0-0-2	1	60% CIE		40	-
10		Liberal Learning	0-0-2	1	100% CIE			-
			28	24				

abbreviations **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **CIE** Continuous In-semester Evaluation

List of Programme Elective 1

Sr. No.	Course Code	Course Title
1	METS5021S	Advanced Thermodynamics
2	METS5022S	Energy and Waste Heat Recovery
3	METS5023S	Design of Thermal Systems

List of Programme Elective 2

Sr. No.	Course Code	Course Name
1	METS5031S	Introduction to Renewable Energy Systems
2	METS5032S	Solar Energy Technology
3	METS5033S	Energy Conservation and Management

List of Programme Elective 3

Sr. No.	Course Code	Course Name
1	METS5041S	Design of Heat Exchanger
2	METS5042S	Thermal Energy - Conversion, and applications
3	METS5043S	Cooling of Electronic System & Microfluidics

List of Programme Elective 4

Sr. No.	Course Code	Course Name
1	METS5051S	Energy: Audit and Policy
2	METS5052S	Energy Efficiency, Storage & Optimization
3	METS5053S	Bio Energy Technologies

List of Open Elective 1

Sr. No.	Course Code	Course Title
1	METS5061S	Energy Conservation and Management

SEMESTER III

Scheme of Instruction					Scheme of Evaluation
Sr. No	Course Code	Course Title	L-T-P	Credits	
1.	METS5091D	Skill Based Course (Project Stage -I)	---	5	100% CIE
2.	METS5092D	Skill Based Course (Project Stage -II)	---	5	100% CIE
3.		Self- Learning Course - 1	1-0-0	1	100% ESE of 3 hours or credit transfer
4.		Self- Learning Course - 2	1-0-0	1	100% ESE of 3 hours or credit transfer
5.		Mandatory Non Credit Course	2-0-0	0	100% ESE of 3 hours or credit transfer
				12	

SEMESTER IV

Scheme of Instruction					Scheme of Evaluation
S. No	Course Code	Course Title	L-T-P	Credits	
1.	METS5093D	Skill Based Course (Project Stage -III)	---	5	100% CIE
2.	METS5094D	Skill Based Course (Project Stage -IV)	---	7	100% CIE
				12	

SEMESTER-I

Programme Name	Master of Technology in Mechanical Engineering with specialization in Thermal Science & Energy Systems
Course Code	METS5001T
Course Title	Computational Methods

Course Outcomes

After completion of course, students would be able to

1. Solve algebraic equations, Eigen value problems
2. Analyze data using interpolation and regression methods.
3. Solve ordinary and partial differential equations using numerical techniques

Course Contents

Introduction

Engineering problems and computational methods; Introduction to numerical methods and analysis.

Error Analysis

Approximations; Round-off and Truncation errors; Backward and Forward error analysis

Roots of Nonlinear Equations

Bisection method, Regula Falsi, Secant method, Fixed point Method; Newton-Raphson method; Multiple roots; Roots of system of non-linear equations; Analysis and order of convergence; Polynomials Mueller's method, Bairstow's method**.**

Solution of System of Linear Equations

Direct methods (Gauss Elimination, Gauss-Jordan, LU decomposition, Thomas Algorithm); Perturbation analyses of direct methods matrix and vector norms, condition number of matrix; Iterative methods (Jacobi and Gauss-Seidel); convergence criteria for Jacobi and Gauss Seidel iterative methods, rate of convergence of iterative methods. Successive over Relaxation.

Solution of System of Nonlinear Equations

Iterative methods, Fixed Point iteration, Newton-Raphson method.

Approximation of functions

Approximation using polynomials (Simple, least squares estimation, orthogonal basis functions, Tchebycheff and Legendre polynomials); Interpolation (Newton's divided difference and Lagrange interpolating polynomials, Spline interpolation); Regression

Eigen values and Eigen vectors

Power, inverse power, and inverse power method with shift, Fadeev-Leverrier method for the formulation of the Characteristic polynomials and QR decomposition

Numerical Differentiation

Introduction to finite difference approximations, Derivation of generalized finite difference approximation of any order and accuracy, truncation error analysis, Richardson's extrapolation

Numerical Integration

Newton-Cotes integration formula, Romberg integration and Gauss Legendre quadrature; Ordinary

Ordinary Differential Equations (Initial Value Problems)

Euler's method, Multi-step methods, Runge-Kutta methods, Predictor Corrector Methods. Stiff ODEs. System of IVPs, Stiff problems and Gear's method

Ordinary Differential Equations (Boundary Value Problems)
Decomposition into Linear System of ODEs, Shooting and direct methods;
Partial Differential Equations Introduction to solution of PDEs, Parabolic (diffusion equation and advective-diffusion equation), Elliptic (Laplace equation) and Hyperbolic (Wave equation) equations; Explicit and Implicit Methods, Crank Nicholson Method

Recommended Reading

1. Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers, McGraw Hill
2. Santosh Gupta, Numerical Methods for Engineers, New age international publishers
3. J.B. Doshi, Differential Equations for Scientists and Engineers, Narosa, 2010
4. Kreyszig, Erwin, I.S., Advanced Engineering Mathematics, Wiley, 1999
5. C. F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education Asia, New Delhi, Sixth Edition, 2006.

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems.**
Course Code	**METS5011S**
Course Title	**Advanced Fluid Dynamics**

COURSE OUTCOMES:

The student should be able to

1. Apply the conservation principles of mass, momentum, and energy to fluid flow systems.
2. Utilize exact and integral solutions of the boundary layer equations.
3. Analyse and apply the fundamentals of turbulent flow to various fluid flow systems.
4. Apply the principles of compressible flow to relevant systems.

Course Contents:

Governing Equations of Fluid Motion

Reynolds transport theorem, Integral and differential forms of governing equations: mass, momentum and energy conservation equations, Navier-Stokes equations, Euler’s equation, Dimensionless form of Navier-Stokes equations

Exact solutions of Navier-Stokes Equations

Couette flow, Poiseuille flow, flow in a pipe, flow between concentric cylinders

Potential Flows

Kelvin's theorem, Irrotational flow, Stream function-vorticity approach

Laminar Boundary Layers

Boundary layer equations, Boundary layer thickness, Boundary layer on a flat plate, similarity solutions, Integral form of boundary layer equations, Approximate Methods, Flow separation

Turbulent Flow

Introduction, Fluctuations and time-averaging, General equations of turbulent flow, laminar turbulent transition Turbulent boundary layer equation, Flat plate turbulent boundary layer, Turbulent pipe flow, universal velocity distribution.

