M. Tech. in
THERMAL ENGINEERING

(Effective from 2022-23)

DEPARTMENT OF MECHANICAL ENGINEERING

MOTILAL NEHRU NATIONAL INSTITUTE OF TECHNOLOGY ALLAHABAD

Vision and Mission of the Institute

VISION

To attain a distinct identity for the Institute through innovation, knowledge creation and dissemination for the benefit of the society.

MISSION

- To nurture an eco-system for continuous enhancement of value-based teaching and learning process in the emerging areas of technology.
- To train quality human and knowledge resources in the service of society.
- To develop sustainable products and technologies.

Vision and Mission of the Department

VISION

To be a centre of excellence in Mechanical, Production and Industrial Engineering education and research for the benefits of society and humanity.

MISSION

- To educate and develop competent human resources for contemporary industry, academia and research.
- To promote interdisciplinary research and innovation skills in the graduates.
- To enhance the efforts to develop sustainable products, processes and technologies by developing competent entrepreneurs for the benefit of the society.

Department of Mechanical Engineering:

Brief about the Department:

The Department of Mechanical Engineering is one of the oldest departments of the institute and was established in the year 1961. We are the largest community of excellent, energetic, and dynamic faculty, staff and students in the institute. The department is having highly qualified and experienced faculty (36 faculty members) in all streams of Mechanical Engineering. The department is broadly divided into three academic streams in which students receive outstanding education with a wide choice of specializations, electives and research areas. These three academic streams are: Design Engineering, Production and Industrial Engineering and Thermal Engineering.

The department offers eight semester (i.e. 4 year) Bachelor of Technology (B. Tech.) programmes in Mechanical Engineering and Production and Industrial Engineering. Every year 223 students are admitted through JEE (mains) and 15% of this intake is through Direct Admission to Students Abroad (DASA) scheme for the above two B. Tech. programmes. Some students are also through ICCR and MEA (Govt. of India) Schemes.

The department also offers four semester (i.e. 2 year) Master of Technology (M. Tech.) programmes in Computer Aided Design and Manufacturing, Design Engineering, Product Design and Development, Production Engineering and Thermal Engineering. Every year 125 students (25 in each specialization) are admitted through GATE in the above five M. Tech. programmes.

The department also offers Doctor of Philosophy (Ph.D.) programme in various areas of Mechanical Engineering as well as Production and Industrial Engineering. The strength of the department lies in its Ph.D. programme with more than 100 PhDs already been awarded till March, 2022. About 80 research scholars are presently pursuing their PhDs. Every year the department admits Ph.D. students equal to half of the number of faculty holding Ph.D. degree. The department is also a QIP centre for PhD and M. Tech programmes.

Today, the world of Mechanical Engineering changes under the influence of advanced computational tools, improved simulation and analysis, and entirely different manufacturing protocols. This has opened up new vistas of research in the department.

List of Programmes offered by the Department:

Program	Title of the Program
B. Tech.	Mechanical Engineering
	Production & Industrial Engineering
M. Tech.	Computer Aided Design and Manufacturing
	Design Engineering
	Product Design and Development
	Production Engineering
	Thermal Engineering
Ph.D.	Mechanical Engineering

M. Tech. – Thermal Engineering
Program Outcomes

PO1	Able to independently carry out research/investigation and development work to solve practical problems in engineering
PO2	Able to write and present a substantial technical report/document
PO3	Able to demonstrate degree of mastery over Thermal Engineering at a level higher Than the appropriate bachelor program
PO4	Able to apply principles of thermodynamics, fluid mechanics, and heat transfer for the analysis and design of renewable and non-renewable thermal energy systems
PO5	Able to evaluate economic feasibility and environmental aspects of thermal systems

SCHEME OF INSTRUCTION

M. Tech. Thermal Engineering – Course Curriculum Structure

S. No.	Code	Course	Credit	L-T-P	Contact Hours
Semester-I					
1	ME21121	Advanced Thermodynamics	4	4-0-0	
2	ME21122	Advanced Energy Technology	4	4-0-0	
3		Elective I	4	4-0-0	
4		Elective II	4	4-0-0	
5		Elective III	4	4-0-0	
		Total	**20**		
Semester-II					
1	ME22123	Design of Thermal Systems	4	4-0-0	
2	ME22221	Thermal Engineering Laboratory	4	0-0-8	
3		Elective IV	4	4-0-0	
4		Elective V	4	4-0-0	
5		Elective VI	4	4-0-0	
		Total	**20**		
Semester-III					
1	ME23671	State of the art Seminar / Special Study / Term Project	4		
2	ME23621	Thesis	16		
		Total	**20**		

Semester-IV					
1	ME24621	Thesis	20		
		Total	**20**		

List of Electives and Minors: M. Tech. (Thermal Engineering)

S. No.	Code	Name
1.	ME21362	Conductive and Radiation Heat Transfer
2.	ME21361	Computational Methods in Engineering
3.	ME21363	Optimization Methods in Engineering
4.	ME21364	Alternative Fuels Technology
5.	ME21366	Design of Cryogenic System
6.	ME21367	Gas Turbine and Jet Propulsion
7.	ME21368	Design of Thermal Turbo Machines
8.	ME21369	Marine Engines and Propulsion
9.	ME22375	Convective Heat Transfer
10.	ME22375	Design and Analysis of Solar Energy Systems
11.	ME22370	Design of Air Conditioning Systems
12.	ME22372	Internal Combustion Engines and Pollution
13.	ME22373	Computational Fluid Dynamics
14.	ME22374	Exergy Analysis of Thermal Systems
15.	ME22376	Energy Systems and Management
16.	ME22377	Fuels and Combustion Engineering
17.	ME22378	Thermo-fluid Dynamics

Course Code: ME 21370	Advanced Thermodynamics	Credits: 4-0-0:4

Prerequisites:

