NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

M.TECH - THERMAL ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

for M.Tech. Program in Thermal Engineering

(Effective from 2021-22)

DEPARTMENT OF MECHANICAL ENGINEERING

Vision and Mission of the Institute

National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stakeholders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department

Department of Mechanical Engineering

VISION

To be a global knowledge hub in mechanical engineering education, research, entrepreneurship and industry outreach services.

MISSION

- Impart quality education and training to nurture globally competitive mechanical engineers.
- Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.
- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

Department of Mechanical Engineering:

Brief about the Department:

The Department of Mechanical Engineering was established in the year 1959. The department presently offers one Under Graduate Programme, i.e., B.Tech in Mechanical Engineering with an intake of 170 students, seven M.Tech programs - Thermal Engineering, Manufacturing Engineering, Computer Integrated Manufacturing, Machine Design, Automobile Engineering, Materials and Systems Engineering Design, Additive Manufacturing, - one PG Diploma in Additive Manufacturing and Ph.D programs. At present, the Department has 48 faculty members with research expertise in different specializations of Mechanical Engineering. The Department has good research facilities for both experimental as well as simulation-based research. The department has liaison with reputed industries and R&D organizations such as NFTDC, DMRL, DRDL, ARCI, BHEL, CPRI, CMTI etc. All the faculty of the department are actively engaged in R&D and Consultancy. Presently the department is handling about 25 funded projects worth Rs. 3.00 Crores. The department has recently acquired Metal 3D Printer at a cost of Rs.1.4 Crores under TEQIP -III grants. The institute is establishing SIEMENS Centre of Excellence in Digital Manufacturing and Industry 4.o in which the department is playing a key role. The department produces a large number of publications, and offers solutions to the industry regularly and is also active with regular outreach activities like workshops, conferences and executive programs for industry personnel. The department has been recognized as QIP Centre for M.Tech and Ph. D. programmes.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Mechanical Engineering
M.Tech.	Thermal Engineering
	Automobile Engineering
	Manufacturing Engineering
	Machine Design
	Computer Integrated Manufacturing
	Materials and Systems Engineering Design
	Additive Manufacturing
PG Diploma	Additive Manufacturing
Ph.D.	Mechanical Engineering

Note: Refer to the following weblink for Rules and Regulations of M.Tech. program:
https://www.nitw.ac.in/main/MTechProgram/rulesandregulations/

M.Tech. – Thermal Engineering

Program Educational Objectives

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. They are consistent with the mission of the Institution and Department. Department faculty members continuously worked with stakeholders (local employers, industry and R&D advisors and the alumni) to review the PEOs and update them periodically.

PEO-1	Analyze, design and evaluate thermal systems using state of the art engineering tools and techniques
PEO-2	Develop methods of energy conservation for sustainable growth
PEO-3	Communicate effectively and support constructively towards team work
PEO-4	Pursue lifelong learning for professional growth with ethical concern for society and environment

Program Articulation Matrix

PEO Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4
Imparting quality education to the students and enhancing their skills to make them globally competitive mechanical engineers.	3	2	3	2
Maintaining vital, state-of-the-art research facilities to provide its students and faculty with opportunities to create, interpret, apply and disseminate knowledge.	3	3	3	3
To develop linkages with world class R&D organizations and educational institutions in India and abroad for excellence in teaching, research and consultancy practices.	2	2	3	3

1-Slightly; 2-Moderately; 3-Substantially

M.Tech. – Thermal Engineering

Program Outcomes

Program Outcomes (POs) are narrower statements that describe what the students are expected to know and be able to do upon graduation. These relate to the knowledge, skills and behavior the students acquire through the program. The POs are specific to the program and facilitate the attainment of PEOs.

PO-1	Carryout independent research/investigation and development work to solve practical problems
PO-2	Write and present a substantial technical report/document
PO-3	Demonstrate a degree of mastery over thermal engineering at a level higher than the Bachelor's program.
PO-4	Design, develop and analyze thermal systems for improved performance.
PO-5	Develop effective technologies to harness viable energy sources.
PO-6	Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence.

Mapping of Program Outcomes with Program Educational Objectives:

PEO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
PEO-1	3	3	2	3	3	2
PEO-2	3	2	2	3	2	2
PEO-3	2	2	2	2	2	3
PEO-4	3	2	3	3	3	3

1-Slightly; 2-Moderately; 3-Substantially

Credits in Each Semester

Category	I Year, Sem – I	I Year, Sem – II	II Year, Sem – I	II Year, Sem – II	Total No. of credits to be earned
Core courses	12	06	--	--	**18**
Electives	06	12	--	--	**18**
Lab Courses	04	04	--	--	**08**
Comprehensive Viva-Voce	--	--	02	--	**02**
Seminar	01	01	--	--	**02**
Dissertation	--	--	12	20	**32**
Total	**23**	**23**	**14**	**20**	**80**

SCHEME OF INSTRUCTION

M.Tech. Thermal Engineering – Course Structure

I - Year, I – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5101	Advanced Fluid Dynamics	3	0	0	3	PCC
2	ME5102	Computational Methods in Thermal Engineering	3	0	0	3	PCC
3	ME5103	Advanced Heat and Mass Transfer	3	0	0	3	PCC
4	ME5104	Experimental Methods in Thermal Engineering	3	0	0	3	PCC
5		Elective – 1	3	0	0	3	PEC
6		Elective – 2	3	0	0	3	PEC
7	ME5105	Thermal Engineering Laboratory	0	1	2	2	PCC
8	ME5106	CFD Laboratory	0	1	2	2	PCC
9	ME5148	Seminar-I	0	0	2	1	SEM
		Total	**18**	**2**	**6**	**23**	

I - Year, II – Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5151	Gas Turbines and Jet Propulsion	3	0	0	3	PCC
2	ME5152	Design and Optimization of Thermal Systems	3	0	0	3	PCC
3		Elective – 3	3	0	0	3	PEC
4		Elective – 4	3	0	0	3	PEC
5		Elective – 5	3	0	0	3	PEC
6		Elective – 6	3	0	0	3	PEC
7	ME5153	Simulation Laboratory	0	1	2	2	PCC
8	ME5154	Energy Systems Laboratory	0	1	2	2	PCC
9	ME5198	Seminar-II	0	0	2	1	SEM
		Total	**18**	**2**	**6**	**23**	

II - Year, I – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6147	Comprehensive Viva-voce	2	CVV
2	ME6149	Dissertation Part-A	12	DW
		Total	**14**	

II - Year, II – Semester

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6199	Dissertation Part-B	20	DW
		Total	**20**	

Note: **PCC** – Professional Core Course **PEC** – Professional Elective Course

List of Professional Elective Courses (M.Tech – Thermal Engineering)

I Year, I Semester

S. No.	Course Code	Course Title	L-T-P	Credits	Cat. Code
Program Specific Professional Elective Courses					
1	ME5111	Refrigeration Technology	3-0-0	3	PEC
2	ME5112	Power Plant Engineering	3-0-0	3	PEC
3	ME5113	Renewable Sources of Energy	3-0-0	3	PEC
4	ME5114	Energy Systems and Management	3-0-0	3	PEC
5	ME5115	Hydraulic Machinery	3-0-0	3	PEC
6	ME5116	Particle Mechanics and its Applications	3-0-0	3	PEC
Elective Courses from M.Tech Automobile Engineering					
1	ME5502	Computational Methods in Automobile Engineering	3-0-0	3	PEC
2	ME5504	Prime Movers for Automobiles	3-0-0	3	PEC
3	ME5513	Alternate Fuels and Emissions	3-0-0	3	PEC
Elective Courses from M.Tech Machine Design					
1	ME5404	Computer Aided Geometric Design	3-0-0	3	PEC
2	ME5415	Mathematical Methods in Engineering	3-0-0	3	PEC
Elective Courses from M.Tech Computer Integrated Manufacturing					
1	ME5311	Enterprise Resource Planning	3-0-0	3	PEC
2	ME5313	Soft Computing Techniques	3-0-0	3	PEC
Elective Courses from M.Tech Materials and Systems Engineering Design					
1	ME5611	Surface Engineering	3-0-0	3	PEC

List of Professional Elective Courses (M.Tech – Thermal Engineering)

I Year, II Semester

S. No.	Course Code	Course Title	L-T-P	Credits	Cat. Code
Program Specific Elective Courses					
1	ME5161	Heating, Ventilation and Air Conditioning (HVAC)	3-0-0	3	PEC
2	ME5162	Advanced Computational Fluid Dynamics	3-0-0	3	PEC
3	ME5163	Convective Heat and Mass Transfer	3-0-0	3	PEC
4	ME5164	Conduction and Radiation Heat Transfer	3-0-0	3	PEC
5	ME5165	Two-Phase Heat Transfer	3-0-0	3	PEC
6	ME5166	Design of Heat Transfer Equipment	3-0-0	3	PEC
7	ME5167	Turbulent Flows	3-0-0	3	PEC
8	ME5168	Industrial Heat Transfer	3-0-0	3	PEC
9	ME5169	Rocket Propulsion	3-0-0	3	PEC
10	ME5170	Essentials of Entrepreneurship	3-0-0	3	PEC
11	ME5171	Combustion and Emission Control	3-0-0	3	PEC
12	ME5172	Solar Energy Systems	3-0-0	3	PEC
13	ME5173	Energy Conservation and Waste Heat Recovery	3-0-0	3	PEC
14	ME5174	Fluid and Heat Transport through Porous Media	3-0-0	3	PEC
Elective Courses from M.Tech Automobile Engineering					
1	ME5561	Fuel Cell Technology	3-0-0	3	PEC
2	ME5564	Hybrid Electric Vehicles	3-0-0	3	PEC
Elective Courses from M.Tech Machine Design					
1	ME5469	Optimization Methods for Engineering Design	3-0-0	3	PEC
Elective Courses from M.Tech Computer Integrated Manufacturing					
1	ME5368	Industry 4.o and IIoT	3-0-0	3	PEC
2	ME5370	Project Management	3-0-0	3	PEC
3	ME5371	AI and ML for Mechanical Systems	3-0-0	3	PEC

DETAILED SYLLABUS

M.Tech. – Thermal Engineering

Course Code: ME5101	ADVANCED FLUID DYNAMICS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Ascertain basic concepts of the fluid mechanics and apply the concepts in the analysis of fluid flow problems
CO2	Analyze the stress, strain and forces involving in the fluid element and to derive the governing equations
CO3	Find the exact and approximate solutions of the governing equations for realistic flow situations
CO4	Analyze the performance of fluid flow in laminar and turbulent flows
CO5	Differentiate compressible and incompressible flows and solve compressible flow problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	1	1
CO2	3	2	3	3	2	1
CO3	3	2	3	3	1	2
CO4	3	2	3	3	1	2
CO5	3	2	2	3	1	2

Syllabus:

Introduction: Review of the fundamentals of Fluid mechanics.

Kinematics of Fluids: Lagrangean and Eulerian systems, Velocity potential, Stream function and Vorticity.

General theory of Stress and Rate of Strain: Stress-strain relations.

Fundamental Conservation Equations: Integral and differential forms.

One-dimensional Inviscid Incompressible Flow: Euler’s equation and Bernoulli’s equation- applications of Bernoulli's equation.

Exact solutions of Navier-Stokes Equations: Couette flow, Hagen-Poiseuille flow, Flow between coaxial and concentric rotating cylinders, Hydrodynamic theory of lubrication, Creeping flows, Unsteady motion of flat plate.

The Laminar Boundary Layer: Prandtl’s Boundary Layer Equations, Blasius solution, Momentum-integral equations and its applications, Boundary layer separation and control.

Turbulent Flows: Introduction to Turbulent Flow, Reynolds modification of N-S equations, Semi - empirical theories, Turbulent boundary layer for internal and external flows, Turbulence modelling.

Dimensional Analysis: Flow over a bluff body – Lift and Drag, Dimensional analysis and similitude.

Introduction to Compressible Flow: Isentropic flow, Flow across normal and oblique shocks, Fanno flow, Rayleigh flow, Expansion waves.

Learning Resources:

Text Books:

1. Introduction to Fluid Mechanics, Fox, R.W., Pritchard, P. J. and McDonald, A. T., Wiley, 2018, 8th Edition.
2. Viscous Fluid Flow, White, F. M., Tata McGraw Hill Book Company, 2021, 4th Edition.

Reference Books:

1. Foundations of Fluid Mechanics, Yuan, S. W., Prentice Hall of India, 2000
2. Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, Yahya, S. M., New Age International Publishers, 2018, 6th Edition.
3. Modern Compressible Flow –with Historical Perspective, Anderson, J. D. Jr., TMH, 2020, 4th edition.
4. Boundary Layer Theory, Schlichting, H and Gersten, K, 9th Edition, Springer, 2018.
5. Advanced Engineering Fluid Mechanics, Muralidhar, K and Biswas, G., Alpha Science International Ltd.,3rd Edition, 2018.

Online Resources:

1. Advanced Fluid Mechanics by Dr. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105218/#)
2. Introduction to Turbulence by Prof. Gautam Biswas (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104120/)

Course Code: ME5102	COMPUTATIONAL METHODS IN THERMAL ENGINEERING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods.
CO2	Derive the governing equations and understand the behavior of the equations.
CO3	Analyze the consistency, stability and convergence of various discretisation schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO4	Analyze variations of SIMPLE schemes for incompressible flows and Variations of Flux Splitting algorithms for compressible flows.
CO5	Analyze various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems.

Course Articulation Matrix:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	3	2	1
CO2	2	2	3	3	2	1
CO3	2	2	3	3	2	1
CO4	2	2	3	3	2	1
CO5	2	2	3	3	2	1

Syllabus:

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods.

Governing equations of fluid dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Mathematical behavior of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations.

Basic aspects of discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.

Grids with appropriate transformation: General transformation of the equations, Metrics and Jacobians, The transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.

Parabolic partial differential equations: Finite difference formulations, Explicit methods - FTCS, Richardson and DuFort-Frankel methods, Implicit methods - Lasonen, Crank-Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.