Compressible Flows

Speed of sound and Mach number, Basic equations for one dimensional flows, Isentropic relations, Normal-shock wave, Rankine-Hugoniot relations, Quasi-one dimensional flows, Fanno and Rayleigh curve

Experimental Techniques

Role of experiments in fluid, layout of fluid flow experiments, sources of error in experiments, data analysis, design of experiments, review of probes and transducers, Introduction to Hot wire Anemometry, Laser Doppler Velocimetry and Particle Image Velocimetry

Recommended Reading:

1. Robert W. Fox, Alan T. McDonald, John W. Mitchell, Introduction to Fluid Mechanics, Tenth Edition, Wiley, 2021.
2. Frank M. White, Fluid Mechanics, Tata McGraw-Hill, Seventh Edition, 2012
3. S K Som, Gautam Biswas, Suman Chakraborty, Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw Hill, Third Edition, 2017
4. Schlichting H., Boundary Layer Theory, Mcgraw Hill, Seventh Edition, 2014
5. Tennekes H. and Lumley J.L., A First Course in Turbulence, The MIT press, 2018
6. John D. Anderson Jr, Modern Compressible Flow with Historical Perspective, McGraw-Hill, Fourth Edition, 2021

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5012S
Course Title	Advanced Heat Transfer

COURSE OUTCOMES:

The student should be able to:

1. Understand the laws of heat transfer and governing equations to a given thermal system.
2. Employ computational methods for simulation of complex conduction and fin heat transfer
3. Apply numerical techniques to convective heat flow
4. Evaluate radiation heat transfer between black body and gray body surfaces & Gas radiation
5. Design a thermal device for steady and unsteady state industrial applications.

Course Contents:

Review of heat transfer fundamentals, Physical concepts and Governing Equations
Heat conduction equation in differential form, solution methods, steady state, unsteady state problems-fins, moving boundaries.
Steady, One-dimensional heat conduction with and without heat generation – Plane walls & Radial systems
Review of steady-state (one and two dimensional), transient conduction heat Transfer and solutions of classical heat conduction problems.
Radiation basics, Gas Radiation and Heat pipes
Introduction to radiation Black bodies, Diffuse surface transfer, enclosures, view-factor, radiation shield.
Equation of radiative transfer; absorbing media, Coupled problems – radiation and conduction Free and forced convection, integral equation, analysis and analogies.
Transpiration cooling, ablation heat transfer, Boiling, condensation and two phase flow mass transfer.
Advanced computational and analytical techniques for conduction, convection & radiation.

References:

1. Frank P. Incropera and David P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley and Sons, 1981.
2. M. Thirumaleshwar Fundamentals of Heat and Mass Transfer, Pearson Education Publication, 2009
3. A. F. Mills and V.Ganesan, Heat Transfer, Pearson Education Publication, 2009.
4. Frank Kreith and Mark S. Bohn, Principles of Heat Transfer, Harper and Row Publishers, 1986
5. R. C. Sachdeva, Fundamentals of Engineering Heat and Mass Transfer, Wiley Eastern Ltd., INDIA

Programme Elective-I

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5021S
Course Title	Advanced Thermodynamics

COURSE OUTCOMES:

The student should be able to

1. Apply the Laws of Thermodynamics to different systems.
2. Apply Entropy Principle to various heat flow systems.
3. Evaluate thermodynamic system using classical and Statistical thermodynamics.
4. Apply the Principles of Combustion Thermodynamics.

Course Contents:

Laws of Thermodynamics

Zeroth and First Law of Thermodynamics applied to macroscopic systems. Second Law analysis applied to macroscopic systems. Concept & Evaluation of entropy, Clausius inequality, Principle of increase of entropy. Maxwell equations, Helmholtz's & Gibbs's energy functions.

Entropy, Exergy and Availability for Single & Multiphase Systems

Available energy, Availability, Exergy & Irreversibility of a closed system in steady flow and their applications in Thermal Engineering. Real gases and their equations of state, Thermodynamic relations for a single component single phase systems. Generalized charts for compressibility, enthalpy changes and fugacity, mixtures of real gases; ideal and non-ideal liquid solutions.

Statistical Thermodynamics

Fundamental concepts of statistical thermodynamics. Thermodynamic properties and kinetics of perfect monatomic gases. Maxwell –Boltzmann, Fermi-Dirac and Bose – Einstein statistics.

Combustion Thermodynamics

Combustion Thermodynamics and Thermochemistry, Heat of Reaction, Calorific Value, Adiabatic Flame Temp, Combustion Kinetics. Combustion Modelling: Gas, Liquid and Solid Combustion.

Recommended Reading

1. F.W. Sears & G.L. Salinger, Thermodynamics Kinetic Theory and Statistical Thermodynamics, Addison – Wesley Publishing Company, 3rd Edition, 1982.
2. Mark W. Zemansky & Richard Dittman, Heat & Thermodynamics, The McGraw-Hill Companies Inc., 7th Edition, 1997.
3. Richard E. Sonntag and Claus Borgnakke, Fundamentals of Thermodynamics, John Wiley & Sons, New York, 8th Edition, 2009.
4. Chang L. Tien and J. H. Lienhard, Statistical Thermodynamics, McGraw Hill Book Company, New York, 2nd Edition, 1979.
5. Stephen Turns, An Introduction to Combustion: Concepts and Applications, McGraw-Hill, 3rd Edition, 2011.

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5022S
Course Title	Energy and Waste Heat Recovery

COURSE OUTCOMES:

The student should be able to:

1. Obtain a comprehensive understanding of energy recovery and waste heat utilization technologies
2. Equip themselves with the skills to design, analyze, and optimize energy recovery systems; to explore the integration of waste heat recovery systems into industrial processes
3. Address the economic, environmental, and social aspects of energy recovery
4. Understand the emerging trends and innovations in energy and waste heat recovery.

Course Content:

Introduction to Energy and Waste Heat Recovery

Global energy scenario and the importance of energy efficiency; principles of energy recovery and waste heat utilization; sources of waste heat in industrial processes; policy and regulatory frameworks in India (e.g., Energy Conservation Act, Perform, Achieve, and Trade (PAT) scheme).

Thermodynamics of Waste Heat Recovery

First and second laws of thermodynamics applied to waste heat recovery; exergy analysis and its application in energy recovery; heat exchangers: types, design, and performance analysis; pinch analysis for process integration and heat recovery.

Waste Heat Recovery Technologies

Recuperators and regenerators; heat pipes and heat pumps; thermoelectric generators; organic Rankine cycle (ORC) systems; Kalina cycle for low-grade heat recovery; steam and gas turbine systems for waste heat recovery.

Industrial Applications of Waste Heat Recovery

Waste heat recovery in cement, steel, and chemical industries; waste heat recovery in power plants and refineries; waste heat recovery in automotive and aerospace applications; case studies of waste heat recovery projects in India and globally.

Energy Storage and Integration

Thermal energy storage systems: sensible heat, latent heat, and thermochemical storage; integration of waste heat recovery systems with energy storage; role of energy storage in grid stability and renewable energy integration.

Economic, Environmental, and Social Aspects

Economic analysis: capital expenditure (CAPEX), operational expenditure (OPEX), and financing models; environmental impact assessment (EIA): reduction in greenhouse gas emissions and carbon footprint; social aspects: job creation and energy access; life cycle assessment (LCA) of waste heat recovery systems.

Emerging Trends and Innovations

Advanced materials for heat exchangers and thermoelectric generators; hybrid energy recovery systems combining multiple technologies; waste heat recovery in renewable energy systems (e.g., solar thermal, geothermal); role of digital technologies (IoT, AI) in optimizing waste heat recovery.