Course Outcomes

S. No.	Outcomes	BT Level	BT Description
CO1	Students will be able to know how to design thermal systems based on its operating conditions and properties of fluids used in the system.	3	Apply
CO2	Students will be able to know the requirement of statistical approach in thermodynamics.	2	Understand
CO3	Students will be able to identify the appropriate equation of state for the modelling of substances.	2	Understand
CO4	Students will be able to find equilibrium state of substances using Gibbs energy minimization.	3	Apply

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	1
CO2	3	2	3	1	1
CO3	2	2	3	2	1
CO4	2	2	3	2	1

Unit	Details	Lectures	CO mapping
1	Temperature, Macroscopic motion, Adiabatic processes, Pressure, Work and quantity of heat. The free energy and thermodynamic potential, Relations between the derivatives of thermodynamic quantities	6	CO1
2	Legendre transform, the thermodynamic scale of temperature, Joule Thomson process, Maximum work, Maximum work done by a body in an external medium, Thermodynamic inequalities	6	CO1
3	Probability and Statistics: Binomial Distribution, Poisson Distribution, Gaussian Distribution, Combinatorial Analysis for Statistical Thermodynamics**,** Ensemble Method of Statistical Thermodynamics Most Probable Microstate, Elementary. Kinetic Theory: Maxwell–Boltzmann Distribution, Ideal Gas Pressure, equation of state of an ideal gas, Ideal gases with constant specific heat, law of equipartition.	6	CO2
4	Bose–Einstein and Fermi–Dirac Statistics, Entropy and the Equilibrium Particle Distribution- The Boltzmann Relation for Entropy, Identification of Lagrange Multipliers, Equilibrium Particle Distribution. Molecular Partition Function.	6	CO2
5	Caloric Properties, Ideal Gases, Real Fluids, Auxiliary Functions, Residual Functions, Fugacity and Fugacity Coefficient,	4	CO3
6	Phase Equilibria, Equations of State, Virial Equation, High Precision Equations of State, Cubic Equations of State, Generalized Equations	4	CO3

	of State and Corresponding States Principle		
7	Chemical potential and equilibrium, Gibbs-Duhem Equation, Criterion for Phase Equilibrium, Gibbs Phase Rule	4	CO4
8	Clapeyron Equation, Isothermal Two-Phase Flash: Successive substitution, Rachford-Rice equation, Gibbs energy minimization.	4	CO4

References:

1	Engineering thermodynamics	Nag, P. K.	Tata McGraw-Hill Education
2	Statistical thermodynamics: fundamentals and applications	Laurendeau, Normand M.	Cambridge University Press
3	Course of theoretical physics	Landau, Lev Davidovich, and Evgenii Mikhailovich Lifshitz	Elsevier
4	Chemical thermodynamics for process simulation	Gmehling, Jürgen, Michael Kleiber, Bärbel Kolbe, and Jürgen Rarey	John Wiley & Sons
5	Thermodynamic models: fundamentals & computational aspects	Michelsen, M. L., and Jr M Mollerup	Holte, Denmark: Tie-Line Publications
6	Chemical Thermodynamics-Principles and Applications	Ott, J. Bevan, and Juliana Boerio-Gates	Academic Press

Course Code: ME21122	Advanced Energy Technology	Credits: 4-0-0:4

Prerequisite: B. Tech degree in Mechanical Engineering

Course Outcomes

S. No.	Outcomes	BT Level	BT Description
CO1	Understand the fundamentals of direct and indirect energy conversion.	2	Understand
CO2	Learn state of the art technologies adopted for energy efficiency improvement in power generation	3	Apply
CO3	Perform numerical analysis of energy conversion systems for performance assessment.	4	Analyse
CO4	Carry out an environmental assessment of power generation systems based on carbon and water footprint as well as an economic assessment based on life cycle cost of energy.	6	Evaluate

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	3	1
CO2	1	3	3	1	2
CO3	2	1	3	3	1
CO4	2	2	3	1	3

Unit	Details	Lectures	CO mapping
1	Energy classification, Sources and utilization, Principle of energy conversion, Indirect / direct energy conversion.	6	CO1
2	Supercritical pressure cycle, Combined Cycle power plants, Natural gas cycles, Repowering, Supplementary firing with biomass for carbon reduction, clean coal technologies, Integrated Gasification Combined Cycle (IGCC), Pressurized fluidized bed combustion (PFBC) based combined cycle, Carbon capture and storage.	8	CO2 & CO3
3	Nuclear power plants: thermal fission, breeder and fusion reactors, environmental and safety aspects of nuclear power generation.	6	CO2&CO4
4	Basic principles of design and operations of (i) Thermoelectric (ii) Thermionic convertors (iii) Photovoltaic energy systems (iv) Fuel cells (v) Magneto Hydrodynamic (MHD) power generation (vi) Green Hydrogen production and storage.	8	CO1 & CO2
5	Seminar presentations related to state of the art in Energy Technology	8	CO2 &CO4

References:

1	Power Plant Technology	Mohamed Mohamed El Wakil	McGraw-Hill, 1984
2	Essentials of Energy Technology	Jochen Fricke and Walter L. Borst,	Wiley, 2013
3	Power Plant Engineering	P.K. Nag,	McGraw-Hill, 2017

Course Code: ME22123	Design of Thermal Systems	Credits: 4-0-0:4

Prerequisites: B. Tech in Mechanical Engineering

Course Outcomes

S. No.	Outcomes	BT Level	BT Description
CO1	Gain an understanding of thermal design based on systems thinking in place of individual components and processes.	2	Understand
CO2	Numerically analyze different design configurations based on industry or field requirements for developing energy efficient designs	4	Analyse
CO3	Suggest and recommend technically feasible, economically viable, and environmentally sustainable design solutions to meet industrial requirements.	5, 6	Synthesis & Evaluate

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	2	2	3	1	1
CO2	2	2	3	3	2
CO3	2	3	3	1	3