Stability analysis: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, Artificial dissipation and dispersion.

Elliptic equations: Finite difference formulation, solution algorithms: Jacobi-iteration method, Gauss-Siedel iteration method, point- and line-successive over-relaxation methods, alternative direction implicit methods.

Hyperbolic equations: Explicit and implicit finite difference formulations, splitting methods, multi-step methods, applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, TVD formulations, entropy condition, first-order and second-order TVD schemes.

Scalar representation of Navier-Stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBS explicit, Dufort-Frankel explicit, McCormack explicit and implicit, BTCS and BTBCS implicit algorithms, SIMPLE algorithm, applications

Grid generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation.

Finite volume method for unstructured grids: Advantages, Cell Centered and Nodal point Approaches, Solution of Generic Equation with tetrahedral Elements, 2-D Heat conduction with Triangular Elements.

Learning Resources:

Text Books:

1. Computational Fluid Dynamics: the Basics with Applications, Anderson, J.D. (Jr), McGraw-Hill Book Company, 2017, Indian Edition.
2. Computational Fluid Dynamics, Vol. I, II and III, Hoffman, K.A., and Chiang, S.T., Engineering Education System, Kansas, USA, 2000, 4th edition.
3. Numerical Heat Transfer and Fluid Flow, Suhas V Patankar, CRC Press, 2018, Special Indian Edition.

Reference Books:

1. Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2014, 2nd Edition.
2. Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2020, 4th Edition.

Online Resources:

1. Introduction to CFD by Prof. M. Ramakrishna (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106045/)

Course Code: ME5103	ADVANCED HEAT AND MASS TRANSFER	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand physical and mathematical aspects of heat and mass transfer.
CO2	Develop mathematical models for steady and unsteady state heat transfer problems.
CO3	Analyze free and forced convection for internal and external flow problems.
CO4	Design heat exchangers
CO5	Apply the concepts of radiation heat transfer for enclosure analysis.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	2	1
CO2	2	2	3	3	2	1
CO3	2	2	3	3	2	1
CO4	2	2	3	3	2	1
CO5	2	2	3	3	2	1

Syllabus:

Introduction: Review of the fundamentals of heat transfer and modes of heat transfer.

One – Dimensional Steady State Heat Conduction: General Heat Conduction Equation in (i) Cartesian, (ii) Polar and (iii) Spherical Coordinate Systems, Heat generation, Variable thermal conductivity, Extended surfaces –Uniform and Non-Uniform cross sections. Inverse heat transfer problems.

Steady- State Two-Dimensional Heat Conduction: Governing equations and solutions, Use of Bessel's functions.

Transient Heat Conduction: Lumped heat capacity system, Infinite plate of finite thickness and Semi-infinite Solid, Heisler and Grober charts for Transient Conduction.

Forced Convection: Conservation equations, Integral and analytical solutions, Boundary layer analogies, Internal and external flows, Laminar and turbulent flows, Empirical relations, cooling of electronic equipment.

Free convection: Governing equations, Laminar and turbulent flows, Analytical and empirical solutions.

Boiling and Condensation: Pool boiling and convective boiling, Film condensation and dropwise condensation.

Thermal Radiation: Fundamental principles, Radiation exchange between surfaces - View factor, Radiation shields, Multimode heat transfer.

Heat Exchangers: Types of heat exchangers, LMTD method and Effectiveness – NTU method, plate and tube heat exchangers, industrial standards for design of heat exchangers.

Mass Transfer: Fick's law of diffusion, Analogy between heat transfer and mass transfer, Mass diffusion and mass convection.

Learning Resources:

Text Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F. P. and De Witt, D. P., 5th Edition, Wiley, Indian Edition, 2018.
2. Heat and Mass Transfer: Fundamentals and Applications, Yunus A. Çengel and Afshin Jahanshahi Ghajar, McGraw-Hill Education, 2020, 6th Edition.
3. Heat Conduction, Sadik Kakac and Yaman Yener., Taylor & Francis, 2018, 5th Edition.
4. Convective Heat and Mass Transfer, Kays, W. M. and Crawford, M. E., Tata McGraw Hill, 2017, 4th Edition.
5. Convection Heat Transfer, Bejan, A., Wiley, 2013, 4th Edition.

Reference Books:

1. Convective Heat and Mass Transfer, Ghiaasiaan, S.M., Cambridge, 2015.
2. Thermal Radiation Heat Transfer, Siegel, R., M. Pinar Menguc and Howell, J. R., Taylor and Francis, 2020, 7th Edition.
3. Inverse Heat Transfer, Fundamentals and Applications, Ozisik, M.N., and Orlande, H.R.B., Taylor and Francis, 2nd Edition, 2021.

Online Resources:

1. NOC:Heat transfer by Prof. Ganesh A. Viswanathan (IIT Bombay), NPTEL Course (Link: https://nptel.ac.in/courses/103/101/103101137/#)
2. NOC:Convective Heat Transfer by Prof. Saptarshi Basu (IISc Bangalore), NPTEL Course (Link: https://nptel.ac.in/courses/112/108/112108246/)
3. NOC:Transport Processes I: Heat and Mass Transfer, Prof. V. Kumaran (IISc Bangalore), NPTEL Course (Link: https://nptel.ac.in/courses/103/108/103108123/)

Course Code: ME5104	EXPERIMENTAL METHODS IN THERMAL ENGINEERING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation and estimation of uncertainty.
CO2	Analyse zeroth, first and second order measurement systems
CO3	Classify sensors for measurement of specific parameters with required accuracy.
CO4	Evaluate measurement systems using uncertainty analysis
CO5	Design experiments by combining measuring devices to acquire desired outputs.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		2	2		2
CO2	3		3	2		2
CO3	3		3	2		2
CO4	3	2	3	2		2
CO5	3	2	3	3		2

Syllabus:

Basics of Measurements: Introduction, general measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction, Presentation of experimental data, Errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis, Dynamic response – zeroth, first and second order measurement systems, Design of Experiments, Data Acquisition Systems, Integration of industrial instrumentation systems and monitoring.

Thermometry and heat flux measurement: Overview of thermometry, Thermoelectric temperature measurement, Resistance thermometry, Pyrometer, Other methods, issues in measurements Heat flux measurement.

Pressure and Flow measurement: Different pressure measurement instruments and their comparison, Transient response of pressure transducers, Flow Measurement, Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, Other methods

Thermal and transport property measurement: Measurement of thermal conductivity, diffusivity, viscosity, humidity, gas composition, etc.

Nuclear, thermal radiation measurement: Measurement of reflectivity, transmissivity, emissivity, nuclear radiation, neutron detection, etc.

Other measurements: Basics in measurement of torque, force, strain

Advanced topics: Issues in measuring thermo physical properties of micro and Nano fluidics.

Learning Resources:

Text Books:

1. Measurement systems by Ernest O Doebelin, Dhanesh N. Manik, Tata McGraw Hill publications, 2019, 7th Edition,.
2. Mechanical Measurements by Thomas G Beckwith, Roy D. Marangoni and John H. Lienhard VPearson publications, 2020, 6th Edition.
3. Experimental Methods for Engineers by J P Holman, Tata McGraw Hill publications, 2017, 7th Edition.

Reference Books:

1. An Introduction to Error Analysis, by John R. Taylor, University Science Books, 1997, 2nd Edition
2. Mechanical Measurements by S P Venkateshan, Ane Books Pvt. Ltd., 2015, 2nd Edition.

Online Resources:

1. Mechanical Measurements and Metrology by Prof. S P Venkateshan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106138/).
2. Principles of Mechanical Measurement by Prof. Dipankar N Basu (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/112/103/112103261/).

Course Code: ME5105	THERMAL ENGINEERING LABORATORY	Credits 0-1-2: 2

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Evaluate the properties of fuels and oils.
CO2	Analyse the performance and emissions of I C Engines
CO3	Demonstrate the vehicle performance on chassis dynamometer
CO4	Analyze the performance of steam power plant components.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	3	3	3	2	1
CO3	2	3	3	3	2	1
CO4	2	3	3	3	2	1

List of Experiments:

- **Redwood Viscometer No. 1:** Determination of kinematic and absolute viscosities of a given oil sample.
- **Distillation apparatus:** Determination of distillation characteristic of a given sample of gasoline.
- **Junker's Calorimeter:** Determination of the calorific value of the given gas sample.
- **Bomb Calorimeter:** Determination of the calorific value of the given sample of liquid/solid fuel.
- **Smoke meter and Exhaust gas analyzer:** Measurement of smoke density and composition of the engine exhaust of a CI Engine during a constant speed performance test.
- **Vehicle emission measurement:** Vehicle emission measurement using chassis dynamometer as per Indian Driving Cycle (IDC).
- **Vehicle performance test:** Vehicle performance test using chassis dynamometer
- **Motoring and retardation test:** Motoring and retardation test on single cylinder Kirloskar Engine for determining the friction power.
- **Constant speed performance test:** Constant speed performance test on a VCR engine by varying fuel injection pressure.
- **Vehicle onboard diagnostic test** :
- **Steam Experiments:**
  - To conduct a constant speed performance test on the steam turbine.
  - To determine the performance characteristics of the nozzles.

Learning Resources:

Text Books:

1. Experimental Methods for Engineers, Holman, J., McGraw Hill Education, 2017, 7th Edition.
2. Internal Combustion Engines, Ganesan, V., McGraw Hill Education; 2017, 4th Edition.

Reference Books:

1. Fuels and Combustion, Samir, S., University Press, 2009, 3rd Edition.

Online Resources:

1. Remote Triggered Virtual Lab on Automotive Systems by Prof. A.R. Mohanty, IIT Kharagpur (Link: http://vlabs.iitkgp.ac.in/rtvlas/#)

Course Code: ME5106	CFD LABORATORY	Credits 0-1-2: 2

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Develop codes for solution of algebraic and differential equations
CO2	Develop skills in the actual implementation of CFD methods with their own codes
CO3	Analyze real life engineering applications with the help of CFD.
CO4	Design thermal engineering equipment using CFD

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	3	3	3	2	1
CO3	2	3	3	3	2	1
CO4	2	3	3	3	2	1

List of Experiments:

- **Solution of Quadratic Equations**
- **Matrix Operations**
- **Solution of Simultaneous Algebraic Linear Equations**
  - Gauss-Siedel Method
- **Solution of 1-D parabolic equations**
  - Explicit (FTCS, DuFort-Frankel)
  - Implicit (Laasonen) Examples:
    - Fin problem with insulated and Convective end [k A Txx = h P (T-Ta)]
    - Couette Problem with and without pressure Gradient [ut = - px /ρ + v uxx]
- **Solution of Elliptic Equations (Tt = α Txx]**
  - With Point Gauss-Seidel method
  - With Point Successive Over Relaxation Method
    - Examples: (i) Temperature Distribution over a rectangular plate with different Boundary conditions on the sides.
- **Solution of Linear Hyperbolic Equations. [ut = -a ux]**
  - Using upwind and Lax explicit methods
  - Using BTCS and Crank-Nicolson implicit methods
    - Examples: Wave propagation at a high altitude
- **Solution of Nonlinear Hyperbolic Equations. [ut = -u ux]**
  - Lax Method
  - MacCormack Method
    - Examples: Shock Tube Problem
- **Solution of Incompressible NSEs**
  - Vorticity-Stream function formulation

- Primitive Variable Formulation
  - Examples:
    - Lid Driven Cavity Problem
    - Mass entering and leaving a Square chamber

Learning Resources:

Text Books:

1. Computational Fluid Dynamics: the Basics with Applications, Anderson, J.D. (Jr), McGraw-Hill Book Company, 2017, Indian Edition.
2. Computational Fluid Dynamics, Vol. I, II and III, Hoffman, K.A., and Chiang, S.T., Engineering Education System, Kansas, USA, 2000, 4th edition.

Reference Books:

1. Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2003, 2nd Edition.
2. Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2012, 3rd Edition.

Online Resources:

1. Introduction to CFD by Prof. M. Ramakrishna (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106045/)

Course Code: ME5148	SEMINAR-I	Credits 0-0-2: 1

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify and compare technical and practical issues related to Thermal Engineering.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of critical thinking and technical writing.
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2			3
CO2	3	2	2			3
CO3	3	3	2			3
CO4	3	3	2			3

Evaluation Scheme:

Task	Description	Weightage (%)
I	Clarity on the topic	10
II	Literature survey	30
III	Content	30
IV	Presentation	20
V	Response to Questions	10
Total		**100**

Task-CO Mapping:

Task/CO	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

Course Code: ME5151	GAS TURBINES AND JET PROPULSION	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Analyze the ideal and practical gas turbine cycles of air-breathing propulsion devices and industrial gas turbines.
CO2	Design the blading and evaluate the performance of centrifugal and axial flow compressors.
CO3	Analyze the combustion process in the gas turbine combustion system.
CO4	Design axial and radial in-flow gas turbines.
CO5	Analyse the off-design performance and matching of the components of a gas turbine.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		2	2		2
CO2	3		3	2		2
CO3	3		3	2		2
CO4	3	2	3	2		2
CO5	3	2	3	3		2

Syllabus:

Introduction: Review of the fundamentals, Classification of turbomachines, Applications of gas turbines.

Gas Turbine Cycles for Shaft Power: Ideal shaft power cycles and their analysis, Practical shaft power cycles and their analysis, Combined cycles and cogeneration schemes.

Gas Turbine Cycles for Propulsion: Propulsive devices - Criteria of performance, Gas turbine cycles for turbojet, turbofan, turboprop and turbo-shaft engines, Thrust augmentation techniques.

Fundamentals of Rotating Machines: Euler's energy equation, Components of energy transfer, Impulse and reaction machines, Degree of reaction, Flow over an airfoil, Lift and drag.

Centrifugal Compressors: Construction and principle of operation, Factors affecting stage pressure ratio, Compressibility effects, Surging and choking, Performance characteristics.

Flow through Cascades: Cascade of blades, Axial compressor cascades, Lift and drag forces, Cascade efficiency, Cascade tunnel.