Recommended Reading:

1. Kreith, Frank, and Yogi Goswami. Principles of Sustainable Energy Systems. 3rd Edition, CRC Press, 2016
2. Bejan, Adrian. Advanced Engineering Thermodynamics. 4th Edition, Wiley, 2016
3. Wang, Lingai, and Didier Grouset. Waste Heat Recovery: Technologies and Applications. Elsevier, 2018

4. Moran, Michael J., and Howard N. Shapiro. Fundamentals of Engineering Thermodynamics. 8th Edition, Wiley, 2014
5. Ministry of Power, India. Energy Conservation Policy Documents and Reports. Available at https://powermin.gov.in
6. International Energy Agency (IEA). Waste Heat Recovery Research Reports. Available at https://www.iea.org.

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5023S
Course Title	Design of Thermal Systems

COURSE OUTCOMES:

The student should be able to

1. Identify design parameters of basic thermal systems
2. Model the thermal systems such as heat exchangers, evaporators, condensers, boilers, condensation of binary mixtures and turbo machinery
3. Construct the simulation of thermal systems
4. Understand the basics of optimum system design

Course Contents:

Fundamentals of Engineering Design

Introduction, Design versus analysis, need for optimization, basic characteristics of thermal systems, analysis, types and examples: energy systems, cooling systems for electronic equipment, environmental and safety systems, air-conditioning, refrigeration and heating systems, heat transfer equipment. Economic analysis. Cost analysis.

Modelling of thermal systems

Basic considerations in design, importance of modelling in design, types of models, mathematical modelling, physical modelling and dimensional analysis, Fundamentals of design, and selection of thermal equipment and processes such as heat exchangers, evaporators, condensers, boilers, binary mixtures and turbo machinery.

Simulation of thermal systems

Numerical modelling and simulation, development of a numerical model, solution procedure, merging of different models, accuracy and validation, system simulation, methods of numerical simulation, numerical simulation versus real systems

Fundamentals of optimum system design

Economic considerations, calculation of interest, worth of money as a function of time, raising capital, economic factors in design, application to thermal systems

Problem formulation for optimization, basic concepts, optimization methods, optimization of thermal systems, practical aspects in optimal design

Knowledge based design and additional considerations, knowledge based systems, additional constraints, sources of information

Recommended Reading:

1. Stoker W. F., Design of Thermal Systems, McGraw Hill
2. Yogesh Jaluria, Design and Optimization of Thermal Systems, McGraw-Hill international editions, 1998
3. Eckert E R G and Drake R M, Analysis of Heat and Mass Transfer, McGraw-Hill, New York, 1972
4. Szucs E, Similitude and Modeling, Elsevier, New York, 1977
5. Wellstead P E, Introduction to Physical System Modeling, Academic Press, New York, 1979

Programme Elective-II

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5031S
Course Title	Introduction to Renewable Energy Systems

Course Outcome:

After the completion of the course, the student should be able to:

1. Obtain a foundational understanding of renewable energy sources and their significance in the global energy landscape.
2. Explore the principles, technologies, and applications of renewable energy systems relevant to mechanical engineering.
3. Investigate the fundamentals of design, analysis, and integration of renewable energy systems.
4. Address the economic, environmental, and social aspects of renewable energy adoption.
5. Recognize hydrogen as a key renewable energy carrier and explore its production, storage, and utilization.

Course Content:

Introduction to Energy Systems and Renewable Energy

Global energy scenario: Fossil fuels vs. renewable energy; Classification of energy sources: Conventional and renewable; Importance of renewable energy in sustainable development; Overview of renewable energy policies in India (e.g., National Solar Mission, Wind Energy Policy, National Hydrogen Mission)

Solar Energy

Solar radiation and its measurement; Photovoltaic (PV) systems: Principles, components, and types of solar cells; Solar thermal systems: Flat plate collectors, evacuated tube collectors, and concentrated solar power (CSP); Applications of solar energy: Power generation, water heating, and space heating

Wind Energy

Wind energy principles and wind turbine technology; Types of wind turbines: Horizontal- axis and vertical-axis; Wind resource assessment and site selection; Applications of wind energy: Onshore and offshore wind farms

Hydropower

Principles of hydropower generation; Types of hydropower systems: Large, small, and micro hydropower; Components of hydropower plants: Turbines, generators, and penstocks; Environmental and social impacts of hydropower projects

Biomass Energy

Biomass resources and their characterization; Biomass conversion technologies: Combustion, gasification, and anaerobic digestion; Biofuels: Biodiesel, bioethanol, and biogas; Applications of biomass energy: Power generation and transportation

Geothermal and Ocean Energy

Geothermal energy: Principles and technologies; Types of geothermal power plants: Dry steam, flash steam, and binary cycle; Ocean energy: Tidal, wave, and ocean thermal energy conversion (OTEC); Applications and challenges of geothermal and ocean energy

Hydrogen Energy

Hydrogen as an energy carrier: Properties and advantages; Methods of hydrogen production: Steam methane reforming (SMR), Electrolysis (alkaline, PEM, SOEC) powered by renewables, Thermochemical and biological methods; Hydrogen storage technologies:

Compressed gas, liquid hydrogen, metal hydrides, and chemical storage; Hydrogen utilization: Fuel cells, hydrogen combustion, and industrial applications; Green hydrogen and its role in decarbonizing sectors like transportation, industry, and power generation

Energy Storage and Hybrid Systems
Energy storage technologies: Batteries, pumped hydro, and flywheels; Design and applications of hybrid renewable energy systems (e.g., solar-wind, solar-diesel); Role of energy storage in grid stability and renewable energy integration

Recommended Reading:

1. Twidell, John, and Tony Weir**.** Renewable Energy Resources. 3rd Edition, Routledge, 2015.
2. Kalogirou, Soteris**.** Solar Energy Engineering: Processes and Systems. 2nd Edition, Academic Press, 2013.
3. Manwell, James F., Jon G. McGowan, and Anthony L. Rogers. Wind Energy Explained: Theory, Design, and Application. 2nd Edition, Wiley, 2010.
4. Gulliver, John S., and Roger E. A. Arndt. Hydropower Engineering Handbook. McGraw-Hill Education, 1991.
5. Klass, Donald L. Biomass for Renewable Energy, Fuels, and Chemicals. Academic Press, 1998.
6. Sørensen, Bent. Hydrogen and Fuel Cells: Emerging Technologies and Applications. 2nd Edition, Academic Press, 2011.
7. Ministry of New and Renewable Energy (MNRE), India. Annual Reports and Policy Documents. Available at https://mnre.gov.in.
8. National Renewable Energy Laboratory (NREL). Research Reports and Technical Papers. Available at https://www.nrel.gov.
9. International Renewable Energy Agency (IRENA). Renewable Energy Statistics and Reports. Available at https://www.irena.org.

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5032S**
Course Title	**Solar Energy Technology**

Course Outcome:

After the completion of the course, the student will be able to:

1. Obtain a comprehensive understanding of solar energy technologies, including photovoltaic (PV) and solar thermal systems.
2. Equip themselves with the skills to design, analyze, and optimize solar energy systems.
3. Explore the integration of solar energy systems into existing power grids and infrastructure.
4. Address the economic, environmental, and social aspects of solar energy adoption.
5. Understand the emerging trends and innovations in solar energy technology.