Unit	Details	Lectures	CO mapping
1	Basic concepts and overview of thermal system design. Characteristics of a thermal system, Formulation of the design problem, Conceptual design, Steps in the design process, Workable and optimum systems.	6	CO1 & CO3
2	Energy-efficient thermal systems: Cogeneration, tri-generation and multi-generation systems; Combined cooling and power systems e.g., Goswami cycle.	8	CO2 & CO3
3	Heat recovery through de-superheating in refrigeration systems, Heat Pumps and their applications, Mechanical Vapor Recompression systems and applications.	8	CO2 & CO3
4	Cascaded V-C and V-A refrigeration systems, District cooling, Energy recovery in air-conditioning systems. Passive cooling and heating systems.	8	CO2 & CO3
5	Case studies on modern developments in thermal systems along with their design, operation and economic aspects.	6	CO3

References:

1	Design of Thermal Systems	W F Stoecker	McGraw-Hill, 1989
2	Essentials of Thermal System Design and Optimization	C. Balaji	Ane Books, 2011
3	Design and Optimization of Thermal Systems	Yogesh Jaluria	CRC press, 2019

Course Code: ME-22221	Thermal Engineering Lab	Credits: 0-0-3:3

Prerequisites: Engineering Thermodynamics, HMT, Internal Combustion Engine, RAC.

Course Outcome

CO1	Identify the components related to internal combustion engines and Refrigeration systems along with their analysis of different performance parameter
CO2	Understand and analyze the various alternative fuels and their properties for IC engine applications
CO3	Understand and Analyze working of various heat transfer equipment.
CO4	Understand and Analyze the basics of solar energy and solar photovoltaic's.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	3
CO2	3	3	3	2	3
CO3	2	3	3	3	2
CO4	3	3	3	3	3

No.	List of Experiments	Practical (Hrs)
1	Assembly and Disassembly of DM10 Single Cylinder Diesel Engine.	3
2	To evaluate the Performance and Emission characteristics of Computerized Single Cylinder Petrol Engine.	3
3	To evaluate the Performance and Emission characteristics of Computerized Single Cylinder Diesel Engine.	3
4	To conduct study and Performance on a Vapour Compression and Vapour Absorption Refrigerator System.	3
5	Biodiesel production and its measurement.	3
6	Determination of Calorific value, Density and Viscosity of various alternative fuels using Bomb Calorimeter, Electronics Density Meter and Digital Viscometer.	3
7	Study of the Heat transfer in natural convection apparatus.	3
8	Study of the Stefen Boltzman apparatus and estimation of Stefen Boltzman's constant.	3
9	To measure the overall Current-Voltage characteristic of two Crystalline & Soler Cell connected on Series & Parallel.	3
10	To calculate Beam Radiation, Diffused Radiation, Global Radiation, Relative Humidity of air, Velocity of air and Light Intensity.	3
11	To measure Light Intensity at various points in a Room and Plot the Graph.	3

Text Books:

1	Internal Combustion Engine Fundamentals	J. B. Heywood	Tata McGraw-Hill
2	Refrigeration and Air-conditioning	C. P. Arora	Tata McGraw-Hill
3	Biodiesel: Production and Properties	Amit Sarin	Royal Society of Chemistry

4	Heat and Mass Transfer	P. K. Nag	Tata McGraw-Hill
5	Solar Energy	S P Sukhatme, J K Nayak	Tata McgrawHill Publications

References:

1	IC Engines	V. Ganeshan	Mc GrawHill Book Co, New York.
2	Refrigeration and air conditioning	W. F.Stoecker, and J. W. Jones	Mc GrawHill Book Co, New York.
3	Practical Handbook on Biodiesel Production and Properties	Mushtaq Ahmad, Mir Ajab Khan, Muhammad Zafar, Shazia Sultana	CRC Press
4	Solar Photo voltaics: Fundamentals, Technologies and Applications	C. S.Solanki	PHI Publications.
5	Solar Energy Fundaments, Design, Modeling & Applications	G.N. Tiwari	Narosa Publications.

Course Code: ME21362	Conduction and Radiation Heat Transfer	Credits: 4-0-0:4

Prerequisites: Engineering Thermodynamics & Fluid Mechanics.

Course Outcomes

CO1	Students will be able to understand the basic concepts of various modes of heat transfer mechanisms (conduction, convection and radiation)
CO2	Students will be able to identify and solve various problems pertaining to transient and steady conduction in 1D and 2D.
CO3	Students will be able apply the basic governing equations to solve conduction heat transfer in semi-infinite solid, 1D and 2-D transient condition in bar, cylinder and sphere, fins.
CO4	Students will be able to apply and analyze the concepts of radiation in both participating and non-participating media. to resolve the problems in practical situations

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	1	2	1	3	2
CO2	3	2	3	3	2
CO3	3	3	3	3	1
CO4	3	3	3	3	1

Unit	Details	Lectures
1	Conduction concepts; One dimensional steady state conduction with and without heat sources; Fins of constant and variable cross-sectional area; Transient heat conduction; Analytical and numerical solutions of steady state heat conduction problems; Use of Heisler and Grober chart to predict temperature within a wall, cylinder and sphere; two-dimensional bar; Heat conduction in anisotropic media	20
2	Conduction in semi-infinite medium, short cylinder, Analytical and Numerical solution of 2D steady state heat diffusion equation	4
3	Radiation, surface properties, view factors; Radiation exchange in black and grey enclosure; Electrical analogy, Radiation exchange between two or three bodies. Interaction of surface radiation with other mode of heat transfer. Introduction to radiation in participating media.	12

Text Books:

1	Fundamentals of Heat and Mass Transfer (in SI Units)	F.P Incropera, D.P. Dewitt	John Wiley and Sons

References:

1	Heat and Mass Transfer: Fundamentals & Applications	Y.A. Cengel, A.J. Ghajar	Mcgraw Hill Education
2	Heat Transfer: A Basic Approach	N Ozisik	McGraw Hill Education
3	Heat Transfer	J.P. Holman, S.,Bhattacharyya	McGraw Hill Education (India
4	A Textbook on Heat Transfer	Sukhatme, S. P	Universities Press, Hyderabad

Course Code: ME21361	Computational Methods in Engineering	Credits: 3-0-0:3

Prerequisites: Engineering Thermodynamics, Heat Transfer, Numerical Methods.