Axial Flow Compressors: Construction and principle of operation, Factors affecting stage pressure ratio, Degree of reaction, Three dimensional flow, Design process, Blade design, Stage performance, Compressibility effects, Off-design performance, Axi-radial flow configurations.

Gas Turbine Combustion System: Operational requirements, Factors affecting combustion chamber design, Combustion process, Flame stabilization, Combustion chamber performance, Practical problems - Gas turbine emissions.

Axial and Radial Flow Turbines: Construction and operation, Vortex theory, Estimation of stage performance, Overall turbine performance, Turbine blade cooling, Radial flow turbines.

Off-Design Performance: Off-design performance of single shaft gas turbine, free turbine engine and jet engine, Methods of displacing the equilibrium running line.

Other Topics: Design of Nozzles, afterburners, anti-icing mechanisms.

Learning Resources:

Text Books:

1. Gas Turbine Theory, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson Prentice Hall, 2017, 7th Edition.
2. Gas Turbines, Ganesan, V., Tata McGraw Hill, 2017, 3rd Edition.
3. Fluid Mechanics and Thermodynamics of Turbomachinery, Dixon, S.L, Elsevier, 2014, 7th Edition.
4. Fundamentals of Jet Propulsion with Applications, Flack, R.D., Cambridge University Press, 2011.

Reference Books:

1. Turbines, Compressors and Fans, Yahya, S. M, Tata McGraw Hill, 2017, 4th Edition.
2. Gas Turbine Combustion – Alternative Fuels and Emissions, Lefebvre, A.H. and Ballal D. R., CRC Press, 2010.

Online Resources:

1. Aircraft Propulsion by Prof. Vinayak N. Kulkarni, NPTEL Course (Link: https://nptel.ac.in/courses/112/103/112103281/)
2. Jet Aircraft Propulsion by Prof. Bhaskar Roy and Prof. A M Pradeep (IIT Bombay), NPTEL Course (Link: https://nptel.ac.in/courses/101/101/101101002/)

Course Code: ME5152	DESIGN AND OPTIMIZATION OF THERMAL SYSTEMS	Credits 3-0-0: 3

Prerequisites: **NIL**

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Perform economic analysis of a thermal system.
CO2	Design turbomachines and heat exchangers
CO3	Use numerical techniques to solve thermal system models
CO4	Apply optimization procedures to design thermal systems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3		2
CO2	3	2	3	2		2
CO3	3		2	2		2
CO4	3	2	3	3		2

Syllabus:

Introduction: Introduction to design and specifically system design. Morphology of design with a flow chart, brief discussion on market analysis, profit, time value of money, an example of discounted cash flow technique. Concept of workable design, practical example on workable system and optimal design.

Design of Turbomachines: Principles of Design of turbo machines, Design of axial flow turbine stage, Design of axial flow compressor stage, Design of centrifugal compressor.

Design of Heat Exchanger : Study of design aspects, fluid flow and heat transfer characteristics, Material requirement of heat exchange equipment, Liquid - to - liquid and Liquid - to - gas heat exchange systems, Familiarity with use of design related industrial standards and codes, Design of Heat exchanger.

Design of Auxiliary systems: Lubrication, fuel, seal and gas conditioning

System Simulation: Classification. Successive substitution method, Newton Raphson method, Gauss Seidel method, Rudiments of finite difference method for partial differential equations.

Optimization: Introduction. Formulation of optimization problems, calculus technique, search methods, method of steepest ascent/ steepest descent, conjugate gradient method, geometric programming, dynamic programming, linear programming, new generation optimization techniques – genetic algorithm and simulated annealing.

Learning Resources:

Text Books:

1. Essentials of Thermal System Design and Optimization, C. Balaji, Ane Books, New Delhi in India and CRC Press in the rest of the world, 2011.
2. Design and optimization of thermal systems, Y. Jaluria, McGraw Hill, 1998.

Reference Books:

1. Elements of thermal fluid system design, L.C. Burmeister, Prentice Hall, 1998.
2. Design of thermal systems, W.F. Stoecker, McGraw Hill, 1989.

Online Resources:

1. Design and Optimization of Energy systems by Prof. C. Balaji (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106064/)

Course Code: ME5153	SIMULATION LABORATORY	Credits 0-1-2: 2

Prerequisites: **Fluid Mechanics, Heat and Mass Transfer**

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Formulate problems in fluid flow and heat transfer
CO2	Analyse the influence of non-dimensional parameters for heat transfer problems
CO3	Solve real life thermal engineering problems using CFD package
CO4	Design thermal engineering equipment using CFD package

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3		1
CO2	2	3	3	3		1
CO3	2	3	3	3		1
CO4	2	3	3	3		1

List of Experiments: (need to re write)

- **Heat conduction through a slab:** To analyze the temperature distribution and hot spot temperature for a slab with different boundary conditions.
- **Lumped heat capacity model:** To revisit the concept of lumped heat capacity analysis via numerical analysis and predict the temperature with time.
- **Laminar pipe Flow:** To list out the assumptions, governing equations and non-dimensional parameters for laminar flow through the pipe. Derive the non-dimensional form of governing equations. Develop the numerical solution using the CFD package and compare the results with analytical solutions.
- **Lid driven Cavity:** To list out the assumptions, governing equations and non-dimensional parameters for lid driven flow in a cavity. Derive the non-dimensional form of governing equations. Develop the numerical solution using the CFD package and compare the results with published research articles.
- **Natural convection in a cavity (steady state):** To list out the assumptions, governing equations and non-dimensional parameters for differentially heated cavity and analyze buoyancy induced flow. Derive the non-dimensional form of governing equations. Develop the numerical solution using the CFD package and compare the results with published research articles.
- **Natural convection in a cavity (Unsteady):** To list out the assumptions, governing equations and non-dimensional parameters for differentially heated cavity and analyze buoyancy induced flow with time. Derive the non-dimensional form of governing equations. Develop the numerical solution using the CFD package and compare the results with published research articles.
- **Turbulent Pipe Flow:** To understand the basics of turbulence and turbulence flow models. To list out the assumptions and governing equations for turbulent flow through the pipe. Develop the numerical solution using the CFD package and compare the results with the literature.

- **Flow over cylinder:** To understand the basics of external flows and flow separation. To list out the assumptions, governing equations and non-dimensional parameters for laminar flow over the cylinder. Derive the non-dimensional form of governing equations. Develop the numerical solution using the CFD package and analyze the phenomena of vortex shedding by comparing the results with published research articles.
- **Heat transfer in porous media:** To understand the basics and formulations of porous media. To list out the assumptions, governing equations and non-dimensional parameters for buoyancy induced flow in a differentially heated porous cavity. Develop the numerical solution using the CFD package and compare the results with the literature.
- **Conjugate heat transfer problem:** To analyze the thermal transport for the combined solid and fluid domains.

Learning Resources:

Text Books:

1. Computational Fluid Dynamics the Basics with Applications, Anderson. J.D(Jr), McGraw Hill Education, 2017.
2. Computational Fluid Dynamics, Hoffman, K.A., and Chiang, S.T., Vol. I, II and III, Engineering Education System, 2000, 4th edition.

Reference Books:

1. Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2014, 2nd Edition.
2. Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2013, 3rd Edition
3. An introduction to computational fluid dynamics: the finite volume method, H.K. Versteeg, W. Malalasekera, Longman Group, England, 2007, 2nd Edition.

Online Resources:

1. Computational Fluid Dynamics using Finite Volume Method by Dr. Kameswararao Anupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
2. Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)

Course Code: ME5154	ENERGY SYSTEMS LABORATORY	Credits 0-1-2: 2

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Evaluate the heat transfer characteristics in conduction, convection and radiation.
CO2	Evaluate the performance of Gas Turbine components.
CO3	Analyze the performance of Solar systems.
CO4	Analyze the performance of Fuel Cells.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	3	3	3	2	1
CO3	2	3	3	3	2	1
CO4	2	3	3	3	2	1

List of Experiments:

- **Heat Pipe Demonstrator:** Demonstration of near isothermal characteristics exhibited by a heat pipe in comparison to stainless steel and copper pipes.
- **Double Pipe Heat Exchanger:** To determine the LMTD and effectiveness of the double pipe heat exchanger in parallel and counter flow modes.
- **Stefan-Boltzmann Apparatus:** Determination of the Stefan-Boltzmann constant and comparison with the theoretical value.
- **Axial flow fan:** Constant speed performance test on an axial flow fan.
- **Centrifugal blower:** Constant speed performance test on a centrifugal blower.
- **Measurements and Calibration:** To calibrate the instruments for the measurement of Torque, Pressure, Flow rate and Velocity.
- **Solar flat plate collectors:** Performance evaluation of solar flat plate collectors in natural and forced circulation modes.
- **Parabolic concentric solar collector:** Performance evaluation of parabolic concentric solar collector
- **Solar PV Module:**
  - Identifying and measuring the parameters of a solar PV Module in the field
  - Series and Parallel connection of PV Modules
  - Estimating the effect of Sun tracking on energy generation by solar PV modules
- **Solar Simulator:**
  - Dark and Illuminated Current-Voltage characteristics of solar cell
  - Solar cells connected in series and in parallel
  - Dependence of Solar cell I-V characteristics on light intensity and temperature
- **Fuel Cells:**
  - Performance evaluation of DMFC
  - Performance evaluation of PEM fuel cells.

Learning Resources:

Text Books:

1. PEM Fuel Cells-Theory and Practice, Frano Barbir, Elsevier Academic Press, 2005, 2nd Edition.
2. Electric Vehicle Technology Explained, James Larmine, John Wiley and Sons, 2013, 2nd Edition.

Reference Books:

1. Solar Energy, Sukhatme, S. P. and Nayak, J. K., McGraw Hill Education, 2017, 4th Edition.
2. Experimental Methods for Engineers, Holman, J., McGraw Hill Education, 2017, 7th Edition

Online Resources:

1. Solar Energy Laboratory, IIT Roorkee, Link: https://www.iitr.ac.in/departments/HRE/pages/Facilities+Solar_Energy_Laboratory.html

Course Code: ME5198	SEMINAR-II	Credits 0-0-2: 1

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify and compare technical and practical issues related to Thermal Engineering.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well-organized report employing elements of critical thinking and technical writing.
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2			3
CO2	3	2	2			3
CO3	3	3	2			3
CO4	3	3	2			3

Evaluation Scheme:

Task	Description	Weightage
I	Clarity on the topic	10
II	Literature survey	30
III	Content	30
IV	Presentation	20
V	Response to Questions	10
Total		**100**

Task-CO Mapping:

Task/CO	CO1	CO2	CO3	CO4
I	**X**			
II		**X**		
III			**X**	
IV				**X**
V				**X**

Course Code: ME5111	REFRIGERATION TECHNOLOGY	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Apply thermodynamic principles to analyze refrigeration systems
CO2	Analyze vapour absorption refrigeration system making use of principles of thermodynamics
CO3	Evaluate conventional and alternative refrigerants and their impact on the environment.
CO4	Evaluate the complete refrigeration system by balancing different system components.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	3
CO2	3	2	3	2	1	2
CO3	3	2	3	2	1	2
CO4	3	2	3	2	1	2

Syllabus:

Vapour Compression Cycles: Recapitulation of standard SSS cycle, multi stage refrigeration systems auto-cascade systems, cascade refrigeration systems.

Vapour Absorption System: Absorption cycle of operation, properties of solutions, Actual vapour absorption cycle-representation on enthalpy concentration h-c diagram, Water lithium bromide absorption system. Electrolux refrigerator- Aqua Ammonia Refrigeration System, Platen-Munters systems, comparison with VCRS.

Refrigeration System Devices: Compressors-selection, expansion valves, condensers, evaporators-types, performance, working, characteristics of compressors, condensers, evaporators and expansion valves. Performance of complete vapour compression system.

Different Refrigeration Systems: Aircraft Refrigeration, Steam jet water vapour system, thermoelectric refrigeration system, Vortex refrigeration system, Pulse refrigeration.

Refrigerants: properties, alternative refrigerants, mixtures, natural refrigerants, secondary refrigerants.

Learning Resources:

Text Books:

1. Principles of Refrigeration, Dossat, R.J. and Horan, T.J., Prentice Hall, 2001, 5th Edition.
2. Refrigeration & Air conditioning, Arora, R.C., PHI, 2010, 1st Edition.

Reference Books:

1. Principles of Refrigeration, Gosney W.B., Cambridge University Press, 1982.

2. Thermal Environmental Engineering, Threlkeld J.L., Prentice Hall, New Jersey 1962.

Online Resources:

1. Refrigeration and Air-Conditioning by Prof. M Ramgopal (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105129/)
2. NOC:Refrigeration and air-conditioning by Prof. Ravi Kumar (IIT Roorkee), NPTEL Course (Link: https://nptel.ac.in/courses/112/107/112107208/)

Course Code: ME5112	POWER PLANT ENGINEERING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Apply the principles of thermodynamics to analyse the performance of steam, gas, combined and nuclear power plants
CO2	Design and develop power plant components for optimum performance
CO3	Select appropriate site and technology for power plants
CO4	Evaluate economic and environmental implications on power plants.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2

Syllabus:

Introduction: Energy resources and their availability, types of power plants, selection of the plants, review of basic thermodynamic cycles used in power plants.

Steam Power Plants: Flow sheet and working of modern-thermal power plants, site selection, plant efficiency

Steam generators and their accessories: High pressure Boilers, design of accessories, Steam generator control, Draught system.

Fuel and combustion: coal storage and preparation, coal handling systems, coal combustion, mass and energy balance of steam generator, feeding and burning of pulverized fuel, Fluidized bed combustion system, ash handling systems, dust collection -mechanical dust collector and electrostatic precipitator.

Condensers: Direct Contact Condenser, Surface Condensers, Effect of various parameters on condenser performance, Design of condensers, Cooling towers and cooling ponds

Combined Cycles: Gas turbine power plants, Arrangements of combined plants (steam & gas turbine power plants), parameters affecting thermodynamic efficiency of combined cycles, Integrated gasification combined cycle, PFBC based combined cycle, re-powering of thermal power plant.

Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, Nuclear cross-section, different components of nuclear power station, PWR, BWR, CANDU, liquid metal cooled, gas cooled, fast breeder, nuclear waste disposal.

Non-conventional energy generation: Geothermal power plant, Tidal and wave power plant, solar power plant, wind power generation, direct to electricity method - Magneto-hydrodynamic

(MHO) power generation

HydroElectric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, comparison with other types of power plants.

Power Plant Economics: load curve, different terms and definitions, base load and peak load plants, energy storage, cost of electrical energy, tariffs, methods of electrical energy, performance & operating characteristics of power plants - incremental rate theory, input-output curves, efficiency, heat rate, economic load sharing, Problems.

Learning Resources:

Text Books:

1. Power Plant Engineering, P. K. Nag, McGraw Hill Education; 2017,4th Edition.

Reference Books:

1. Power Plant engineering, P. C. Sharma, S.K. Kataria & Sons, New Delhi, 2010.

Online Resources:

1. NOC:Power Plant Engineering by Prof. Ravi Kumar (IIT Roorkee), NPTEL Course (Link: https://nptel.ac.in/courses/112/107/112107291/)

Course Code: ME5113	RENEWABLE SOURCES OF ENERGY	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify the renewable energy sources, their utilization and storage
CO2	Understand the basic concepts of the solar radiation and analyze the solar thermal systems for their utilization
CO3	Understand the principle of working of solar cells and their modern manufacturing techniques
CO4	Analyze wind energy, biomass and Fuel cell systems and their applications
CO5	Design of solar thermal and energy storage systems for specific applications
CO6	Evaluate the energy conversion from ocean thermal energy, geothermal energy, biomass and magneto hydrodynamic power generation

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	3	3
CO2	3	2	2	3	3	2
CO3	2	2	3	3	3	2
CO4	2	2	2	1	3	2
CO5	3	3	3	2	3	2
CO6	2	2	2	1	3	2

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns. Classification of energy resources, Environmental Aspects of Energy – Global warming & Climate change – Role of Renewables, Energy-Environment-Economy, energy scenario in the world and India, Thermodynamics of Energy Sources – A brief review.

Energy storage: Necessity for energy storage. Classification of methods of energy storage. Thermal energy storage; sensible heat storage, latent heat storage., Mechanical energy storage: Pumped hydel storage, Compressed air storage and Flywheel storage, Reversible chemical reaction storage. Electromagnetic energy storage. Hydrogen energy storage. Chemical battery storage.

Basic sun-earth relationships: Definitions. Celestial sphere, altitude-azimuth, declination-hour angle and declination-right ascension coordinate systems for finding the position of the sun, celestial triangle and coordinates of the sun. Greenwich Mean Time, Indian Standard Time, Local Solar Time, sunrise and sunset times & day length.

Solar radiation: Nature of solar radiation, solar radiation spectrum, solar constant, extra-terrestrial radiation on a horizontal surface, attenuation of solar radiation, beam, diffuse and global radiation. Measurement of global, diffuse and beam radiation. Prediction of solar radiation; Angstrom model, Page model, Hottel's model, Liu and Jordan model etc. Insolation on an inclined surface, angle of incidence.

Solar thermal systems: Principle of working of solar water heating systems, solar cookers, solar desalination systems, solar ponds, solar chimney power plant, central power tower power plants etc. Classification of solar concentrators, Basic definitions such as concentration ratio, angle of acceptance etc., Tracking of the sun; description of different tracking modes of solar collectors and the determination of angle of incidence of insolation in different tracking modes , Concept of Green building and associated design parameters.

Photovoltaic energy conversion: Introduction. Single crystal silicon solar cell, i-v characteristics, effect of insolation and temperature on the performance of silicon cells. Different types of solar cells. Modern technological methods of producing these cells. Indian and world photovoltaic energy scenario. Solar Cell, Module, and Array Construction, Maximizing the Solar PV Output and Load Matching.

Wind energy: Origin of winds, nature of winds, wind data measurement, Variation of Wind Speed with Height, Basics of fluid mechanics, Estimation of Wind Energy at a Site: Betz's law, Wind Turbine Aerodynamics, wind turbine types and their construction, wind-diesel hybrid system, environmental aspects, Wind Energy Storage, wind energy programme in India and the world.

Fuel cells: Introduction, applications, classification, different types of fuel cells such as phosphoric acid fuel cell, alkaline fuel cell, PEM fuel cell, MC fuel cell. Thermodynamic analysis of fuel cells, Development and performance fuel cells.

Biomass: Introduction, photosynthesis, biofuels, biomass resources, biomass conversion technologies, urban waste to energy conversion, biomass to ethanol conversion, biomass energy scenario in India, biogas production, constant pressure and constant volume biogas plants, operational parameters of the biogas plant, design of bio-digester, Energy Farming

Other forms of Energy: Ocean energy : Ocean thermal energy; open cycle & closed cycle OTEC plants, environmental impacts, challenges, present status of OTEC systems. Ocean tidal energy; single basin and double basin plants, their relative merits. Ocean wave energy; basics of ocean waves, different wave energy conversion devices, relative merits; **Geothermal energy:** Origin, applications, types of geothermal resources, relative merits; **Magneto hydrodynamic Power Generation:** applications; Origin and their types; Working principles.

Learning Resources:

Text Books:

1. Non conventional Energy Resources, B.H.Khan, Tata McGraw Hill, New Delhi, 2017, 3rd edition
2. Energy Technology: Non-Conventional, Renewable and Conventional, S.Rao and B.B.Parulekar, Khanna Publishers, 2010, 1st Edition.

Reference Books:

1. Solar Energy-Principles of Thermal Collection and Storage, S.P.Sukhatme and J.K.Nayak, TMH, 2010, 3rd edition (6 reprint).
2. Solar Energy Thermal Processes, J.A.Duffie and W.A.Beckman, John Wiley, 2013, 4th edition.

Online Resources:

1. Non-conventional Energy Resources by Prof. Prathap Haridoss (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/121/106/121106014/)

Course Code: ME5114	ENERGY SYSTEMS AND MANAGEMENT	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the fundamentals of energy management
CO2	Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
CO3	Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
CO4	Design viable energy projects.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	3	3	2
CO2	3		3	3	2	2
CO3	3	2	3	3	3	2
CO4	3	3	3	2	2	2

Syllabus:

Introduction: Review of the concepts of Thermodynamics, Fluid Mechanics and Heat Transfer, Need for energy storage, Grid balancing: Supply and demand concept for energy management. Heat transfer equipment- Heat exchangers, Steam plant

Energy storage Methods and systems: Thermal, Electrical and Mechanical energy storage methods and systems, Energy saving in IC engines and Gas turbines.

Direct Energy Conversion methods: Magneto-hydrodynamic (MHO) power generation, Thermionic power generation, Thermoelectric power generation, Fuel cells, Hydrogen energy system

Heat recovery systems: Incinerators, regenerators and boilers

Energy Conservation: Methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems

Energy Management: Principles of Energy Management, Energy demand estimation, Organising and Managing Energy Management Programs, Energy pricing

Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries, Economic Analysis: Scope, Characterization of an Investment Project and Case studies.

Learning Resources:

Text Books:

1. Energy Management audit & Conservation, De, B. K., Vrinda Publication, 2010, 2nd Edition.
2. Energy Management, Murphy, W. R., Elsevier, 2007, 1st Edition.

Reference Books:

1. Energy Management Hand book, Doty, S. and Truner, W. C., Fairmont Press, 2009, 7th edition.

Online Resources:

1. International Energy Agency Website, (Link: https://www.iea.org/)
2. Indian Renewable Energy Development Agency Limited Website, (Link: https://www.ireda.in)
3. Ministry of Power, GoI, Website, (Link: https://powermin.gov.in/)

Course Code: ME5115	HYDRAULIC MACHINERY	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify various fluid machinery and their application in industries
CO2	Apply fluid and thermodynamic concepts to understand the working of hydraulic machines.
CO3	Understand energy exchange in hydraulic machines and their performance
CO4	Select a hydraulic turbo machine depending on the industrial requirement
CO5	Design hydraulic machinery for specific conditions

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	2	3	3
CO2	3	2	2	3	1	2
CO3	2	2	3	3	2	2
CO4	2	2	2	1	1	2
CO5	2	2	2	1	2	2

Syllabus:

Introduction: Euler's turbomachinery equation, aerofoil and cascade theory, impulse and reaction principle, specific speed.

Hydraulic Turbines: Classification, Pelton, Francis, Kaplan, propeller and bulb turbines, velocity triangles, power and efficiency calculations, draft tube, cavitation, Thoma's cavitation factor, governing of impulse and reaction turbines.

Reaction turbine design: General procedure, general project layout, design of a Francis runner, design of the spiral casing and the distributor, draft tube role, CFD validation of the design, design fix.

Pelton turbine design: general procedure, project layout, injector design, bucket design, mechanical problems.

Rotodynamic Pumps: Classifications, centrifugal, mixed and axial flow pumps, velocity triangles; Head, power and efficiency calculations, system losses and system head, impeller slip and slip factors, Hydraulic design of fans and compressors, internal and stage efficiency, stalling.

Performance Characteristics of Rotodynamic Machines: Head, capacity and power measurement, performance characteristics, operating characteristics, model testing, similarity laws, Muschal or constant efficiency curves.

Learning Resources:

Text Books:

1. Hydraulic Machines, Lal, J., Metropolitan Book Co. Private Limited, 2003, 6th edition.

2. A treatise on Turbomachines, Gopal Krishnan & Prithviraj, Scitech Publications, 2002

Reference Books:

1. Introduction to fluid Mechanics, Som and Biswas, Tata McGraw Hill, 2nd Edition
2. Water Power Development, Mosonyi, E., Vol. I and II, Nem Chand & Bros, 2009, 3rd edition.

Online Resources:

1. https://hre.iitr.ac.in/departments/HRE/pages/Publications+Standard_and_Guidelines_for_SHP_Development.html

Course Code: ME5116	PARTICLE MECHANICS AND ITS APPLICATIONS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand molecular models, minimization techniques and force fields used in molecular simulations.
CO2	Apply various ensembles for simulating typical physical processes
CO3	Analyze thermo-fluid characteristics in nanoscale systems.
CO4	Understand the modeling of nanofluidic processes using the dissipative particle dynamics

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	1
CO2	3	1	2	2	1	1
CO3	3	1	3	3	1	1
CO4	2	1	2	1	1	1

Syllabus:

Statistical mechanics fundamentals: Ergodicity, Sampling from ensembles, Common statistical ensembles, Simple thermodynamic averages, Fluctuations, Structural quantities, Time correlation functions.

Force field models: Introduction, Born-Oppenheimer approximation, Pair potentials and their limitations, potentials for ionic systems, Many-body potentials.

Energy minimization: Simplex method, Sequential Univariant method, Steepest descents method, Conjugate gradients minimisation, Newton-Raphson method.

Monte Carlo simulations: Introduction, Monte-Carlo integration, The Metropolis method, Isothermal-Isobaric Monte Carlo, Grand canonical Monte Carlo, Semi-grand canonical Monte Carlo.

Molecular dynamics simulations: Equations of motion for atomic systems, finite-difference methods, Temperature and Pressure Control, Efficient calculation of forces and energy, Neighbour lists, periodic boundary conditions, Treatment of long-range interactions, Analysis and interpretation of results

Free energy calculations: Thermodynamic integration method, Particle insertion method, Umbrella sampling method

Applications in nanoscale systems: Thermal conductivity of liquids in nanochannels, shear viscosity near interfaces, Mass diffusivity, Wetting, Transport properties across interfaces

Dissipative particle dynamics: Introduction, Justification of the method, Implementation, classical dissipative particle dynamics (DPD), Multi-body dissipative particle dynamics, Energy conservation in DPD, Applications.

Learning Resources:

Text Books:

1. Computer Simulation of Liquids, Tildesley, D. J., and M. P. Allen., Oxford University Press, New York, 2017, 2nd Edition.
2. Understanding Molecular Simulation: From Algorithms to Applications, D. Frenkel and B. Smit., Academic press, 2001.
3. Statistical Mechanics, Donald A. Mcquarrie, Univ Science Books, 2008.

Reference Books:

1. Molecular Modelling: Principles and Applications, Andrew R. Leach., Prentice Hall press, 2001, 2nd Edition.

Online Resources:

1. Advanced Thermodynamics and Molecular Simulations by Prof. Prateek Kumar Jha (IIT Roorkee), NPTEL COurse (Link: https://nptel.ac.in/courses/103/107/103107208/)

Course Code: ME5502	COMPUTATIONAL METHODS IN AUTOMOBILE ENGINEERING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the Finite Element Formulation procedure for automotive structures.
CO2	Analyse the structural and dynamic response of automotive components.
CO3	Solve thermal and fluid flow problems of automotive applications
CO4	Analyse the coupled Fluid-Structure interaction problems in Automotive Engineering

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	1
CO2	2	2	2	3	3	1
CO3	2	3	3	3	3	1
CO4	1	2	3	3	2	1

Syllabus:

Introduction: Historical Perspective of Computational methods in automobile engineering, A brief review on steady state, propagation and transient problems in engineering analysis, Need of Finite Element and Finite Volume methods and their applicability to various structural, heat transfer and fluid flow problems in Automotive Engineering, Comparison of FDM, FEM, FVM, Advantages and limitations of FEM and FVM, A brief discussion on Commercial FEM and FVM packages for Automotive Engineering.

Approximate Solutions of BVP: Need of Approximate Solutions of BVP and their accuracy with respect to Analytical Solutions, Various Boundary Conditions of BVP, Strong and weak forms of General BVP, Weighted Residual Methods (Least Squares Method, Collocation Method, Galerkin Method, and Modified Galerkin Methods), Energy or Variational Methods.

Finite Element Formulation: Basic Finite Element Concepts, General finite element solution procedure, Concept of discretisation, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility, Assembly and boundary considerations.