Course Content:

Introduction to Solar Energy

Global energy scenario and the role of solar energy; solar radiation: principles, measurement, and estimation; solar energy potential in India and global trends; policy and regulatory frameworks in India (e.g., National Solar Mission, net METSring policies).

Photovoltaic (PV) Technology

Fundamentals of PV systems: working principles and components; types of solar cells: crystalline silicon (monocrystalline, polycrystalline), thin-film (CdTe, CIGS, a-Si), and emerging technologies (perovskite, organic PV); PV system design: grid-connected, off-grid, and hybrid systems; performance analysis: efficiency, degradation, and loss mechanisms.

Solar Thermal Technology

Principles of solar thermal energy conversion; types of solar thermal systems: low-temperature applications (flat plate collectors, evacuated tube collectors), medium-temperature applications (parabolic troughs, linear Fresnel reflectors), high-temperature applications (solar towers, parabolic dish systems); design and performance analysis of solar thermal systems.

Concentrated Solar Power (CSP)

CSP technologies: parabolic trough, solar tower, parabolic dish, and linear Fresnel reflectors; thermal energy storage systems: molten salt, phase change materials (PCMs); integration of CSP with conventional power plants (hybrid systems); case studies of CSP projects in India and globally.

Solar Energy System Design and Optimization

Resource assessment: solar irradiance data and site selection; system sizing: load analysis, component selection, and optimization techniques; software tools for solar energy system design (e.g., PVsyst, SAM, HOMER); economic analysis: levelized cost of energy (LCOE), payback period, and return on investment (ROI).

Emerging Trends in Solar Energy

Bifacial solar panels and tracking systems; floating solar photovoltaic (FPV) systems; agrivoltaics: combining solar energy with agriculture; building-integrated photovoltaics (BIPV); solar energy and green hydrogen production.

Economic, Environmental, and Social Aspects

Economic analysis: capital expenditure (CAPEX), operational expenditure (OPEX), and financing models; environmental impact assessment (EIA): land use, water consumption, and carbon footprint; social aspects: community engagement, energy access, and job creation; life cycle assessment (LCA) of solar energy systems.

Recommended Reading

1. Kalogirou, Soteris. Solar Energy Engineering: Processes and Systems. 2nd Edition, Academic Press, 2013.
2. Messenger, Roger A., and Jerry Ventre. Photovoltaic Systems Engineering. 3rd Edition, CRC Press, 2010.
3. Duffie, John A., and William A. Beckman. Solar Engineering of Thermal Processes. 4th Edition, Wiley, 2013.
4. Twidell, John, and Tony Weir. Renewable Energy Resources. 3rd Edition, Routledge, 2015.
5. Nelson, Jenny. The Physics of Solar Cells. Imperial College Press, 2003.
6. Ministry of New and Renewable Energy (MNRE), India. Solar Energy Policy Documents and Reports. Available at https://mnre.gov.in.
7. National Renewable Energy Laboratory (NREL). Solar Energy Research Reports. Available at https://www.nrel.gov.

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5033S
Course Title	Energy Conservation and Management

Course Outcomes:

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

Course Content:

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

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

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

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

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

Reference Books:

1. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,.Logman Scientific & Technical, ISBN-0-582-03184, 1990.

2. Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.

3. Bureau of Energy Efficiency - Energy Management Series

4. Larry C Whitetal, Industrial Energy Management & Utilization

Laboratory Courses

Programme Name	**Master of Technology in Mechanical Engineering with specialization in Thermal Science & Energy Systems**
Course Code	**METS5071L**
Course Title	**Laboratory-1 Computational Methods Laboratory**

Course Outcomes:

After completion of course, students would be able to

1. Write codes that use computational methods to numerically solve problems in a variety of disciplines in Mechanical Engineering.
2. Learn open-source packages that implement popular computational methods.
3. Apply the mathematical concepts for the Computational Methods course.

Course Contents:

The lab will involve the development of programs based on numerical methods using Python/Matlab/Scilab etc. for solving a variety of common Mechanical Engineering problems.

1. Program for solving system of linear equations
2. Program for regression analysis and curve / function fitting to a given data set
3. Program for root finding on non-linear equations
4. Program for Numerical Differentiation and Integration
5. Program for solving differential equations based on Runge-Kutta formulation
6. Program for Boundary Value Problems in Ordinary and Partial Differential Equations

Programme Name	**Master of Technology in Mechanical Engineering with specialization in Thermal Science & Energy Systems**
Course Code	**METS5072L**
Course Title	**Laboratory-2 Experimental Thermal Engineering Laboratory**

COURSE OUTCOMES:

The student should be able to

1. Apply the fundamental understanding of fluid dynamic and Heat Transfer concepts to practical problems
2. Measure pressure distribution, lift and drag around cylinders and Aerofoils.
3. Identify the effect of various parameters on the system and able to correlate them.
4. Apply the principles of compressible flow.
5. Use various thermal measurement devices for a thermal system.
6. Perform experiments on heat flow devices and examine the rate of heat transfer.
7. Evaluate heat transfer for different heat exchange devices.

Experiments:

1. Drag on a flat plate parallel and normal to flow
2. Pressure distribution around the cylinder
3. Drag on a cylinder
4. Pressure distribution around the NACA2412 Aerofoil
5. Drag and Lift on the NACA2412 Aerofoil
6. Drag & Lift Measurement of NACA2412 Aerofoil with variable Flap
7. Shock tube
8. Particle Image Velocimetry
9. Demonstration of thermal gun and thermal camera used in various industrial thermal devices
10. Experimentation on variation of radiation heat flux using pyrometer.
11. Experimentation on computerized heat exchanger devices to find heat dissipation rate

Programme Name	**Master of Technology in Mechanical Engineering with specialization in Thermal Science & Energy Systems**
Course Code	**METS5073L**
Course Title	**Laboratory-3 Modeling and Simulation of Thermal Systems Laboratory**

COURSE OUTCOMES:

The student should be able to

1. Model the thermal systems.
2. Construct the simulation of thermal systems.
3. Optimize the design of thermal system.

Course Contents:

The lab will involve Mathematical Modeling of Thermal Equipment for Simulation and optimization. e.g.

1. Heat exchangers
2. Evaporators
3. Condensers
4. Boilers
5. Compressor,
6. Pumps
7. Turbines

Recommended Reading:

1. Stoker W. F., Design of Thermal Systems, McGraw Hill

SEMESTER-II

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5002S**
Course Title	**Research Methodology and IPR**

Course Outcomes

After completion of course, students would be able to

1. Understand research problem formulation and approaches of investigation of solutions for research problems.
2. Learn ethical practices to be followed in research and apply research methodology in case studies and acquire skills required for presentation of research outcomes
3. Discover the importance of Intellectual Property Rights.
4. Promote Intellectual Property Right and patenting.

Course Contents:

Research Problem

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Literature Review

Effective literature studies approach, analysis, Plagiarism, Research ethics,

Technical Writing

Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Nature of Intellectual Property

Patents, Designs, Trade and Copyright. Process of Patenting and Development technological research, innovation, patenting, development. International Scenario International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

New Developments in IPR

Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies.