Course Outcomes

CO1	To understand various discretization methods for solving PDE problems
CO2	To understand fundamental matrix algebra concepts to solve simultaneous linear equations numerically
CO3	To apply numerical methods to obtain approximate solutions and evaluate the accuracy of common numerical methods
CO4	To apply numerical methods for solving steady and transient heat transfer problems numerically

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	2	2
CO2	3	3	3	3	2
CO3	2	2	2	2	3
CO4	3	2	3	3	3

Unit	Details	No. Hrs
1	**Introduction to Discretization Methods**: Finite difference method (FDM, Finite element method (FEM) and Boundary Element Method (BEM).	5
2	**Introduction, history, applications, merits and demerits of FDM:** Discretization Methods: Method for solving discretization equations, Consistency, stability and convergence; Representation of a Derivative; Backward Difference; Central difference; Forward, backward and central difference stencil; Stencil in y direction; 2nd Order and Mixed Derivative; Boundary Consideration; Polynomial Approach; Order of Approximation. Application of FDM to thermal engineering problems: 1D Steady State Conduction; Treatment of Boundary Condition; Algebraic Equations and Matrix Form; Unsteady Heat Conduction with FDM; Extensive Application to transient heat transfer by FDM. Use of FDM for finding solution of 2D and 3D heat transfer problems: Steady State Heat Conduction; Flux Boundary Condition, Convective Boundary Condition and Insulated Boundary.	6
3	**Finite Element Method (FEM):** Introduction, history, applications, merits and demerits of FEM; Variational and Weighted Residual Approaches of FEM; Finite Elements and Interpolation Functions (1D, 2D and 3D); Finite Element Formulation (Variational and Galerkin's) of 1D, 2D and 3D Heat transfer Problems; FE formulation of 1D heat transfer with mass Transport using Galerkin's method.	8
4	**Boundary Element Method (BEM**): Introduction, history, applications, merits and demerits of BEM; Approach of BEM; Numerical Implementation: Determination of Ci; Tackling kernel singularity; 3D BE formulation for transient heat transfer problems; Examples: Temperature distribution in cutting tool, thermal design of blast furnace bottom and laser heating problems.	7

References:

1	Numerical Heat Transfer and Fluid Flow	Suhas V. Patankar	CRC Press
2	Fundamentals of Heat and Mass Transfer	Incropera, F.P., Dewitt D.P.	John Wiley and Sons, New York
3	Heat Transfer: A Basic Approach	Ozisik,N.	McGraw-Hill Inc.,US

Course Code: ME 21367	Gas Turbine and Jet Propulsion	Credits: 4-0-0:4

Prerequisites: Gas Turbine and Jet Propulsion

Course Outcomes

S. No.	Outcomes	BT Level	BT Description
CO1	Understand the fundamentals of Gas Turbine and Jet Propulsion systems	2	Understand
CO2	Understand the role of different components in a Gas Turbine and Jet Propulsion System	2	Understand
CO3	Evaluate the performance of Gas Turbine propulsion system.	3	Evaluate

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	3	1
CO2	3	3	3	3	1
CO3	3	3	3	3	3

Unit	Details	Lectures	CO mapping
1	Review of gas dynamics: Physical difference between incompressible, subsonic and supersonic flows Three reference speeds, dimensionless velocity concepts of static and stagnation parameters. Pressure waves, finite shock and detonation waves, compound waves, analysis of piston excited waves, shock tubes, one dimensional isentropic flow, normal shocks Rayleigh flow, fanno flow.	8	CO1
2	Gas turbine outlines: Review of thermodynamic principles, Gas turbine cycles, main component of Gas turbine power plants, performance characteristics, typical Gas turbine plants, method of improving efficiency and power output of Gas turbine plants.	8	CO1, CO2
3	Design considerations of centrifugal and axial flow compressors.	3	CO2
4	Types of Gas turbine plants and their theory of operation, design consideration of Gas turbine plants. Detailed study of main systems of Gas turbine plants.	6	CO1, CO2
5	Selection of materials of Gas turbine components trouble shooting, maintenance and actual performance evaluation of a Gas turbine plants, recent development of a Gas turbine plants.	3	CO2
6	Jet propulsion outline: Basic theory of jet & rocket propulsion devices and historical development. Types of various jet propulsion plants like air screw, turboprop, turbojet, ram jet, rocket propulsion etc. And their comparative study.	6	CO2, CO3
7	Performance study of various jet propulsion devices from ideal and practical consideration.	3	CO3
8	Study and design considerations of main components of jet propulsion plants. Thrust	3	CO2

	augmentation devices and their thermodynamic analysis.		
9	Combustion performance, products at combustion and their properties, recent advances in jet propulsion and rocket propulsion devices.	5	CO3

References:

1	Gas Dynamics	E. Rathakrishnan	Prentice Hall of India
2	Compressible Fluid Flow	M.A. Sand	Prentice Hall of India
3	The Dynamics and Thermodynamics of Fluid Flow	A.H.Shapiro	Ronal Press
4	Gas Turbine Fundamentals	Cohen and Rogers and Sarvanmutto	Pearson
5	Jet Propulsion	Jack D. Mattingly	McGraw Hill Inc.
6	Gas Turbine	V. Ganeshan	Tata-McGraw-Hill, New Delhi

Course Code: ME22375	Design and Analysis of Solar Energy Systems	Credits: 4-0-0:4