1D Elements for Structural Problems: Axial deformation in bars and Springs, Formulation of stiffness matrix, FE Formulation for Truss elements, Global, Local and Natural coordinates, Plane truss and Space truss, Stresses due to lack of fit and temperature changes, FE Formulation for Beam elements, Calculation of stresses in beams, Thermal stresses in beams, Plane Frame and Space frames, Thermal stresses in frames, General 1D BVP and its applications (Heat Transfer, Fluid Mechanics, Column Buckling), Introduction to higher order elements, Shape functions for higher order problems, Iso-parametric mapping, Advantages and disadvantages of higher order elements.

2D Elements for Structural Problems: Solution of 2D BVP with triangular and quadrilateral elements, Numerical integration schemes, Iso-Parametric elements, Applications of 2D BVP (Ideal fluid flow around an irregular object, Two dimensional steady state heat flow, Torsion of prismatic bars), 2D Elasticity (Plane stress and Plane strain), Axisymmetric elasticity problems, Introduction to 3D Elements.

Structural and Dynamic Analysis: 1D & 2D dynamic problems in Solid mechanics, Dynamics problems representation in FE, Free vibration problem formulation, Torsion of non-circular shaft - axisymmetric problem

Thermal analysis: Review of basic equations of steady and transient heat conduction, 1D & 2D problems in conduction heat transfer

Finite elements in flow problems: Review of basic equations of convection dominated flows, Solutions through Galerkin approximation for convection dominated flows, Babuška–Brezzi Condition, Need of Stabilization in Convection dominated flows.

Finite Volume Method and Fluid-Structure Interaction: A brief introduction to Finite Volume Method for fluid flow problems, Advantages and Limitations of FVM over FEM for flow problems, Discretization of Navier-Stokes Equation through FVM, Coupled FE and FV analyses for Fluid-Structure Interaction problems, Arbitrary Lagrangian-Eulerian description, One-way and two-way coupling, Applications of FSI in automotive systems.

Learning Resources:

Text Books:

1. Fundamental Finite Element Analysis and Applications: with Mathematica and Matlab Computations, Bhatti, M.A., Wiley, 2005.
2. Finite Element Procedures in Engineering Analysis, Klaus-Jürgen Bathe, Prentice-Hall, 1982
3. Finite Element Method in Engineering, Reddy, J.N., Tata McGraw Hill, 2007.

Reference Books:

1. Applied Finite Element Analysis, Larry J. Segerlind, 2nd Edition, Wiley.
2. The Finite Element Method: Its Basis and Fundamentals, J. Z. Zhu, Olgierd Zienkiewicz, and Richard Taylor, Sixth Edition, Elsevier, 2005.

Online Resources:

1. Finite Element Analysis by Prof. B.N Rao (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/105/106/105106051/)
2. Finite Element Procedures for Solids and Structures by Prof. Klaus-Jürgen Bathe (MIT Massachusetts), MIT OpenCourseware (Course Link: https://ocw.mit.edu/resources/res-2-002-finite-element-procedures-for-solids-and-structures-spring-2010/)

Course Code: ME5504	PRIME MOVERS FOR AUTOMOBILES	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the importance of an IC engine as a prime mover and compare its performance on the basis of thermodynamic cycles and combustion process.
CO2	Identify harmful IC engine emissions and use viable alternate fuels in engines.
CO3	Classify alternate power sources for automobiles.
CO4	Analyse and evaluate the configurations of battery, hybrid and fuel cell electric vehicles

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	2
CO2	3	2	2	3	3	2
CO3	2	2	3	2	3	2
CO4	2	2	3	2	2	2

Syllabus:

Introduction to IC engines: Classification of Prime Movers; IC Engines as Prime Movers; Historical Perspective of IC Engines; IC Engines-Classification, Mechanical cycle and Thermodynamic cycle, Air standard cycles-Diesel, Otto, Dual and Miller cycles. Differences between 2-stroke and 4-stroke cycle engines, Differences between SI and CI engines.

Combustion in SI and CI Engines: SI Engines: Brief treatment on Flame Propagation-Combustion phenomena (Normal and Abnormal), Factors affecting, Detonation, Ignition quality(Octane rating), Requirements of good combustion Chamber-Types, HUCR; **CI Engines:** Importance of air motion and Compression Ratio, Mixture Preparation inside the CC. Normal and abnormal combustion - Ignition Quality (Cetane rating) ; Characteristics of a Good Combustion Chamber- Classification of Combustion Chambers (DI and IDI).

Fuel Metering in SI and CI Engines: Brief treatment on Carburetion and fuel injection systems for SI Engines; Types of Fuel injection Systems - Individual, Unit and Common Rail (CRDI), Fuel Injectors-Nozzle types, Electronic Control Unit (ECU)-Numerical problems on fuel injection.

Supercharging of IC Engines: Need of Supercharging and advantages, Configurations of Supercharging-Numerical problems on turbocharging.

Pollutant emissions from IC Engines: Introduction to clean air, Pollutants from SI and CI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen (NO-NOX) and Particulate Matter. Mechanism of formation of pollutants, Factors affecting pollutant formation. Brief treatment on Measurement of engine emissions-instrumentation and pollution Control Strategies, Emission norms-EURO and Bharat stage norms.

Performance of IC Engines: Classification of engine performance parameters-Measurement of brake power, indicated power and friction power. Engine and Chassis dynamometers, driving cycles, Factors affecting performance, Heat loss, Air-fuel ratio, Energy Balance: Pi and Sankey diagrams Numerical problems.

Alternate Fuels: Need for Alternate fuels, Desirable Characteristics of a good Alternate Fuel-Liquid and Gaseous fuels for SI and CI Engines, LPG, Alcohols, Bio-fuels, Natural Gas and Hydrogen. Brief treatment on production and use of alternate fuels in IC Engines.

Batteries: Battery: Battery parameters; Types of batteries- Technical characteristics-Ragone plots.

Electric Vehicles: Introduction: History of EVs, EV system, basic structure- Electric vehicle drivetrain-advantages and limitations, Components of EV Battery run EVs and Electric Motor run EVs- Brief treatment on types of electric machines for EVs (Power-Torque characteristics), regenerative braking system.

Hybrid Vehicles: Configurations of hybrids, advantages and limitations- basic structure of series, parallel and series-parallel configurations, Power-Torque characteristics. Hydrogen: Production-Hydrogen storage systems-reformers.

Fuel Cell vehicles: Introduction-Fuel cell characteristics, Fuel cell types: Brief introduction to PEMFC and DMFCs.

Learning Resources:

Text Books:

1. Internal Combustion Engine Fundamentals, John.B. Heywood , McGraw Hill Co.2018 II Edition.
2. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.

Reference Books:

1. Engineering Fundamentals of IC Engine, W.W. Pulkrabek , PHI, 2002, II Edition
2. Electric vehicle technology explained, John Lowry and James Larmine, John Wiley and Sons, 2012.
3. PEM Fuel Cells - Theory and Practice, Frano Barbir, Elsevier Academic Press, 2005.

Online Resources:

1. Introduction to Hybrid and Electric vehicles by Dr. Praveen Kumar and Prof. S. Majhi (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/108/103/108103009/)

Course Code: ME5513	ALTERNATE FUELS AND EMISSIONS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the need of alternate fuels
CO2	Evaluate the performance of the engine with alternate fuels and blends with petroleum derived fuels.
CO3	Examine the viable production and storage methods of alternate fuels.
CO4	Measure the pollutant emissions as per standards and describe emission control methods.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3	3	2
CO2	2	2	2	2	2	2
CO3	2	2	2	2	2	2
CO4	2	2	2	3	2	2

Syllabus:

Introduction: Present energy scenario (worldwide and India)- Statistics of petroleum fuels- of liquid and gaseous fuels in Automobiles-Problems with highly exploited petroleum derived fuels-Desirable properties of a good alternate fuel – Availability and properties of alternate fuels, ASTM standards.

Alcohols: General Use of Alcohols – Thermo-combustion properties as Engine fuel – Gasolene and alcohol blends – Production methods of widely used alcohols-Performance in SI and CI Engines – Methanol and ethanol and Gasolene/diesel blends – Combustion Characteristics in engine – emission characteristics-Modification required to operate with alcohols and its blends with petrol and diesel-brief details of flexi fuel engines(FFE)-use of higher alcohols.

Natural Gas, LPG: Use of natural gas as CNG and LNG-Availability of CNG and LNG-, properties, modification required to use in engines – performance and emission characteristics of CNG using LPG in SI & CI engines.-Production and storage of CNG/LNG.

Bio-gas: Production methods of bio-gas, properties of bio-gas as a fuel, performance and emission characteristics of engine with bio-gas and its blends with petrol/diesel-brief information on compressed gio-gas and its storage.

Vegetable oils: Characteristics of vegetable oils as alternate fuel- edible and non-edible vegetable oils-conversion of vegetable oils into diesel like fuel(biodiesel) -esterification, blending and micro-emulsions-Performance and emission characteristics of engines with biodiesel and blends-B20.

Hydrogen : Suitable characteristics of hydrogen fuel- hydrogen production methods- storage of hydrogen-use of hydrogen as fuel in engines -Hydrogen in fuel cells.

Engine Emissions : Harmful effects of engine-out emissions-Mechanism of formation of pollutant emissions such as carbon monoxide, unburned hydrocarbons, oxides of hydrogen and aldehydes.

Emission measurement and control methods: Measurement of pollutants using flame ionization detection, NDIR, chemiluminescent analyzer and particulate matter(soot/smoke)-Emission norms-EURO and Bharat stage Engine emission control methods-in cylinder and after treatment methods.

Learning Resources:

Text Books:

1. Alternative Transportation Fuels: Utilisation in Combustion Engines, M.K. Gajendra Babu , K.A. Subramanian CRC Press ,2013
2. Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines,Akhilendra Pratap Singh, Yogesh C. Sharma, Nirendra N. Mustafi ,Avinash Kumar Agarwal, Springer 2020.

Reference Books:

1. Engine Emissions: Pollutant formation and advances in control Technology, Norbe Pundir B.P, Narosa Publishing House, 2013.
2. Alternative Fuels for Transportation, Ramadhas, A S,CRC Press 2012.

Online Resources:

IC Engines: Combustion and Emissions by Prof. B.P. Pundir (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104033/)

Course Code: ME5404	COMPUTER-AIDED GEOMETRIC DESIGN	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Apply geometric transformations and projection methods in CAD
CO2	Develop geometric models to represent curves
CO3	Design surface and solid models for engineering design
CO4	Apply mesh generation techniques for engineering analysis

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	2	2
CO2	3		3	3	2	2
CO3	3	2	3	3	3	2
CO4	3	2	3	3	3	2

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections, Implementation of the projection formulations using computer codes.

Introduction to Geometric Modeling for Design: Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

Curves in Geometric Modeling for Design: Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversion of one form of curve to other. Implementation of all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, Parametric representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD softwares. Data Exchange Formats and CAD Applications:

Meshing Methods for Engineering Analysis: FEM, Meshing, Quality of meshing, Mesh generation methods.

Learning Resources:

1. Geometric Modeling, Michael E. Mortenson, Tata McGraw Hill, 2013.
2. Computer-Aided Engineering Design, Saxena and B. Sahay, Anamaya Publishers, New Delhi, 2005.
3. An introduction to NURBS: with historical perspective, Rogers, David F.Morgan Kaufmann Publishers, USA, 2001.
4. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, TMH, 2008.
5. Principles of CAD/CAM/CAE systems, Kunwoo Lee, Addison-Wesley (1999).

Course Code: ME5415	MATHEMATICAL METHODS IN ENGINEERING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Formulate a design task as an optimization problem
CO2	Identify constrained and unconstrained optimization problems and solve using corresponding methods
CO3	Solve nonlinear optimization problems with evolutionary methods
CO4	Apply data driven methods to solve engineering problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	1	2
CO2	2	2	3	3	2	2
CO3	3		3	3	3	2
CO4	3		3	3	3	2

Syllabus:

Mathematical Modeling: Modeling of systems related to mechanical engineering, assumptions, appropriate methods and fundamental of a computer implementation

Numerical Linear Equations: Introduction, Basic Ideas of Applied Linear Algebra, Systems of Linear Equations, Square, Non-Singular Systems, the Algebraic Eigenvalue Problem, Matrix Decompositions, Computer implementation of the methods for applications in engineering analysis.

Outline of Optimization Techniques: Introduction to Optimization, Multivariate Optimization, Constrained Optimization, Optimality Criteria, Computer implementation of the methods for applications in design optimization, manufacturing and thermal process optimization.

Topics in Numerical Analysis: Interpolation, Regression, Numerical Integration, Numerical Solution of ODE's as IVP Boundary Value Problems. Application of numerical methods for research in mechanical engineering.

Overviews: PDE's and Variational Calculus: Separation of Variables in PDE's, Hyperbolic Equations, Parabolic and Elliptic Equations, Membrane Equation, and Calculus of Variations. Applications in mechanical engineering research.

Learning Resources:

1. Advanced Engineering Mathematics, E. Kreyszig , Wiley, 2010.
2. Applied Mathematical Methods, B. Dasgupta , Pearson Education, 2006.
3. Scientific Computing, M. T. Heath, McGraw-Hill Education, 2001.
4. Applied Numerical Methods with Matlab, Steven Chapra, McGraw-Hill Education, 2011.

Course Code: ME5311	ENTERPRISE RESOURCE PLANNING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the concepts of ERP and managing risks.
CO2	Choose the technologies needed for ERP implementation.
CO3	Develop the implementation process.
CO4	Analyze the role of Consultants, Vendors and Employees.
CO5	Evaluate the role of PLM, SCM and CRM in ERP.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	2	2	1
CO2	2	1	2	2	3	2
CO3	2	2	2	2	2	1
CO4	2	1	2		1	1
CO5	2	1	2	2	2	1

Syllabus:

Introduction to ERP: Enterprise – an overview, brief history of ERP, common ERP myths, Role of CIO, Basic concepts of ERP, Risk factors of ERP implementation, Operation and Maintenance issues, Managing risk on ERP projects.