Recommended Reading

1. Ranjit Kumar, Research Methodology A Step by Step Guide for beginners, 2nd Edition
2. C.R. Kothari, Research Methodology Methods and Techniques
3. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd., 2007.
4. Mayall, Industrial Design, McGraw Hill, 1992.
5. Niebel, Product Design, McGraw Hill, 1974.
6. T. Ramappa, Intellectual Property Rights under WTO, S. Chand, 2008

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5013S
Course Title	Solar and Wind Energy System Design

Course Outcome:

After the completion of the course, the student will be able to:

1. Understand the basics of solar and wind energy systems, including their design, analysis, and optimization
2. Equip themselves with the skills to design and integrate solar and wind energy systems for various applications
3. Explore the economic, environmental, and social aspects of renewable energy system design
4. Understand the emerging trends and technologies in solar and wind energy.

Course Content:

Introduction to Solar and Wind Energy Systems

Global energy scenario and the role of renewable energy; overview of solar and wind energy technologies; solar and wind energy potential in India; policy and regulatory frameworks in India (e.g., National Solar Mission, Wind Energy Policy).

Solar Energy System Design

Solar radiation principles and measurement; photovoltaic (PV) systems: working principles, components, and types of solar cells; PV system design: grid-connected, off-grid, and hybrid systems; solar thermal systems: flat plate collectors, evacuated tube collectors, and concentrated solar power (CSP); performance analysis and optimization of solar energy systems.

Wind Energy System Design

Wind energy principles and wind turbine technology; types of wind turbines: horizontal-axis and vertical-axis; wind resource assessment and site selection; wind turbine design: aerodynamics, blade design, and power output estimation; performance analysis and optimization of wind energy systems.

Hybrid Solar-Wind Energy Systems

Design principles of hybrid solar-wind energy systems; component selection and sizing: solar panels, wind turbines, inverters, and controllers; energy storage systems: batteries, pumped hydro, and flywheels; case studies of hybrid solar-wind energy projects.

System Integration and Grid Connectivity

Grid integration challenges: intermittency, variability, and power quality; smart grid technologies and demand-side management; microgrids and decentralized energy systems; role of energy storage in grid stability and renewable energy integration.

Emerging Trends and Innovations

Bifacial solar panels and tracking systems; floating solar photovoltaic (FPV) systems; agrivoltaics: combining solar energy with agriculture; building-integrated photovoltaics (BIPV); advanced wind turbine designs: floating wind turbines and vertical-axis turbines; green hydrogen production using solar and wind energy.

Recommended Reading:

1. Kalogirou, Soteris. Solar Energy Engineering: Processes and Systems. 2nd Edition, Academic Press, 2013
2. Messenger, Roger A., and Jerry Ventre. Photovoltaic Systems Engineering. 3rd Edition, CRC Press, 2010
3. Duffie, John A., and William A. Beckman. Solar Engineering of Thermal Processes. 4th Edition, Wiley, 2013
4. Manwell, James F., Jon G. McGowan, and Anthony L. Rogers. Wind Energy Explained: Theory, Design, and Application. 2nd Edition, Wiley, 2010
5. Twidell, John, and Tony Weir. Renewable Energy Resources. 3rd Edition, Routledge, 2015
6. Ministry of New and Renewable Energy (MNRE), India. Solar and Wind Energy Policy Documents and Reports. Available at https://mnre.gov.in
7. National Renewable Energy Laboratory (NREL). Solar and Wind Energy Research Reports. Available at https://www.nrel.gov.

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5014T
Course Title	Computational Fluid Dynamics

COURSE OUTCOMES:

The student should be able to –

1. Analyze methodologies used in CFD.
2. Apply finite volume method to heat transfer and fluid flow problems.
3. Develop computer codes for simulation of heat transfer and fluid flow problems.

Course Contents:

Fundamentals of CFD

Overview of CFD, need, Advantages of CFD, Numerical vs. Analytical vs. Experimental, Applications of CFD, CFD methodology, grid independence, Verification and validation

Governing equations of mass, momentum and energy

Derivation, Discussion of physical meanings and presentation of forms particularly suitable to CFD, Boundary Conditions – Dirichlet, Neumann, Robbins, initial conditions, mathematical behavior of partial differential equations – Elliptic, parabolic & hyperbolic equations, impact on CFD

Discretisation methods

Introduction to Finite Difference Method, Finite Volume Method, Finite Element Method. Concepts of Convergence, consistency, stability. Solution of discretised equations, Direct methods and iterative methods, Tri Diagonal Matrix Algorithm, iterative convergence

Finite volume method for diffusion problems (Conduction)

Steady state one dimensional heat conduction with or without heat generation, Dirichlet, Neumann, and Robins type boundary conditions, Multi-solid heat conduction, Non-linear Heat Conduction, Unsteady heat conduction-Explicit, Crank-Nicolson, Implicit schemes, stability of solutions, two dimensional steady and unsteady heat conduction. Gauss-Seidal point by point and line by line TDMA methods. Solution of problems using computer code.

Finite volume method for Convection-diffusion problems

One dimensional convection-diffusion- Advection Schemes-Central, first order upwind, exponential, hybrid, power law, Second order upwind, QUICK etc., Conservativeness, boundedness, transportiveness, False diffusion, Extension to two dimensional steady and unsteady convection – diffusion; Solution of problems using computer code.

Solution algorithms for pressure velocity coupling

Staggered grids and co-located grids, SIMPLE, SIMPLER, SIMPLEC, PISO algorithms, unsteady flows Solution of problems using computer code.

Geometry Modeling and Grid Generation

Domain discretization, Practical aspects of computational modelling of flow domains, Grid Generation, Types of mesh and selection criteria, Mesh quality, Key parameters and their importance

Turbulence modeling

Turbulence, Reynolds Averaged Navier-Stokes (RANS) equations, introduction to turbulence modeling - DNS, LES, k-ε , k-ω, RSM models

Recommended Reading:

1. S V Patankar, Numerical Heat Transfer and Fluid Flow, Special Indian 1st Edition, Ane Books-New Delhi.
2. H K Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics-The Finite Volume Method, Second Indian Edition, Pearson Education, 2008
3. Atul Sharma, Introduction to Computational Fluid Dynamics: Development, Application and Analysis, John Wiely and Sons Ltd, 2017
4. Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Computational Fluid Dynamics: A Practical Approach, Elsevier, Third Edition, 2018
5. D. A Anderson, I.I. Tannehill , and R.H. Pletcher , Computational fluid Mechanics and Heat Transfer, CRC Press, 3rdEdition, 2012
6. John. D. Anderson, Jr., Computational Fluid Dynamics - The basics with applications, McGraw-Hill Education (India) , 1st Edition
7. Ferziger and Peric, Computational Methods for Fluid Dynamics, 3rd Edition, Springer, 2008

Programme Elective-III

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5041S**
Course Title	**Design of Heat Exchanger**

Course Outcomes:

After completion of course, the student should be able to -

1. Analyse theory and working of various heat exchangers.
2. Investigate the design methodology of a Hairpin and Shell-&-Tube heat exchangers.
3. Evaluate the performance of governing parameters for Plate heat exchangers.
4. Design Regenerative compact heat exchangers.