Prerequisites: Heat and Mass Transfer, Basic concepts of Energy and Solar Energy

Course Outcomes

S. No.	Outcomes	BT Level	BT Description
CO1	Identifying importance and basics of solar energy, measurement, applications and classifications.	2	Understand
CO2	Apply the designing concepts of various solar energy applications and classification.	3	Apply
CO3	Analyzing various designs of solar energy applications.	4	Analyze
CO4	Evaluate the performance of various solar energy applications.	5	Evaluate

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	2	2
CO2	3	3	3	3	3
CO3	3	3	3	3	3
CO4	3	3	3	3	3

Unit	Details	Lectures
1	Introduction, Solar Radiation and its Measurement, Various Solar Energy Systems, Classifications, sun-earth angles, Weather classification, climatic zones.	6
2	Design and analysis of Solar water heater, Solar air heater, and Solar distillation system.	8
3	Solar passive house, Principles of solar passive house, Thermal comfort and its parameters, Sol-air temperature for bare, wetted, and glazed systems, Trombe's wall, solarium etc.	8
4	Photovoltaics, Working Principle, conversion efficiency, fill factor, I-V characteristics, Classification, Applications, Design and analysis of photovoltaic plant.	6
5	Working principle, Design and analysis ofother solar energy systems such as solar aquaculture, Solar greenhouse system, Solar refrigeration and air-conditioning, Solar thermal power generation plant, Solar cooker.	6
6	Energy, Exergy analysis of solar energy systems, Enviro-economic analysis of various solar energy systems.	6

Text Books:

1	Solar Energy-Fundamentals, Design, Modeling& Applications'	G.N. Tiwari	Narosa Publishing House, New Delhi, India
2	Solar Energy	S.P. Sukhatme, J.K. Nayak	Mcgraw Hill
3	Solar Photovoltaics - Fundamentals, Technologies and Applications	C.S. Solanki	PHI

References:

1	The Passive Solar House: The complete guide to heating and cooling your home	J. Kachadorian	Chelsea Green Publishing
2	Solar Refrigeration	S. Kapil	Lambert Academic Publishing
3	Solar Air-conditioning and Refrigeration	J.C. McVeigh, A. A. M. Sayigh	Pergamon Press

Course Code: ME22373	Computational Fluid Dynamics	Credits: 3-0-0:3

Prerequisites: Engineering Thermodynamics, Heat Transfer, Numerical Methods in Engineering

Course Outcomes

CO1	To understand various discretization methods for solving PDE problems
CO2	To understand fundamental matrix algebra concepts to solve simultaneous linear equations numerically
CO3	To apply numerical methods to obtain approximate solutions of General Transport equations
CO4	To apply FVM method for solving Navier Stokes equation numerically

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	2	2
CO2	3	2	2	2	2
CO3	2	3	3	2	3
CO4	3	2	3	3	3

Unit	Details	Lectures
1	**Mathematical Description of the Physical Phenomena-** Governing equations—mass, momentum, energy, species, General form of the scalar transport equation, Elliptic, parabolic and hyperbolic equations, Behaviour of the scalar transport equation with respect to these equation type.	5
2	**Discretization Methods-** Methods for deriving discretization equations- Introduction to finite difference, finite volume and finite element methods, Method for solving discretization equations – iterative methods, Consistency, stability and convergence - Von-Neumann stability analysis.	6
3	**Diffusion Equation-** 1D-2D steady and transient diffusion, Treatment of source terms, non-linearity, Boundary conditions, interface diffusion coefficient, Under-relaxation, Unsteady diffusion, Explicit, Implicit and Crank-Nicolson scheme, Two dimensional conduction, Boundeness, accuracy, stability and convergence for diffusion problems.	8
4	**Convection and Diffusion-** Steady and transient one-dimensional convection and diffusion, Upwind, exponential, hybrid, power, QUICK scheme, Two-dimensional convection-diffusion, Accuracy of Upwind scheme; false diffusion and dispersion, Boundary conditions.	7
5	**Flow Field Calculation-** Incompressibility issues and pressure-velocity coupling, Primitive variable versus other methods, Vorticity-stream function formulation, Staggered grid, SIMPLE family of algorithms.	8
6	Latest Developments in CFD Techniques and newer applications	5

References:

1	Numerical Heat Transfer and Fluid Flow	Suhas V. Patankar	CRC Press
2	Computational Fluid Dynamics - The basics with applications	Jr. Anderson	TATA McGraw Hill
3	An Introduction to Computational	H. Versteeg, W.	Pearson

Fluid Dynamics: The Finite Volume Method	Malalasekera

Course Code: ME22378	Thermo-Fluid Dynamics	Credits: 4-0-0:4

Prerequisites: Basic Thermodynamics and Fluid mechanics

Course Outcomes

CO1	Students will be able to understand the fundamentals of thermodynamics, heat transfer and fluid mechanics.
CO2	Students can be able to derive the fundamental governing equations for different types of problems of fluid flow and heat transfer.
CO3	Students will be able to apply the acquired knowledge in design of different thermal systems involving the concept of Thermodynamics, Fluid Mechanics and Heat Transfer.
CO4	Students can develop the analytical ability to solve a practical problems and prepare technical reports

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5
CO1	1	-	2	2	1
CO2	2	1	3	3	1
CO3	2	1	3	3	2
CO4	2	3	3	3	2