ERP and Related Technologies: BPR, Data Warehousing, Data Mining, OLAP, PLM, SCM, CRM, GIS, Intranets, Extranets, Middleware, Computer Security, Functional Modules of ERP Software, Integration of ERP, SCM and CRM applications.

ERP Implementation: Why ERP, ERP Implementation Life Cycle, ERP Package Selection, ERP Transition Strategies, ERP Implementation Process, ERP Project Teams.

ERP Operation and Maintenance: Role of Consultants, Vendors and Employees, Successes and Failure factors of ERP implementation, Maximizing the ERP system, ERP and e-Business, Future Directions and Trends.

Learning Resources:

Text Books:

1. Enterprise Resource Planning, Alexis Leon, Tata McGraw Hill, Second Edition, 2008.
2. ERP in Practice, Jagan Nathan Vaman, Tata McGraw Hill, 2007.
3. ERP: Tools, Techniques, and Applications for Integrating the Supply Chain, Carol A Ptak, CRC Press, 2003, 2nd Edition.

Course Code: ME5313	SOFT COMPUTING TECHNIQUES	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Classify and differentiate problem solving methods and tools.
CO2	Apply A*, AO*, Branch and Bound search techniques for problem solving.
CO3	Formulate an optimization problem to solve using evolutionary computing methods.
CO4	Design and implement GA, PSO and ACO algorithms for optimization problems in Mechanical Engineering.
CO5	Apply soft computing techniques for design, control and optimization of Manufacturing systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			1			
CO2	2		2	3	1	
CO3	3		2	1	2	
CO4	3		3	3	2	
CO5	3	2	2	3	2	1

Syllabus:

Problem Solving Methods and Tools: Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison, A*, AO*, Branch and Bound search techniques, p type, Np complete and Np Hard problems.

Evolutionary Computing Methods: Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming.

Genetic Algorithm and Genetic Programming: Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications.

Swarm Optimization: Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms.

Advances in Soft Computing Tools: Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems.

Deep Neural Networks: Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting backpropagation training, applications.

Application of Soft Computing to Mechanical Engineering/Production Engineering Problems: Application to Inventory control, Scheduling problems, Production, Distribution, Routing, Transportation, Assignment problems.

Learning Resources:

Text Books:

1. Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Tettamanzi Andrea, Tomassini and Marco, Springer, 2001.
2. Artificial Intelligence, Elaine Rich, McGraw Hill, 2/e, 1990.
3. Multi-objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley and Sons, 2001.
4. Optimization for Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, Ltd, 2012.

References:

1. https://in.mathworks.com/content/dam/mathworks/ebook/gated/machine-learning-ebook-all-chapters.pdf.

Online Resources:

1. https://www.iitk.ac.in/kangal/index.shtml

Course Code: ME5611	SURFACE ENGINEERING	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the micro mechanisms involved in failure at different service conditions.
CO2	Identify the materials for surface engineering and characteristics.
CO3	Understand the fundamentals of basic surface modification techniques.
CO4	Select thick and thin layer coating technology to enhance the surface properties.
CO5	Evaluate the metallurgical, mechanical and tribological properties of engineered surfaces.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	3	2	
CO2	2		3	3	2	
CO3	3		3	3	2	
CO4	3		3	3	2	
CO5	3		3	3	2	

Syllabus:

Introduction: Concept and Importance, classification of surface modification techniques, advantages and their limitations.

Surface Degradation: Causes, types and consequences of surface degradation, Forms of wear – adhesive, abrasive, surface fatigue, corrosive, fretting and erosive wear, Classical governing laws related to wear, techniques to evaluate the wear damage.

Materials for Surface Engineering: Materials characteristics, their importance in surface engineering, wear resistant materials, selection of materials for engineering the surfaces for specific applications, New coating concepts including multi-layer structures, functionally gradient materials (FGMs), intermetallic barrier coatings and thermal barrier coating, Presurface treatment.

Conventional surface engineering practice: Surface engineering by material removal: like etching, grinding, polishing, etc. Surface engineering by material addition: like hot dipping, Electro-plating, carburizing, Cyaniding, etc.

Coating based Surface Modification Techniques: Principles and application of weld surfacing: SMAW, SAW, GMAW, Thermal spraying – flame spraying, electric arc spraying, plasma spraying, detonation gun spraying and high velocity oxy fuel spraying, Cold-Gas Spraying Method (CGSM), Principles, Process Parameters, Coating Properties.

Irradiation based and beam based techniques: Laser cladding, alloying, glazing, laser and induction hardening, heat treatment of steel and remelting by laser / TIG. Microwave glazing.

Thin Film coating techniques: Ion implantation, chemical vapour deposition (CVD) and physical vapour deposition (PVD), carburizing, nitriding, plasma nitriding, cyaniding.

Post-Spray Treatment: Heat Treatment, Electromagnetic Treatment, Furnace Treatment, Hot Isostatic Pressing (HIP), Combustion Flame Re-melting, Impregnation Inorganic Sealants Organic Sealants Finishing Grinding Polishing and Lapping.

Characterization of coatings and surfaces: Measurement of coatings thickness, porosity & adhesion of surface coatings, Measurement of residual stress & stability, Surface microscopy, topography and Spectroscopic analysis of modified surfaces.

Learning Resources:

Text Books:

1. Surface engineering: Enhancing the life of tribological components, Dheerendra Kumar Dwivedi, Springer, New Delhi, 2018.
2. Surface Engineering D.Srinivasa Rao, Daya Publishing House, 2017.

Reference Books:

1. Surface Engineering for Corrosion and Wear Resistance, J.R. Davis, ASM International, 2001.
2. ASM Handbook – Surface Engineering, ASM International, vol. 5, 9th edition, 1994.
3. Surface Engineering for Wear Resistances by K.G. Budinski. Prentice Hall Publisher, 1988.

Online Resources:

1. NOC:Surface Engineering for Corrosion and Wear Resistance Application by Prof. I. Manna, Prof. Jyotsna Dutta Majumder (IIT Kharagpur), NPTEL Course [Link: https://nptel.ac.in/courses/113/105/113105086/]
2. NOC:Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations by Dr. D. K. Dwivedi (IIT Roorkee), NPTEL Course [Link: https://nptel.ac.in/courses/112/107/112107248/]

Course Code: ME5161	HEATING VENTILATION AND AIR CONDITIONING (HVAC)	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the fundamentals of Psychrometry
CO2	Apply human comfort indices and comfort charts to design indoor conditions of HVAC systems.
CO3	Estimate heating and cooling loads for buildings according to ASHRAE procedures and standards.
CO4	Design and evaluate a complete air distribution system including fan, duct, and installation requirements for a typical HVAC system.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	2	2
CO2	2	2	2	2	2	2
CO3	3	2	2	2		2
CO4	3	2	2	2		2

Syllabus:

Introduction: brief history of air conditioning and impact of air conditioning. HVAC systems and classifications, Heat Pumps

Psychrometry of Air Conditioning Processes: Thermodynamic properties of moist air, Important Psychrometry properties, Psychrometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

Comfort Air Conditioning: Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

Heat Transfer Through Building Structures: Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method – Use of tables, Numerical and other methods, Heat transfer through fenestration – Governing equations, SHGF/SC/CLF Tables

Load Calculation: Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

Ventilation System: Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the workplace, HVAC interface with fire and gas detection systems - system requirements, devices and their functioning.

Learning Resources:

Text Books:

1. Principles of Refrigeration, Dossat, R.J. and Horan, T.J., Prentice Hall, 2001, 5th Edition.
2. Refrigeration & Air conditioning, Arora, R.C., PHI, 2010

Reference Books:

1. Principles of Refrigeration, Gosney W.B., Cambridge University Press, 1982.
2. Thermal Environmental Engineering, Threlkeld J.L., Prentice Hall, New Jersey 1962.

Online Resources:

1. Refrigeration and Air-Conditioning by Prof. M Ramgopal (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105129/)
2. NOC:RAC Product Design by Prof. Sanjeev Jain (IIT Delhi) and Prof. Bhupinder Godara (IIT Delhi), NPTEL Course (Link: https://nptel.ac.in/courses/112/102/112102248/)

Course Code: ME5162	ADVANCED COMPUTATIONAL FLUID DYNAMICS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Derive the governing equations and understand the behaviour of the equations.
CO2	Derive algebraic equations using finite volume methods for various fluid flow and heat transfer problems.
CO3	Solve systems of linear and non-linear equations using state of the art iterative algorithms.
CO4	Analyze the error and uncertainty in numerical models used for various algorithms.
CO5	Model the radiation heat transfer and turbulent flow problems using advanced techniques.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3		1
CO2	2	2	3	3		1
CO3	2	2	3	3		1
CO4	2	2	3	3		1
CO5	2	2	3	3		1

Syllabus:

Introduction: Revision of Fluid Mechanics and Heat transfer fundamentals.

Governing equations of fluid dynamics: The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Finite volume method for diffusion problems: Derivation of equations for 1-D, 2-D and 3-D steady state diffusion, Solution of 1-D, 2-D and 3-D steady state heat conduction of slab.

Finite volume method for convection-diffusion problems: Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes.

Pressure Velocity Coupling in steady flows: Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC and PISO algorithms, Worked examples of the above algorithms.

Solution of discretized equations: Direct and Indirect or iterative methods, TDMA algorithm, Point-iterative methods (Jacobi method, Gauss-Seidel Method, Relaxation method), Multigrid methods

Finite volume method for 1-D unsteady flows: 1D unsteady heat conduction (Explicit, Crank-Nicolson and fully implicit schemes), Transient problems with QUICK, SIMPLE schemes, Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundary condition.

Errors and uncertainty in CFD modelling: Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guidelines for best practices in CFD, Reporting and documentation of CFD results.

CFD modelling of turbulent flows: Characteristics of turbulence, Effect of turbulent fluctuations on mean flow, Turbulent flow calculations, Turbulence modelling, Large Eddy Simulation, Direct Numerical Simulation.

Grid Generation: Unstructured grid generation, Domain nodalization, Domain triangulation, Advancing front methods, The Delaunay method, The respective algorithms with examples.

CFD for radiation heat transfer: Governing equations for radiation heat transfer, Popular radiation calculation techniques using CFD, The Monte-Carlo method, The discrete transfer method, Raytracing, The discrete ordinates method.

Learning Resources:

Text Books:

1. An introduction to computational fluid dynamics: the finite volume method, H.K. Versteeg, W. Malalasekera, Longman Group, England, 2007, 2nd Edition.
2. Computational Fluid Dynamics the Basics with Applications, Anderson. J.D(Jr), McGraw Hill Education, 2017.

Reference Books:

1. Computational Fluid Dynamics, Hoffman, K.A., and Chiang, S.T., Vol. I, II and III, Engineering Education System, 2000, 4th edition.
2. Computational Fluid Dynamics, Chung, T.J., Cambridge University Press, 2014, 2nd Edition.
3. Computational Fluid Mechanics and Heat Transfer, Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., CRC Press, 2013, 3rd Edition.

Online Resources:

1. Computational Fluid Dynamics using Finite Volume Method by Dr. Kameswararao Anupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
2. Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)
3. Computational Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105045/)

Course Code: ME5163	CONVECTIVE HEAT AND MASS TRANSFER	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the fundamental principles of convection heat and mass transfer
CO2	Formulate and solve convective heat transfer problems for internal and external flows
CO3	Analyze turbulent boundary layer flow problems
CO4	Apply the principles of mass transfer to solve complex problems
CO5	Understand the principles of convection in porous media

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	2		2
CO2	3		3	2		2
CO3	3	2	3	2		2
CO4	3		3	2		2
CO5	3		3	2		2

Syllabus:

Introduction: Course structure, Basics of Thermodynamics, Fluid mechanics and Heat transfer.

Fundamental Principles: Continuity, momentum and energy equations, Reynolds transport theorem, Second law of TD, Rules of Scale analysis, Concept of Heat line visualization.

Laminar forced convection: **External flows:** Boundary layer concept, velocity and thermal boundary layer, Governing equations, Similarity solutions, various wall heating conditions, Flow over sphere, wedge and stagnation flow.

Laminar forced convection: Internal flows: Fully developed laminar flow: Constant heat flux, Constant wall temperature, developing length.

External Natural convection: Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Boundary layer equations, Scale analysis, Low and high Prandtl number fluids, vertical walls, horizontal walls, sphere.

Internal Natural Convection: Natural convection in enclosures: isothermal and constant heat flux. Sidewalls, triangular enclosures, heated from below, inclined enclosures, annular space between horizontal cylinders.

Turbulent boundary layer flow: Boundary layer equations, mixing length model, flow over single cylinder, crossflow over array of cylinders, Natural convection along vertical walls, turbulent duct flow.

Mass transfer: Formulation of the Mass Transfer Problem using different Models, Application of Reynolds Flow Model to different problems involving simultaneous heat/mass transfer.

Convection in porous media: Basics of porous media, flow models (Darcy, Brinkmann, Forchheimer and Generalized non-Darcy model).

Learning Resources:

Text Books:

1. Convection Heat Transfer, Bejan, A., John Willey and Sons, New York, 2001.
2. Convective Heat and Mass Transfer, Ghiaasiaan, S.M., Cambridge, 2015.

Reference Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F. P. and De Witt, D. P., John Wiley and Sons, New York, 2006, 5th Edition.
2. Convective Heat and Mass Transfer, Kays, W. M. and Crawford, M. E., Tata McGraw Hill, 2017, 4th Edition.
3. Convective Heat Transfer, Louis, C. Burmeister, John Willey and Sons, New York, 2003.