Course Contents:

Classification & Basic Design of Heat Exchangers

Basic types of heat exchange devices, Classification of heat exchangers, Advantages / limitations of various types of heat exchangers, Guidelines for selection of heat exchangers. Performance enhancement of heat exchangers, fouling and corrosion, Testing, Maintenance of heat exchangers. Basic design methods, Theoretical analysis of parallel flow, counter flow, crossflow and multi-pass heat exchangers, LMTD Approach, Effectiveness-NTU Approach, Use of various charts for calculation of performance factors.

Design of Hairpin (Double Pipe) Heat Exchangers

Counterflow double pipe heat exchangers, calculation of Fouling Factor, calculation of Pressure Drop in pipes and annuli. Kern method for design of Double Pipe heat exchangers. Double Pipe heat exchangers in series-parallel arrangements.

Design of Shell & Tube Heat Exchangers

Heat exchanger tubes, joints, baffles, and their various configurations. TEMA Standards and nomenclatures. Heat Transfer Coefficients and Pressure Drop calculations using Kern method, Bell-Delaware method, Willis-Johnston method.

Design of Plate Heat Exchangers

Plate heat exchangers – Gasketted, Spiral, Lamella. Plate heat exchangers – applications, advantages & limitations. Theoretical design of Plate heat exchangers. ASME Pressure Vessel Standards.

Regenerative Heat Exchangers

Compact heat exchangers, Regenerative heat exchangers Basic design methodologies for regenerative heat exchangers.

Recommended Reading:

1. Donald Q. Kern, Process Heat Transfer, McGraw-Hill Inc., 1st Edition, 1978.
2. G. F. Hewitt, G. L. Shires and T. R. Bott, Process Heat Transfer, CRC Press, 1st Edition, 1994.
3. Sadik Kakac and Hongtan Liu, Heat Exchanger Selection, Rating and Thermal Design, CRC Press, 3rd Edition, 2012.
4. Arthur P. Frass, Heat Exchanger Design Handbook, Hemisphere Publishing Corporation, 2nd Edition, 2012.
5. ASME Section VIII Div-1, 2 & 3 Ed. 2010 Addenda 2011A.
6. W. M. Kays and A. L. London, Compact Heat Exchangers, McGraw-Hill Inc., 1st Edition, 1964.

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5042S**
Course Title	**Thermal Energy Conversion and application**

COURSE OUTCOMES:

1. Identify components and technology solutions in modern combined power and heating station technology and carry out calculations on such energy systems
2. Apply energy and exergy analyses of energy systems where the primary energy sources up to energy services are included in the system
3. Critically process composite analyses of thermodynamic flows, exergy flows and environmental impact
4. Critically process exergy analyses, thermoeconomic analyses and pinch analyses on heat exchanger networks

Course Contents:

Fundamentals of thermodynamics - system and surroundings, second law of thermodymanics, Entropy and availability, First law combined with Second Law of thermodynamics, Thermodynamic properties.

Gas turbines - Air standard analysis, Brayton cycle & amp; gas power plants, Aircraft engines

Steam power plants - Rankine cycle including reheat and regeneration, Cogeneration and combined gas-vapor power cycles

Refrigeration and Heat Pumps - Vapour-compression refrigeration, system components, Heat pumps, Absorption refrigeration cycle, energy efficiency calculations in various systems Pinch Analysis in heat exchange processes, Air conditioning processes Fuel cells including SOFC-Gas turbine hybrid systems

Textbooks:

1. P.K Nag, Engineering Thermodynamics, Tata Mc-Graw Hill, New Delhi, 1991.
2. Y.A Cengel and M.A Boles, Thermodynamics: An Engineering Approach, Tata Mc-Graw Hill, New Delhi,
1998.
3. C.P Arora, Refrigeration and Airconditioning, Tata Mc-Graw Hill, New Delhi, 2004.
4 R. Yadav, Steam and gas turbine and Power Plant Engg, Central Publishing House, Allahabad 2011.

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5043S**
Course Title	**Cooling of Electronic System & Microfluidics**

COURSE OUTCOMES:

The student should be able to

1. Understand microscale fluid mechanism and flow
2. Apply fundamentals of the physics of flows at micro-level in terms of Knudsen number
3. Analyze single phase and two-phase convective phenomenon in microfluidics system.
4. Explore conservation equations and scaling effects in micro fluidics.
5. Develop the numerical technique to design heat flow microdevices using CFD softwares.

Course Contents:

Introduction, objectives of thermal control, heat sources, heat transmission, steady and unsteady heat transfer. Electronic equipment for airplanes, missiles, satellites, spacecraft, ships, submarines, personal computers, microcomputers and microprocessors.

Cooling techniques: i) air cooling-natural cooling ii) air cooling-forced convection iii) liquid cooling. Thermal contact conductance, fundamentals of heat transfer across an interface, real contact area, applications to microelectronics, enhancement of contact conductance. Extended surface arrays for air cooled systems, parameterizations, the fin input admittance, the limitations of the fin efficiency, Introduction to impinging jet theory, description of the principal flow regimes, single nozzle and multi-nozzle test rig, Taxonomy of liquid jet impingement conditions

Micro-scale fluid mechanics: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Flow in Microchannels, Overview of Macroscopic Thermal sciences – Convection, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Physics at the micrometric scale, molecular dynamics, Hydrodynamics & thermal transfers in microfluidic systems

Laminar convection – Internal flow, boundary-driven flow, Couette flow Poiseuille flow Convection heat transfer & Conservation Equations at microscale. Single -phase heat transfer & Thermophysical properties at the microscale

Microflow sensors, Differential pressure flow sensors, Drag force flow sensors, Lift force flow sensors, Coriolis flow sensors, Thermal flow sensors. Micromixers, Microparticle separator, principles of separation and sorting of micro particles, design and applications.
Microfluidics applications: Drug delivery, Diagnostics, Bio-sensing and IOT application using microfluidics.

Recommended Reading:

1. Nguyen, N. T., Werely,S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002.
2. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
3. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002.
4. Tabeling,P., Introduction to microfluidics, Oxford University Press Inc., 2005.
5. Kirby,B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
6. Colin,S., Microfluidics, John Wiley & Sons, 2009.
7. Frank P. Incropera and David P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley and Sons, 1981.
8. W. M. Kays and M. E. Crawford, Convective Heat and Mass Transfer, McGraw Hill Inc., 1993.

Programme Elective-IV

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5051S
Course Title	Energy: Audit & Policy

COURSE OUTCOMES:

The student should be able to:

1. Analyze national and international energy scenarios and challenges of climate change & peak oil.
2. Identify energy conservation opportunities in various industrial processes
3. Analyze the data collected during performance evaluation and recommend energy saving measures
4. Generate scenarios of energy consumption and predict the future trend energy analysis.
5. Integrate energy economics and relevance of sound energy policies for sustainable development.

Course Contents:

Introduction Energy Scenario-world and India. Energy Resources Availability in India. Energy consumption pattern. Energy conservation potential in various Industries and commercial establishments. Energy intensive industries - an overview. Peak oil. Energy conservation and energy efficiency – needs and advantages.

Pollution from Energy Generation Coal and Nuclear based Power Plants – Fly Ash generation and environment impact, Fly ash utilization and disposal, nuclear fuel cycle, radioactive wastes – treatment and disposal- Environmental pollution limits guidelines for thermal power plant pollution control- Environmental emissions from extraction, conversion, transport and utilization of fossil fuels- Greenhouse effect- Global warming. Role of Non-Conventional Energy Sources in Energy Conservation; Need and Kyoto Protocol, Carbon Credits and Clean Development Mechanism (CDM).