Unit	Details	Lectures
1	Review of Thermodynamic Laws and Entropy: Thermodynamic statements and their applications, Second law and their discussion, Equivalence of Kelvin-Planck and Clausius statements, Carnot engine and Carnot refrigeration, Thermodynamic temperature scale and absolute zero temperature, Clausius theorem and Clausius inequality, concept and characteristics of entropy, Principle of increase of entropy and entropy of universe.	6
2	Thermodynamic State Equations: Perfect and real gases, state equation of perfect gas, Amagat's isothermals, Detailed study of Van der Waal, Dieterio, Berthelot, Redlich and Kwong and other state equations for real gases, compressibility factor and compressibility chart, generalized chart. Availability and Irreversibility: Available energy lost work and degradation of energy, Maximum work, Availability – in a closed system and in a steady flow system, Gibbs function, Helmholtz function, Irreversibility and its measurement.	8
3	Governing Equations: Continuity, Momentum and Energy Equations and their derivations in different coordinate systems, Boundary layer Approximations to momentum and energy. Laminar External flow: (a) Similarity solutions for flat plate (Blasius solution), flows with pressure gradient (Falkner-Skan and Eckert solutions), and flow with transpiration, flows with pressure gradient (von Karman-Pohlhausen method). Laminar internal flow: Exact solutions to N-S equations for flow through channels and circular pipe,	12
4	Laminar External Flow and Heat Transfer: Integral method solutions for flow over an isothermal flat plate, flat plate with constant heat flux and with varying surface temperature (Duhamel's method), Laminar Internal Flow and Heat Transfer: Fully developed forced convection in pipes with different wall	8

	boundary conditions, Forced convection in the thermal entrance region of ducts and channels (Graetz solution), heat transfer in the combined entrance region, (b) Integral method for internal flows with different wall boundary conditions.	
5	Natural Convection heat transfer: Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Similarity solutions for Laminar flow past a vertical plate with constant wall temperature and heat flux conditions, Integral method for natural convection flow past vertical plate, effects of inclination, Natural convection in enclosures, mixed convection heat transfer past vertical plate and in enclosures.	8

Text Books:

1	Engineering Thermodynamics	P. K. Nag	McGraw Hill Education
2	Fundamentals of Heat and Mass Transfer	F.P. Incropera and D. Dewitt	John Wiley
3	Introduction of Fluid Mechanics & Fluid Machines	Som, S.K., Biswas G, and Chakraborty, S.	TMH, New Delhi

References:

1	Fundamentals of Engineering Thermodynamics	Moran & Shapiro	Willey
2	Fluid Mechanics	F. M. White	McGraw- Hill
3	Convection Heat Transfer	A. Bejan	John Wiley
4	Convective Heat and Mass Transfer	W. Kays, M. Crawford and B. Weig	McGraw Hill International

Course Code: ME21363	Optimization Methods in Engineering	Credits: X-0-0:X

Introduction: Terminology, Design Variables, Constraints, Objective Function, Variable Bounds, Problem Formulation.
Linear Programming: Simplex Method, Duality in Linear Programming.
Single Variable Optimization Problems: Optimality Criterion, Bracketing Methods: Exhaustive Search Method, Bounding Phase Method, Region.
Elimination Methods: Interval Halving Method, Fibonacci Search Method, Golden Section Method, Successive Quadratic Estimation Method.
Gradient Based Methods: Newton-Raphson Method, Bisection Method, Secant Method.
Multivariable Optimization Algorithms: Optimality Criteria, Unidirectional Search, Direct Search Methods: Box Method, Hooke-Jeeves Pattern Search Method, Powell's Conjugate Direction Method. Gradient Based Methods: Cauchy's Steepest Descent Method, Newton's method, Marquardt's Method, Conjugate Gradient Method, Variable-metric (DFP) Method.
Constrained Optimization Algorithms: Kuhn Tucker Conditions, Transformation Methods: Penalty Function Method, Method of Multipliers (MOM), Sensitivity Analysis.
Specialized Algorithms: Integer Programming: Penalty Function Method, Branch and Bound Method, Geometric Programming.
Non-Traditional Optimization Algorithms: Genetic Algorithms, Simulated Annealing, Tabu Search, Ant Colony Optimization, Particle Swarm Optimization. Applications to Engineering Optimization Problems.

References:

1. Kalyanmoy Deb, 2010.Optimization for engineering design: algorithms and examples. Prentice-Hall of India Private Limited, New Delhi
2. Kalyanmoy Deb, 2014.Multi-Objective Optimization using Evolutionary Algorithms. Wiley India Pvt. Ltd., New Delhi.
3. Singiresu S Rao, 2009. Engineering optimization: theory and practice. Fourth Edition, New Age International(P) Limited Publishers, New Delhi.

A. Ravindran, K. M. Ragsdell, G. V. Reklaitis, 2006. Engineering optimization - methods and applications. Second Edition, John Wiley & Sons, Inc.

Course Code: ME21364	Alternative Fuels Technology	Credits: X-0-0:X

Fossil fuels and their limitations: Introduction: Estimate of petroleum reserve, need for alternate fuel, and availability and comparative properties of alternate fuels.
Alternative fuels- Liquid and gaseous fuels, Physico-chemical characteristics, Alternative liquid fuels, Alternative gaseous fuels.
Alcohol fuels- Ethanol & methanol, Fuel composition, Fuel induction techniques, Fumigation, Emission of oxygenates, Applications to engines and automotive conversions.
Biodiesel: Formulation techniques, Transesterification, Application in diesel engines, Performance and emission characteristics.
Biomass: Broad classification, Production of biomass, Separation of components of solid wastes and processing techniques, Bioconversion into biogas, mechanism, Bioconversion of substrates into alcohols, Thermo chemical conversion of biomass, conversion to solid, liquid and gaseous fuels, case studies.
Other alternative fuels: DME (Dimethyl ether), LPG and PNG, CNG components, application to engine technology, mixtures and kits, fuel supply system and emission studies and control, Hydrogen combustion characteristics, Flashback control techniques, Safety aspects and system development.
Hybrid vehicles: Theory and types Hybrid vehicle safety issues Special tools and equipment needed to diagnose and repair alternative vehicles.