Online Resources:

1. Convective Heat Transfer by Prof. Ajit K. Kolar (IIT Madras) and Dr. Arvind Pattamatta (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106170/)
2. NOC:Convective Heat Transfer by Prof. Saptarshi Basu (IISc Bangalore), NPTEL Course (Link: https://nptel.ac.in/courses/112/108/112108246/)
3. Convective Heat and Mass Transfer by Dr. Amaresh Dalal (IIT Guwahati), Prof. Gautam Biswas (IIT Kanpur) and Prof. Vijay K Dhir (UCLA), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104159/)

Course Code: ME5164	CONDUCTION AND RADIATION HEAT TRANSFER	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the physics of conduction and radiation heat transfer
CO2	Apply mathematical techniques to solve the 2-D and 3-D conduction problems analytically
CO3	Solve conduction and radiation heat transfer problems for industrial applications
CO4	Estimate radiative properties and analyze gray, non-gray, diffuse and non-diffuse surfaces
CO5	Understand the concepts of radiation heat transfer in participating medium

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	2
CO2	3	2	3	3	2	2
CO3	3	2	3	3	2	2
CO4	3	2	3	2	2	1
CO5	3	2	3	2	2	2

Syllabus:

Recapitulation of conduction heat transfer: Introduction to Conduction- Recapitulation: Steady and Transient conduction; Fins, Lumped parameter and semi-infinite solid approximations, Heisler and Grober charts; 3-D conduction, isotropic, orthotropic and anisotropic solids.

Analytical Methods: Analytical Methods- Mathematical formulations, analytical solutions, variation of parameters, integral method, periodic boundary conditions, Duhamels theorem and Greens function

Applications to Specific Problems: Stationary and moving heat sources and sinks. Moving boundary problems. Inverse heat conduction problems, freeze drying problems

Recapitulation of Radiation: Introduction to Radiation- Recapitulation: Radiative properties of opaque surfaces, Intensity, emissive power, radiosity, Planck's law, Wien's displacement law, Black and Gray surfaces, Emissivity, absorptivity, Spectral and directional variations, View factors.

Transparent, diffuse, gray surfaces: Enclosure with Transparent Medium- Enclosure analysis for diffuse-gray surfaces and non-diffuse, nongray surfaces, net radiation method.

Radiation in participating Medium: Enclosure with Participating Medium- Radiation in absorbing, emitting and scattering media. Absorption, scattering and extinction coefficients, Radiative transfer equation.

Learning Resources:

Text Books:

1. Conduction Heat Transfer, Dimos Poulikakos, Prentice-Hall, October 1993
2. Analytical Methods in Conduction Heat Transfer, G. Myers, Amch; 2nd edition (1998)
3. Heat Conduction, N. Ozisik, A Wiley - Interscience Publication, Johh Wiley & Sons, Inc., Newyork, 2nd Edition, 1993
4. Conduction Heat Transfer, Vedat S. Arpaci, Addison-Wesley Publishing Company, 2007

Reference Books:

1. Thermal Radiation Heat Transfer: R. Siegel and J. Howell, Taylor & Francis, CRC Press, 2001, 4th Edition.
2. Radiative Heat Transfer: M. F. Modest, Elsevier, Netherland, 2012, 3rd Edition.
3. Radiation Heat Transfer: E. M. Sparrow and R. D. Cess, Brooks Pub. Co., Hemisphere Publishing Corporation, 2007.

Online Resources:

1. Conduction And Radiation by Prof. C. Balaji (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106155/)

Course Code: ME5165	TWO-PHASE HEAT TRANSFER	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the fundamentals of two-phase flow and condensation
CO2	Analyze flow regimes with appropriate models
CO3	Analyze pool boiling and flow boiling
CO4	Measure parameters in multi-phase flow

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	2	1	2
CO2	3	1	3	3	2	1
CO3	3	2	3	3	2	1
CO4	3	1	3	2	1	2

Syllabus:

Hydrodynamics of two-phase flow: Introduction to multiphase flow, types and applications, Common terminologies, flow patterns and flow pattern maps. One dimensional steady homogeneous flow, Concept of choking and critical flow phenomena; The separated flow model for stratified and annular flow, General theory of drift flux model, Application of drift flux model to bubbly and slug flow, Pressure Drop in Two-Phase Flow, Brief Discussion on Critical Flow and Unsteady Flow. Measurement techniques for multiphase flow, void fraction and flow rate measurement.

Pool and flow boiling: Description and Classification of Boiling, Pool Boiling Curve, Nucleation and Dynamics of Single Bubbles, Heat Transfer Mechanisms in Nucleate Boiling, Nucleate Boiling Correlations, Hydrodynamic of Pool Boiling Process, Pool Boiling Crisis, Film Boiling Fundamentals, Flow Boiling, Forced-Flow Boiling Regimes, Nucleate Boiling in Flow, Subcooled Nucleate Flow Boiling, Saturated Nucleate Flow Boiling, Flow Boiling Correlations, Flow Boiling Crisis.

Condensation: Film and dropwise condensation.

Learning Resources:

Text Books:

1. Boiling Heat Transfer and Two-Phase Flow, L. S. Tong and Y. S. Tang, Taylor and Francis, 1997
2. Convective boiling and condensation, J. B. Collier, and J. R. Thome, Oxford Science Publications, 1994.

Reference Books:

1. Fundamentals of Multiphase Flow, C.E. Brennen, Cambridge University Press, New York, 2005.

Course Code: ME5166	DESIGN OF HEAT TRANSFER EQUIPMENT	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the physics and the mathematical treatment of typical heat exchangers.
CO2	Apply LMTD and Effectiveness - NTU methods in the design of heat exchangers
CO3	Design the shell and tube heat exchanger.
CO4	Apply the principles of boiling and condensation in the design of boilers and condensers
CO5	Design cooling towers from the principles of psychrometry

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	1	2		
CO2	3	2	2	2	2	3
CO3	3	2	2	3	2	2
CO4	3	2	3	3	2	3
CO5	3	2	2	3		2

Syllabus:

Introduction to Heat Exchangers: Definition, Applications, Various methods of classification of heat exchangers with examples.

Governing Equation for heat exchangers: Derivation from steady-state steady-flow considerations.

Mathematical treatment of Heat Exchangers: Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Ill-Effects of fouling, Numerical Problems.

Concept of Logarithmic Mean Temperature Difference: Expression for single-pass parallel-flow and single-pass counter flow heat exchangers – Derivation from first principles, Special Cases, LMTD for a single-pass cross-flow heat exchanger – Nusselt's approach, Chart solutions of Bowman et al. pertaining to LMTD analysis for various kinds of heat exchangers, Numerical Problems, Arithmetic Mean Temperature Difference [AMTD], Relation between AMTD and LMTD, Logical Contrast between AMTD and LMTD, LMTD of a single-pass heat exchanger with linearly varying overall heat transfer coefficient [U] along the length of the heat exchanger.

Concept of Effectiveness: Effectiveness-Number of Transfer Units Approach, Effectiveness of single-pass parallel-flow and counter-flow heat exchangers, Physical significance of NTU, Heat capacity ratio, Different special cases of the above approach, Chart solutions of Kays and London pertaining to Effectiveness-NTU approach, Numerical Problems.

Hair-Pin Heat Exchangers: Introduction to Counter-flow Double-pipe or Hair-Pin heat exchangers, Industrial versions of the same, Film coefficients in tubes and annuli, Pressure drop, Augmentation of performance of hair-pin heat exchangers, Series and Series-Parallel arrangements of hair-pin heat exchangers, Comprehensive Design Algorithm for hair-pin heat exchangers, Industrial standards, Numerical Problems.

Shell and Tube Heat Exchangers: Single-Pass, One shell-Two tube [1S-2T] and other heat exchangers, Industrial versions of the same, Classification and Nomenclature, Baffle arrangement, Types of Baffles, Tube arrangement, Types of tube pitch lay-outs, Shell and Tube side film coefficients, Pressure drop calculations, Numerical Problems.

Plate heat exchangers: Introduction, Mechanical Features - Plate pack and the frame, Plate types, Advantages and performance limits, Passes and flow arrangements, Heat transfer and pressure drop calculations, Numerical problems

Principles of Boilers and Condensers: Boiling, Fundamentals and Types of boiling – Pool boiling curve, Various empirical relations pertaining to boiling, Numerical problems on the above, Condensation – Classification and Contrast, Types of condensers, Nusselt's theory on laminar filmwise condensation, Empirical Refinements, Several empirical formulae, Numerical problems.

Cooling Towers: Cooling towers – basic principle of evaporative cooling, Psychrometry, fundamentals, Psychrometric chart, Psychrometric Processes, Classification of cooling towers, Numerical problems.

Learning Resources:

Text Books:

1. Compact Heat Exchangers, Kays, W. M. and London, A. L., McGraw – Hill, New York, 2nd Edition, 1998.
2. Fundamentals of Heat Exchanger Design, Shah, R. K. and Sekulic, D. P., John Wiley and Sons, New Jersey, 2003.

Reference Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F. P. and Dewitt, D. P., 7th Edition, John Wiley and Sons, New York, 2013.

Online Resources:

1. Heat Exchangers: Fundamentals And Design Analysis by Prof. Indranil Ghosh, IIT Kharagpur, NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105248/)

Course Code: ME5167	TURBULENT FLOWS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the origin, statistical nature and applications of turbulence.
CO2	Employ the statistical methods to derive Reynolds averaged Navier-Stokes (RANS) equations.
CO2	Analyze momentum and heat transport in free-shear and wall bounded flows through RANS equations
CO4	Derive the turbulence models and analyze various industrial complex flows in thermal applications.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2		2
CO2	3	1	3	2		2
CO3	3	1	3	3		2
CO4	3	1	3	3		2

Syllabus:

Introduction: The nature of turbulence, Consequences of Turbulence, Origin of turbulence, Examples of Laminar-Turbulent Transition, Turbulent diffusivity, Laminar and Turbulent Boundary layers, Length scales of turbulent flows, Turbulent flows in industrial applications.

Statistical description of turbulence: Random nature of turbulence, Characterization of random variables, Two-point correlation functions and spectra, Probability density functions and averaging.

Governing equations of Turbulent Transport: Continuum hypothesis, Eulerian and Lagrangian fields, Elements of Kinetic Theory of gases, Continuity, Momentum and Scalar transport equations, Role of Pressure, Rates of Strain and Rotation, Vorticity dynamics and vortex stretching, The Reynolds decomposition, Equations of Mean Flow (Momentum and Scalar transport), Reynolds Stresses, Gradient diffusion and Turbulent viscosity hypothesis, Estimation of Reynolds Stresses, Turbulent heat transfer.

The scales of turbulent motion: Energy Cascade and Kolmogorov Hypothesis, Fourier modes, Velocity Spectra, Spectral view of energy cascade, Limitations, Shortcomings and refinements

Free-shear flows: Plane shear flows in Turbulent wakes, jets and mixing layers, Streamwise and cross-stream momentum equations, Momentum integral and momentum thickness, turbulent energy budget for wakes, jets and mixing layers, Thermal plumes.

Wall-bounded flows: Turbulent boundary layers on smooth wall, Inertial sublayer, Core region, Logarithmic frictional law, Viscous sublayer, Turbulent flow in pipe, Experimental data on pipe flow, flow over rough surfaces, planetary boundary layers, Downstream development of turbulent boundary layers, Turbulent scalar transport in wall bounded flows.

Modelling and Simulation of turbulent flows: History of turbulence modelling, Reynolds-Averaged Navier Stokes Equations, The Closure Problem, Boussinesq Eddy-viscosity approximation, Mixing length hypothesis, Algebraic Models, One-equation and two-equation models, Application of various turbulence models to free shear flows and wall bounded flows, Near wall treatment, Direct Numerical Simulation (DNS), Large Eddy Simulation (LES) and related techniques.

Learning Resources:

Text Books:

1. Turbulent Flows, Stephen B. Pope, Cambridge University Press, 2000
2. Turbulent flows: Fundamentals, experiments and modeling, Biswas, G., and V. Eswaran, eds., CRC Press, 2002.

Reference Books:

1. A First Course in Turbulence, Hendrik Tennekes and John L. Lumley, MIT Press 1972
2. Turbulence: An Introduction for Scientists and Engineers, Peter Davidson, Cambridge University Press, Oxford University Press; 2015, Second Edition.

Online Resources:

1. Introduction to Turbulence by Prof. Gautam Biswas (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104120/)
2. Introduction to Turbulent Flows and their prediction by Prof. E.G. Tulapurkara (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106060/)

Course Code: ME5168	INDUSTRIAL HEAT TRANSFER	Credits 3-0-0: 3

Prerequisites: Heat Transfer, Fluid mechanics

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understanding the basics for single and two phase cooling and insulation
CO2	Analysis of various heat transfer techniques and devices
CO3	Apply thermo-fluidic principles to design cooling techniques and devices
CO4	Design of experimental systems for air and liquid cooling

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	1	2
CO2	3	1	3	3	2	1
CO3	3	2	3	3	2	1
CO4	3	2	3	3	2	1

Syllabus:

Introduction: Introduction to requirement of heat transfer alteration. Overview of heat generation components and processes in electric vehicle, gas turbine, electronic and electrical systems, Review of conservation equations.

Air cooling: Active and passive methods, heat transfer and pressure drop for flow through channels, jet impingement, film cooling, wall jet etc. Measurement of temperature, velocity and pressure. Application in industry, Design of experimental systems for air cooling applications. Case study of air cooling in Gas turbines.

Liquid cooling: Basics of microfluidics – pressure driven and surface tension driven flows, key components of liquid cooled systems, types of fluids, thermal design of liquid cooled system, Case study of liquid cooling in electronic systems.

Two phase cooling: Two phase flow basics. Heat pipe – working, mathematical modelling, types of heat pipe. PCM – introduction, modelling, types. Mini-channel two phase flow. Application in industry.