Energy Auditing: Energy Conservation Act 2001. Energy Auditing- Definition, need, types of energy audit methodologies, barriers. Role, Duties and responsibilities of energy managers and auditors. – Energy audit questionnaire. Energy management (audit) approach: Understanding energy costs, bench marking, energy performance, matching energy use to requirement, optimizing the input energy requirements; Fuel & energy substitution.

Energy Economics: Investment - need, appraisal and criteria, financial analysis techniques - break even analysis- simple payback period, return on investment, net present value, internal rate of return, cash flows, DSCR, financing options, ESCO concept.

Energy forecasting Energy forecasting techniques - Energy demand – supply balancing, Energy models, Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics (OLS) and statistical analysis (Multiple Regression), Econometrics techniques used for energy analysis and forecasting with case studies from India.

Energy Policies National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five-Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy- Carbon Trading- Renewable Energy Certification – CDM. The Sustainable Energy Utility (SEU) Model.

Recommended Reading:

1. General Aspects of Energy management and Audit, Guide book for energy manager and energy auditor, Bureau of energy efficiency
2. Energy Efficiency in Thermal Utilities, Guide book for energy manager and energy auditor, Bureau of energy efficiency
3. Energy Efficiency in Electrical Utilities, Guide book for energy manager and energy auditor, Bureau of energy efficiency
4. Energy Performance Assessment for Equipment and Utility Systems, Guide book for energy manager and energy auditor, Bureau of energy efficiency
5. Steve Doty, Wayne C. Turner, Energy Management Handbook
6. Jason Houck, Wilson Rickerson, The Sustainable Energy Utility (SEU) Model for Energy Service Delivery, http://online.sagepub.com
7. S Rao and B B Parulekar , Energy Technology, Khanna Publishers, 1999
8. B.G. Desai, M.D.Parmar, R.Paraman and B.S. Vaidya, Efficient Use of Electricity in Industries, ECQ series Devki R & D. Engineers, Vadodara
9. L.C. Witte, P.S. Schmidt, D.R.Brown, Industrial Energy Management and Utilization, Hemispherical Publication, 1988.
10. I.G.C. Dryden, The Efficient Use of Energy, Butterworth, London, 1982.
11. Albert Thumann, W. J. Younger, T. Niehus, Handbook of Energy Audits, CRC Press

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5052S**
Course Title	**Energy Efficiency, Storage & Optimization**

COURSE OUTCOMES:

1 Understand the principles, concepts, and operation of thermal energy storage systems
2 Select suitable energy storage materials
3 Design thermal energy storage systems
4 Evaluate the performance of thermal energy storage systems for different applications

Course Contents:

Introduction
Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Thermodynamics of Energy Storage, System Types, Environmental Impact.
Sensible Heat Storage Systems: Introduction, Types, Principles of Sensible Heat Storage Systems, Limitations, Advantages and Future Trend.
Latent Heat Storage Systems: Introduction, Types, Selection Criteria, Thermophysical Properties, Thermal Stability, Corrosion, Phase Segregation, Sub Cooling, Applications.

Microencapsulation and Nanoencapsulation:
Introduction, Microencapsulation and Nanoencapsulation of Phase Change Materials, Methods, Shape Stabilized Phase Change Materials, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation, Applications.
Design of Latent Heat Storage System: Introduction, Requirements and Considerations for the Design, Design Methodologies, Applications of Latent Heat Storage Systems Incorporating Pcms, Future Trends.

Modelling of Heat Transfer in PCMs:
Introduction, Inherent Physical Phenomena in Phase Change Materials, Modelling Methods and Approaches for the Simulation of Heat Transfer in Pcms for Thermal Energy Storage, Examples of Modelling Applications, Future Trends. Phase Change Materials for Energy Conservation in Buildings: Introduction, Integration of Pcms into Building Envelop, PCM Containment, Measurement of Thermal Properties of PCM Integrated in Buildings, Experimental and Numerical Studies.

Thermochemical Heat Storage: Introduction, Phenomena and Principles, Thermochemical Energy Storage Systems, Applications, Remarks.

Thermal Energy Storage Systems Applications: Introduction, Solar Air Heating, Solar Water Heating, District Heating, Heat to Waste, Cogeneration and Trigeneration Systems, Concentrated Solar Power, Cooling.

Textbooks:

1. Thermal Energy Storage Technologies for Sustainability Systems Design, Assessment and Applications, Kalaiselvam, S., Parameshwaran, R., Elsevier, 2014.
2. Advances in Thermal Energy Storage Systems - Methods and Applications, Luisa F. Cabeza, Elsevier, 2015.
3. Thermal Energy Storage: Systems and Applications, Ibrahim Dinçer, Marc A. Rosen, John Wiley & Sons Ltd., 2010.

Ralph Zito, Energy storage: A new approach, Wiley (2010)

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems
Course Code	METS5053S
Course Title	Bio Energy Technologies

COURSE OUTCOMES:

1 To understand biomass and its constituents for its various applications
2 To study chemical methods of biomass conversion for sustainable environment
3 To obtain knowledge on liquid fuel production and characterization
4 To learn and apply thermochemical processing of various feedstocks for fuel production

Course Contents:

Sources and classification – Chemical composition, properties of biomass – Energy plantations. Size reduction, Briquetting, drying storage and handling of biomass, Feedstock for biomass, Microbial and biochemical aspects – operating parameters for biogas production, kinetics and mechanism- high-rate digesters for industrial wastewater treatment incenaration – Processing for liquid fuel production,

Pyrolysis – effect of particle size, temperature and products obtained. Gasification- effect of temperature, pressure, steam and oxygen. Industrial effluents [food waste, textile, distilleries, glue, paper and pulp, Dairy and Miscellaneous]. Waste to energy [Domestic sewage, municipal solid waste] Biorefinaries

Combustion of rice husk and woody biomass – Life cycle analysis of biofuels. Environmental aspects of biofuel utilization, techno-economic features of biofuels.

Textbooks:

1 VVN Kishore 'Renewable Energy Engg and Technologies' TERI
2 Chakraverthy A, 'Biotechnology and alternative technologies for utilization biomass or agricultural wastes' Oxford and IBH publishing Co 1989
3 Venkata Ramana and Srinivas S.N ' Biomass Energy Systems' Tata Energy Research Institute, 1996

Laboratory Courses

Programme Name	Master of Technology in Mechanical Engineering with Specialization in Thermal Engineering
Course Code	**METS5074L**
Course Title	**Laboratory-4 Computational Fluid Dynamics Laboratory**

COURSE OUTCOMES:

The student should be able to –

1. Implement CFD process by using CFD software.
2. Interpret data obtained from the numerical solution

List of Practical's:

Use of CFD software (commercial/open source)

1. Flow between two parallel plates (laminar/turbulent) (with or without heat transfer)
2. Flow in pipe (laminar/turbulent)
3. Boundary layer on a flat plate
4. Flow over an aerofoil
5. Compressible flow through a nozzle
6. Supersonic flow Over a wedge
7. Convection in a pipe (laminar/turbulent)
8. Flow past a cylinder

Project:

Students will use CFD software (commercial/open source) for solution of a problem (sample problems given in the list, however students can select their own project topic) and present their results.