References:

1. Sunggyu Lee, James G. Speight, Sudarshan K. Loyalka “Handbook of Alternative Fuel Technologies”.
2. Gadepalli Ravi KiranSastry, “Bio-diesel: Bio-degradable Alternative Fuel for Diesel Engines”.
3. Michael F. Hordeski, “Alternative Fuels: The Future of Hydrogen”.
4. Maxwell et al, Alternative Fuel: Emission, Economic and Performance, SAE, 1995.
5. Watson, E.B., Alternative fuels for the combustion engine, ASME, 1990
6. Bechtold, R., Alternative fuels guidebook, 1998.

Course Code: ME21366	Design of Cryogenic System	Credits: X-0-0:X

Properties of engineering materials at cryogenic temperatures, mechanical properties ,thermal properties, electric & magnetic properties, super conducting materials ,thermo electric materials, composite materials, properties of cryogenic fluids, super fluidity of He 3 &He4.

Measurement systems for low temperatures:-Temperature measurements, pressure measurements, flow measurements, liquid level measurements, fluid quality measurements.

Cryogenic insulation: - various types such as expanded foams, gas filled& fibrous insulation, vacuum insulation, evacuated powder& fibrous insulation, opacified powder insulation, multi layer insulation, comparison of performance of various insulations .

Applications of cryogenic systems: - Super conductive devices such as bearings, motors, cryotrons, magnets, D.C. transformers, tunnel diodes, space technology, space simulation, cryogenics in biology and medicine, food preservation and industrial applications, nuclear propulsions ,chemical propulsions.

Hazards:-Physical hazards, Chemical hazards, Physiological hazards, combustion hazards, oxygen hazards, accidents in cryogenic plants & prevention.

Safety in handling of cryogens, care for storage of gaseous cylinders, familiarization with regulations of department of explosives.

References:

1. Cryogenic systems-Baron, McGraw-Hill book
2. Cryogenic fundamentals-Haselden, Academic press New York
3. Advance cryogenic –bailey, plenum press

Course Code: ME21368	Design of Thermal Turbo Machines	Credits: X-0-0:X

Centrifugal compressors: Principle of operation, work done and pressure rise, Components of Centrifugal Compressor, Stage Pressure, Stage Efficiency, Degree Reaction, Dimensionless Parameters, Slip Factor, Causes of Slip, Velocity Triangles, Euler Work, Design of Impeller, Design of Diffuser, Design of Vane less Diffuser, Design of Volute Casing.
Axial flow compressors: Basic operation, elementary theory, factors affecting stage pressure ratio, blockage in the compressor annulus, degree of reaction, three-dimensional flow, design process, blade design, calculation of stage performance, compressibility effects, off-design performance, axial compressor characteristics, closure.
Axial and radial flow turbines: Elementary theory of axial flow turbine, vortex theory, choice of blade profile, pitch and chord, estimation of stage performance, overall turbine performance, The cooled turbine, the radial flow turbine.
Prediction of performance of simple gas turbines: Component characteristics, off-design operation of the single-shaft gas turbine, equilibrium running of a gas generator, off-design operation of free turbine engine, off-design operation of the jet engine, methods of displacing the equilibrium running line, incorporation of variable pressure losses.

References:
1. Centrifugal compressors: A basic guide- M.P Boyce.
2. Gas turbine Theory- Cohen, Rogers
3. Axial flow compressors: A strategy for aerodynamic design and analysis - R. Aungier
4. Turbo Compressors and Fans – S.M. Yahya

Course Code: ME21369	Marine Engines and Propulsion	Credits: X-0-0:X

Diesel engines, Gas Turbine, Steam turbines, Main Boilers, Feed systems, Pumps and pumping systems, Auxiliaries Fuel oils, lubricating oils and their treatment, Refrigeration, air conditioning and ventilation, Deck machinery and hull equipment. Marine shafting, gearing and propellers, Auxiliary system and machineries, Oil monitoring and propulsion, Steering gear, instrumentation and control.

References:

1. Basic Marine Engineering by T K Grover, Anmol Publisher Pvt Ltd.
2. Introduction to Marine Engineering by D. A. Taylor, Butterworth-Heinemann publications.
3. Marine Propellers and Propulsion by J S Carlton, Butterworth-Heinemann publications.
4. Marine Internal Combustion Engines by A. B Kane, Shroff Pub & Dist. Pvt. Ltd.

Course Code: ME22375	Convective Heat Transfer	Credits: X-0-0:X

Course Code: ME22370	Design of Air Conditioning Systems	Credits: X-0-0:X

Air Conditioning systems, Moist air systems and processes, applications of psychometrics to airconditioning process, Indoor air quality, design comfort conditions, Heat transmission in buildings, conduction heat transfer through the building envelope, estimating heat loss or gain, Space heat loads, estimating heating requirements for a space or building, internal heat generation, Methods for estimating the space heat gains and the cooling loads, Energy calculations, Degree day concepts estimating seasonal energy costs, Pump and liquid system design, hot and steam heating systems, Space air diffusion, selection and location of air vents to space for optimal air movement, Fans and building air distribution systems, basics of sizing and selecting air handling equipment, Refrigeration equipment. Operation and control of vapor compression refrigeration systems

References:

1. Refrigeration and air-conditioning - C P Arora, Tata McGraw-Hill, 2nd edition, 2000.
2. ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) Handbook.

Course Code: ME22372	Internal Combustion Engines and Pollution	Credits: X-0-0:X

Engine types and their operation, Engine Design and operating parameters, Combustion Stoichiometry, Ideal models of Engine cycles
Gas Exchange: 4-Stroke, Gas Exchange: 2-Stroke, Mixture Preparation, Turbocharging Fuel Injection System in Diesel Engine, Charge motion within the cylinder, swirl, squish and tumble Thermodynamic analysis of Spark-ignition Engine Combustion, Flame structure and speed, Cyclic variations in combustion, partial burning and misfire, Knock fundamentals.
Types of diesel combustion systems, fuel spray behaviour, ignition delay, mixing controlled combustion.
Introduction to Engine Emissions and air pollution, Genesis and formation of pollutants, Kinetics and modeling of thermal NO formation, Dependence of NO formation on temperature, Unburned hydrocarbon emissions, Flame quenching and Oxidation fundamentals, Adsorption desorption phenomenon, crevice effect on HC emissions, HC emission mechanism in diesel engine, CO formation Soot and Particulate formation, Soot inception, surface growth, Coagulation and Aggegation, NOxParticulate trade-off, Effect of SI and CI engine design and operating variables on engine emission. Emission test procedures and regulations, Emission measurement: Instrumentation and methods, SI and CI engine Emission Control Technology, Catalytic converter, Exhauust gas recirculation, Diesel particulate filters, HCCI Engines.
Engine heat transfer, friction and lubrication, 2-Stroke and 4-Stroke Spark Engine Performance and Testing, Diesel Engine Performance and Testing, Engine operating characteristics, Alternative fuels.

References:

1. Internal Combustion Engine Fundamentals- J.B. Heywood, McGraw-Hill
2. Engine Emissions Pollutant formation and advances in controlTecnology- B.P Pundir, Nrosa
3. IC. Engine-V. Ganeshan, Tata McGraw-Hill
4. Fundamental of Internal combustion Engine- Z. Smith, Gill.
5. Internal Combustion Engine- W.W. Pulkrabek, Prentice Hall.

Course Code: ME22374	Exergy Analysis of Thermal Systems	Credits: X-0-0:X

Exergy Destruction: Lost available work referred to heat engine cycle, refrigeration cycle, heat pump cycle, non-flow and steady flow processes, Mechanism of exergy destruction, modified Gouy-Stodola theorem, concept of effective temperature.

Exergy Analysis of Simple Processes: Mixing and separation process of fluids of different temperature, heat transfer across a temperature difference, expansion and compression process, combustion process.

Exergy Analysis of Power Plant Cycles: Maximum power subject to size constraint with fixed heat input and its application to Brayton cycle Steam turbine power plants: External and internal irreversibility, super heater, reheater, vacuum condenser, regenerative feed water heating, combined feed water heating and reheating Gas turbine power plant: External and internal irreversibility, regeration, reheater, and intercooler, combined steam and gas turbine power plant.

Exergy analysis of Refrigeration cycle: Joule-Thomson Expansion, Work-Producing Expansion, Brayton Cycle, Optimal Intermediate Cooling, Exergy analysis of Air-conditioning applications: Mixtures of air and water vapour, total flow exergy of humid air & liquid water, Evaporative cooling process and other aspects.

Exergy-economic Analysis: Fundamental of exergy-economics, exergy costing of different thermal components: steam or gas turbine, boiler, cogeneration system Exergy analysis of renewable energy systems.

References:

1. Advanced Engineering Thermodynamics by Adrian Bejan, John Wiley & Sons, Inc.
2. The Exergy Method of Thermal Plant Analysis by T J Kotas, Krieger Publishing Company.
3. Thermal Design and Optimization by Adrian Bejan, George Tsatsaronis, Michael Moran, John Wiley & Sons, Inc.
4. Advance Thermodynamics for Engineers by Winterbore D E, Arnold Publication
5. Advanced Thermodynamics for Engineers by Kenneth Wark, McGraw Hill Publishing Co. Ltd.
6. Fundamentals of Engineering Thermodynamics by Michel J Moran, Howard N Shapiro, Daisie D Boettner, Margaret B Bailey, John Wiley & Sons, Inc.
7. Exergy: Energy, Environment and Sustainable Development, I. Dincer, M.A. Rosen, 2nd edition, Elsevier.

Course Code: ME22376	Energy System and Management	Credits: X-0-0:X

Introduction: the energy-economy link, patterns of energy use in developed and developing countries, characteristics of conventional and renewable energy resources.
Efficient energy conversion through combined cycles, cogeneration and tri-generation systems. Energy conservation: energy auditing, bench marking, process energy and gross energy requirements, energy recovery in refrigeration and air-conditioning systems, mechanical vapor recompression systems. Energy conservation in buildings.
Environmental aspects of energy resource utilization: combustion generated air pollution, global warming, acid rain, fly ash disposal, radioactive pollution and nuclear waste disposal.

References:

1. Energy Systems and Sustainability by Godfrey Boyle et al, Oxford University Press
2. Energy efficiency by Eastop and Croft, Longman Scientific and Technical
3. Energy: Management, Supply and Conservation by Clive Beggs, Butterworth- Heinemann
4. www.bee-india.nic.in Bureau of Energy Efficiency, Ministry of Power, Government of India.

Course Code: ME22377	Fuels and Combustion Engineering	Credits: X-0-0:X

Thermodynamics (1st & 2nd law for pure, non-reacting (mixture) and reacting systems; stoichiometry, thermo-chemistry, Clausius-Clapeyron equation etc.); Conservation Equations (Continuity, momentum, total & thermal energy and species); Fluid Mechanics; Heat Transfer & Mass Transfer.
Molecularity and order of reaction, Rates of reaction, Arrhenius equation. Conservation equations of mass, momentum, energy and species for a multicomponent system. Premixed and diffusion flames, Laminar and turbulent flames. Concepts of kinetically controlled and diffusion controlled reactions, Flammability limits, Ignition, Burning velocity, Flame structure and Stability for laminar flames.
Atomization of liquid, various atomizers and their performances Evaporation of droplets in high temperature gas streams, Simple model of droplet burning, Physical and mathematical models of spray flames.
Description of carbon sphere combustion, Diffusional theory of carbon combustion of pulverized coal. Pollutant formation in various combustion processes and their controlling measures.

References:

1. An Introduction to Combustion: Concepts and Applications - S. R. Turns.
2. COMBUSTION: Fundamentals & Application - A. Datta, Narosa Publications.
3. Combustion Engineering - Gary L. Borman and K. W. Ragland.