1. Lid driven cavity
2. Flow in a bend
3. Flow over backward facing step (laminar/turbulent)
4. Flow over Ahmed body
5. Fluid flow and heat transfer in a wavy channel
6. Flow over pick-up truck
7. Cooling electronic components in a computer

Recommended Reading

1. Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Computational Fluid Dynamics: A Practical Approach, Elsevier, Second Edition, 2012
2. https://confluence.cornell.edu/display/SIMULATION/FLUENT+Learning+Modules
3. https://courses.ansys.com/index.php/fluids/
   https://www.openfoam.com/documentation/

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Engineering**
Course Code	**METS5075L**
Course Title	**Laboratory-4 Solar Energy Laboratory**

Course Learning Objectives:

To provide the hands-on experience on the various Environmental Engineering / Solar Energy related instruments and data analysis.

Course Content:

SOLAR ENERGY:

1. Study of direct and diffused beam solar radiation
2. Study of greenhouse effect
3. Performance evaluation of solar flat plate collector
4. Study the effect of solar flat plate collector in parallel combination
5. Performance evaluation of concentrating solar collector
6. Performance evaluation of solar cooker
7. Performance evaluation of a solar PV panel
8. Performance of PV panel in series and parallel combination

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Thermal Engineering***
Course Code	**METS5076L**
Course Title	**Laboratory 6 - Microfluidics and MEMS Laboratory**

COURSE OUTCOMES:

The student should be able to –

1. Apply numerical techniques in internal and external heat flows of microdevices.
2. Perform experiments on micro convection heat transfer devices to examine heat dissipation rate.
3. Evaluate heat transfer phenomenon and friction, pressure drop characteristics in micro fluidics devices.
4. Apply computational techniques, skills, and modern engineering tools like CFD software to solve complex microfluidics problems

Contents:

1. Determination of heat transfer coefficient of flow over a bluff body
2. Numerical simulation of free stream flow over a circular cylinder and demonstrating the effect of Reynolds number and vortex shedding in a pipe.
3. Determination of boundary layer thickness in flow over a flat plate using concept of numerical analysis in external flow
4. Numerical study of Internal flow in a pipe and study of boundary layer formation with uniform velocity and temperature profile at inlet.
5. computational and analytical techniques to find heat transfer & pressure drop in a circular geometry
6. Determination of Nusselt number, Prandtl number and heat transfer in a flow through pipe
7. Study of velocity and temperature & pressure distribution at various sections of geometry.
8. Study & demonstration of components of microfluidics
9. Study of various components of particle image velocimetry.
10. Experimentation to find velocity & pressure variation using particle image velocimetry.

Open Elective-I

Programme Name	**Master of Technology in Mechanical Engineering with Specialization in Thermal Science & Energy Systems**
Course Code	**METS5061S**
Course Title	**Energy Conservation and Management**

COURSE OUTCOMES:

The student should be able to

1. Analyze national and international energy scenarios and challenges of climate change & peak oil.
2. Identify energy conservation opportunities in various industrial processes
3. Analyze the data collected during performance evaluation and recommend energy saving measures
4. Generate scenarios of energy consumption and predict the future trend energy analysis.
5. Integrate energy economics and relevance of sound energy policies for sustainable development.

Course Contents:

Introduction

Energy Scenario-world and India. Energy Resources Availability in India. Energy consumption pattern. Energy conservation potential in various Industries and commercial establishments. Energy intensive industries - an overview. Peak oil. Energy conservation and energy efficiency – needs and advantages.

Pollution from Energy Generation

Coal and Nuclear based Power Plants – Fly Ash generation and environment impact, Fly ash utilization and disposal, nuclear fuel cycle, radioactive wastes – treatment and disposal-Environmental pollution limits guidelines for thermal power plant pollution control-Environmental emissions from extraction, conversion, transport and utilization of fossil fuels-Greenhouse effect- Global warming. Role of Non-Conventional Energy Sources in Energy Conservation; Need and Kyoto Protocol, Carbon Credits and Clean Development Mechanism (CDM).

Energy Auditing

Energy Conservation Act 2001. Energy Auditing- Definition, need, types of energy audit methodologies, barriers. Role, Duties and responsibilities of energy managers and auditors. – Energy audit questionnaire. Energy management (audit) approach: Understanding energy costs, bench marking, energy performance, matching energy use to requirement, optimizing the input energy requirements; Fuel & energy substitution.

Energy conservation

Energy Efficiency in relevant utilities: Mechanical/Thermal – Boilers, Steam System, Furnaces, Insulation and Refractories, Cogeneration, Waste Heat Recovery, Heat Exchangers

Electrical – Electrical Systems - Demand control, Demand Side Management (DSM), Power Factor Improvement, benefits and ways of improvement, Load scheduling, Electric motors, losses,

efficiency, energy efficient motors, motor speed control, variable speed drive, Compressed air system, HVAC and refrigeration system, Fans and Blowers, Pumps and pumping system, Cooling Tower, Lighting system, Diesel/Natural Gas Power generating system
Civil – Energy Conservation in buildings and ECBC. Green Building, LEED rating, Application of Non-Conventional and Renewable Energy Sources Textile – Textile industry

Energy Economics
Investment - need, appraisal and criteria, financial analysis techniques - break even analysis- simple payback period, return on investment, net present value, internal rate of return, cash flows, DSCR, financing options, ESCO concept.

Energy forecasting
Energy forecasting techniques - Energy demand – supply balancing, Energy models, Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics (OLS) and statistical analysis (Multiple Regression), Econometrics techniques used for energy analysis and forecasting with case studies from India.

Energy Policies
National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five-Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy- Carbon Trading- Renewable Energy Certification – CDM. The Sustainable Energy Utility (SEU) Model.

Recommended Reading:

1. General Aspects of Energy management and Audit, Guide book for energy manager and energy auditor, Bureau of energy efficiency
2. Energy Efficiency in Thermal Utilities, Guide book for energy manager and energy auditor, Bureau of energy efficiency
3. Energy Efficiency in Electrical Utilities, Guide book for energy manager and energy auditor, Bureau of energy efficiency
4. Energy Performance Assessment for Equipment and Utility Systems, Guide book for energy manager and energy auditor, Bureau of energy efficiency
5. Steve Doty, Wayne C. Turner, Energy Management Handbook
6. Jason Houck, Wilson Rickerson, The Sustainable Energy Utility (SEU) Model for Energy Service Delivery, http://online.sagepub.com
7. S Rao and B B Parulekar , Energy Technology, Khanna Publishers, 1999
8. B.G. Desai, M.D.Parmar, R.Paraman and B.S. Vaidya, Efficient Use of Electricity in Industries, ECQ series Devki R & D. Engineers, Vadodara
9. L.C. Witte, P.S. Schmidt, D.R.Brown, Industrial Energy Management and Utilization, Hemispherical Publication, 1988.
10. I.G.C. Dryden, The Efficient Use of Energy, Butterworth, London, 1982.
11. Albert Thumann, W. J. Younger, T. Niehus, Handbook of Energy Audits, CRC Press