Insulation: Heat loss calculations, critical diameter, hot insulation, cold insulation, insulation materials and types, application in industry,

Learning Resources:

Text Books:

1. Gas Turbine Heat Transfer and Cooling Technology, Je-Chin Han, Sandip Dutta, and Srinath Ekkad, CRC Press (2000)
2. Thermal Design of Liquid Cooled Microelectronic Equipment, Lian-Tuu Yeh, ASME Press (2019)

Reference Books:

1. Heat Pipe Design and Technology- A Practical Approach, Bahman Zohuri, CRC Press (2011)

Online Resources:

1. Two Phase Flow and Heat Transfer by Prof. Arup Kumar Das (IIT Roorkee), NPTEL Course (Link: https://nptel.ac.in/courses/112/107/112107207/)
2. Microfluidics by Dr. Ashis Kumar Sen (IIT Madras), NPTEL Course, Link: https://nptel.ac.in/courses/112/106/112106169/)

Course Code: ME5169	ROCKET PROPULSION	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the principles of Rocket propulsion
CO2	Analyze the performance of Rocket components
CO3	Select suitable solid, liquid and hybrid propellants for specific application
CO4	Evaluate the performance parameters of Rocket engines

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	2	1
CO2	2	2	3	3	2	1
CO3	2	2	3	3	2	1
CO4	2	2	3	3	2	1

Syllabus:

MOTION IN SPACE: REQUIREMENT FOR ORBIT: Motion of Bodies in space, Parameters describing motion of bodies, Newton's Laws of motion, Universal law of gravitational force, Gravitational field, Requirements of motion in space, Geosynchronous and geostationary orbits, Eccentricity and inclination of orbits, Energy and velocity requirements to reach a particular orbit, Escape velocity, Freely falling bodies, Means of providing the required velocities.

THEORY OF ROCKET PROPULSION: Illustration by example of motion of sled initially at rest, Motion of giant squid in deep seas, Rocket principle and rocket equation, Mass ratio of rocket, Desirable parameters of rocket, Rocket having small propellant mass fraction, Propulsive efficiency of rocket, Performance parameters of rocket, Staging and clustering of rockets, Classification of rockets.

ROCKET NOZZLE AND PERFORMANCE: Expansion of gas from a high pressure chamber, Shape of the nozzle, Nozzle area ratio, Performance loss in conical nozzle, Flow separation in nozzles, Contour or bell nozzles, Unconventional nozzles, Mass flow rates and characteristics velocity, Thrust developed by a rocket; Thrust coefficient, Efficiencies, Specific impulse and correlation with C* and CF, General Trends.

CHEMICAL PROPELLANTS: Small value of molecular mass and specific heat ratio, energy release during combustion of products, Criterion for choices of propellants, Solid propellants, Liquid propellants, Hybrid propellants.

SOLID PROPELLANTS ROCKETS: Mechanism of burning and burn rate, Choice of index n for stable operation of solid propellant rockets, Propellant grain configuration, Ignition of solid propellant rockets, Pressure decay in chamber after propellant burnout, Action time and burn time, Factors influencing burn rate, Components of a solid propellant rocket.

LIQUID PROPELLANT ROCKETS: Propellant feed system, Thrust chamber, Performance and choice of feed system cycle, Turbo pumps, Gas requirements for draining of propellants from storage tanks, Draining under microgravity condition, Trends in development of liquid propellant rockets.

HYBRID ROCKETS: Working principle, Choice of fuels and oxidizer, Future of hybrid rockets

Learning Resources:

Text Books:

1. Rocket Propulsion, Ramamurthi K., Macmillan Publishers India Ltd., 2010
2. Gas Turbine Theory, 6th Edition, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson PrenticeHall, 2008.

Reference Books:

1. Introduction to Rocket Technology, Feedesiev, V. I. and Siniarev, G. B., Academic Press, New York, 2000.
2. Rocket Propulsion, Barrere, M., Elsevier Pub. Co., 1990.
3. Rocket Propulsion Elements, Sutton, G. P., John Wiley, New York, 1993.

Online Resources:

1. NOC:Rocket Propulsion by Prof. K. Ramamurthi and Prof. S. Varunkumar (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106082/)
2. NOC:Introduction to Rocket Propulsion by Dr. D.P. Mishra (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/101/104/101104078/)

Course Code: ME5170	ESSENTIALS OF ENTREPRENEURSHIP	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand entrepreneurship and entrepreneurial process and its significance in economic development
CO2	Develop an idea of the support structure and promotional agencies assisting ethical entrepreneurship
CO3	Identify entrepreneurial opportunities, support and resource requirements to launch a new venture within legal and formal framework
CO4	Develop a framework for technical, economic and financial feasibility to prepare a written business plan
CO5	Understand the stages of establishment, growth, barriers, and causes of sickness in industry to initiate appropriate strategies for operation, stabilization and growth

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	1			2
CO2	2	3	3			3
CO3	1	2	1		2	2
CO4	2	3	3		2	3
CO5	3	2	1		2	3

Syllabus:

Entrepreneur and Entrepreneurship: Introduction; Entrepreneur and Entrepreneurship; Role of entrepreneurship in economic development; Entrepreneurial competencies and motivation; EDP models, Institutional Interface for Small Scale Industry/Enterprises.

Business Idea generation: Opportunity Scanning and Identification; Creativity and product development process; The technology challenge – Innovation in a knowledge-based economy, sources of innovation pulses – Internal and external; Drucker's 7 sources of innovation impulses, General innovation tools, role of innovation during venture growth; Market survey and assessment; choice of technology and selection of site.

Planning a Start-up Enterprise: Forms of business organization/ ownership; Financing new enterprises – sources of capital for early-stage technology companies; Techno Economic Feasibility Assessment; Preparation of Business Plan for grants, loans and venture capital.

Operational Issues for new enterprises: Financial management issues; Operational/ project management issues in SSE; Marketing management issues in SSE; Relevant business and industrial Laws.

Performance appraisal and growth strategies: Strategies to anticipate and avoid pitfalls associated with launching and leading a technology venture; Management performance assessment and control; Causes of Sickness in SSI, Strategies for Stabilization and Growth.

Learning Resources:

Text Books:

1. Technology Ventures: From Ideas to Enterprise, Byers, Dorf, and Nelson, McGraw Hill. ISBN-13: 978-0073380186., 2010
2. Entrepreneurship: Successfully Launching New Ventures, Bruce R Barringer and R Duane Ireland, Pearson Edu., 2013 3rd ed.
3. Entrepreneurial Development, S.S. Khanka, S Chand & Company Ltd., 2012, 4th ed.
4. Entrepreneurship: A South-Asian Perspective, D.F. Kuratko and T.V. Rao, Cengage Learning, 2013.

Reference Books:

1. A Handbook for New Entrepreneurs, Entrepreneurship Development Institute of India, Ahmedabad, 1988.
2. The practice of entrepreneurship, G.G. Meredith, R.E. Nelson & P.A. Neck, ILO, 1982
3. Management of Small-Scale Enterprises, Dr. Vasant Desai, Himalaya Publishing House, 2004.

Course Code: ME5171	COMBUSTION AND EMISSION CONTROL	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the concepts of combustion phenomena in IC Engines and Gas Turbines.
CO2	Apply the knowledge of adiabatic flame temperature in the design of combustion devices.
CO3	Identify the phenomenon of flame stabilization in laminar and turbulent flames.
CO4	Analyse the possible harmful emissions and measure as per the legislation standards.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	3	2	2
CO2	2	1	2	2	1	2
CO3	2	1	2	2	1	2
CO4	2	2	1	1	2	2

Syllabus:

Combustion Principles: Combustion – Combustion equations, heat of combustion - Theoretical flame temperature – chemical equilibrium and Dissociation -Theories of Combustion - Flammability Limits - Reaction rates – Laminar and Turbulent Flame Propagation in Engines. Introduction to spray formation and characterization.

Combustion in S.I. Engines: Stages of combustion, normal and abnormal combustion, knocking, Variables affecting Knock, Features and design consideration of combustion chambers. Flame structure and speed, Cyclic variations, Lean burn combustion, Stratified charge combustion systems. Heat release correlations.

Combustion In C.I. Engines: Stages of combustion, vaporization of fuel droplets and spray formation, air motion, swirl measurement, knock and engine variables, Features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion, Direct and indirect injection systems.

Combustion in Gas Turbines: Flame stability, Re-circulation zone and requirements - Combustion chamber configurations, Cooling, Materials.

Pollutant Emissions from IC Engines: Introduction to clean air, Pollutants from SI and CI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen (NO-NOX) and Particulate Matter, Mechanism of formation of pollutants, Factors affecting pollutant formation. Measurement of engine emissions-instrumentation, Pollution Control Strategies, Emission norms-EURO and Bharat stage norms. Effect of emissions on environment and human beings. Brief treatment on harmful emissions from Gas Turbines, Gas turbine-NOx control (DLE - Dry Low Emission).

Control Techniques for Reduction of Harmful Emissions from IC Engines: Emission control measures for SI and CI engines and gas turbines. Design modifications – Optimization of operating factors – Fuel modification – Evaporative emission control - Exhaust gas recirculation – SCR – Fumigation – Secondary Air injection – PCV system – Particulate Traps-Thermal reactors – Catalytic converters – Catalysts – Use of unleaded petrol-brief treatment.

Test Procedure, Instrumentation & Emission Measurement: Definition of Vehicle Driving Cycle-Test procedures INDIAN DRIVING CYCLE (IDC) – ECE Test cycle – FTP Test cycle – NDIR analyser – Flame ionization detector – Chemiluminescent analyser – Continuous Volume Sampling-Dilution tunnel – Gas chromatograph – Smoke meters.

Learning Resources:

Text Books:

1. Internal Combustion Engine Fundamentals, John.B. Heywood , McGraw Hill Co., 2018, II Edition.
2. Gas Turbine Theory, Cohen, H, Rogers, G, E.C, and Saravanamuttoo, H.I.H., Pearson, Pearson, 2019,7th Edition.

Reference Books:

1. Introduction to Combustion, Stephen, R. Turns., McGraw Hill, 2005.
2. Engine Emissions Fundamentals and Advances in Control, B.P. Pundir B P Narosa Publications. 2017, 2/E
3. Combustion: Physical and Chemical Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation Warnatz, Ulrich Maas and Robert W. Dibble, Springer, 2012.

Online Resources:

1. Emission Standards, www.dieselnet.com
2. Automotive Emission Test Procedures, www.araiindia.com

Course Code: ME5172	SOLAR ENERGY SYSTEMS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the fundamentals of solar energy and its conversion techniques
CO2	Estimate solar energy through radiation principles
CO3	Design thermal and electrical energy storage systems
CO4	Design solar thermal and photovoltaic systems
CO5	Understand solar passive architecture

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	2	3	2
CO2	2	2	1	2	3	1
CO3	3	2	3	3	3	2
CO4	3	2	3	3	3	2
CO5	2	2	2	2	2	2

Syllabus:

INTRODUCTION: Overview of the course; Examination and Evaluation patterns; Basic concepts of energy; Introduction to Renewable Energy Technologies; Energy and Environment: Global warming, acid rains, Depletion of ozone layer; Global and Indian Scenario of renewable energy sources.

ENERGY STORAGE: Thermal – sensible and latent heat storage materials, electrical – lead acid and lithium ion batteries, design and analysis of thermal and electrical energy storage systems.

SOLAR RADIATION AND COLLECTORS: Solar angles - day length, angle of incidence on tilted surface – Sun path diagrams - shadow determination – extraterrestrial characteristics - measurement and estimation on horizontal and tilted surfaces – flat plate collector thermal analysis - heat capacity effect - testing methods-evacuated tubular collectors - concentrator collectors – classification - design and performance parameters - tracking systems –compound parabolic concentrators - parabolic trough concentrators - concentrators with point focus - Heliostats – performance of the collectors.

APPLICATIONS OF SOLAR THERMAL TECHNOLOGY: Principle of working, types - design and operation of - solar heating and cooling systems - solar water heaters – thermal storage systems – solar still – solar cooker – domestic, community – solar pond – solar drying.

SOLAR PV FUNDAMENTALS: Semiconductor – properties - energy levels - basic equations of semiconductor devices physics. Solar cells - p-n junction: homo and hetro junctions – metal semiconductor interface - dark and illumination characteristics - figure of merits of solar cell - efficiency limits - variation of efficiency. with band-gap and temperature - efficiency measurements - high efficiency cells - preparation of metallurgical, electronic and solar grade

Silicon - production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method - Design of a complete silicon – GaAs- InP solar cell - high efficiency III-V, II- VI multi junction solar cell; a-Si-H based solar cells quantum well solar cell - thermophotovoltaics.

SOLAR PHOTOVOLTAIC SYSTEM DESIGN AND APPLICATIONS: Solar cell array system analysis and performance prediction- Shadow analysis: reliability - solar cell array design concepts - PV system design - design process and optimization - detailed array design - storage autonomy - voltage regulation - maximum tracking - use of computers in array design - quick sizing method – array protection and trouble shooting - centralized and decentralized SPV systems – stand alone - hybrid and grid connected system - System installation - operation and maintenances - field experience - PV market analysis and economics of SPV systems.

SOLAR PASSIVE ARCHITECTURE: Thermal comfort - heat transmission in buildings- bioclimatic classification – passive heating concepts: direct heat gain - indirect heat gain - isolated gain and sunspaces - passive cooling concepts: evaporative cooling - radiative cooling - application of wind, water and earth for cooling; shading - paints and cavity walls for cooling – roof radiation traps - earth air-tunnel. – energy efficient landscape design – thermal comfort – concept of solar temperature and its significance - calculation of instantaneous heat gain through building envelope.

Learning Resources:

Text Books:

1. Solar Energy, Sukhatme S P and Nayak J K, Tata McGraw Hill, 2017, 4th Edition.
2. Solar Engineering of Thermal Processes, Duffie, J. A. and Beckman, W. A., John Wiley, 2013, 4th Edition.
3. Solar Energy: Fundamentals & Applications, Garg H P., Prakash J., Tata McGraw Hill, 2017, 1st revised edition.
4. Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube, Academic Press, 1983.

Reference Books:

1. Handbook of Solar Energy - Theory, Analysis and Applications, Tiwari G.N.., Arvind Tiwari and Shyam, Springer, 2016.
2. Principles of Solar Engineering, Goswami, D.Y., Kreider, J. F. and Francis., 2000.

Online Resources

1. Solar Engineering Technology by Prof. V.V. Satyamurty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105051/)
2. Solar Photovoltaics: Fundamentals, Technology and Applications by Prof. Soumitra Satapathi (IIT Roorkee), NPTEL Course (Link: https://nptel.ac.in/courses/115/107/115107116/)

Course Code: ME5173	ENERGY CONSERVATION & WASTE HEAT RECOVERY	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify and assess the energy conservation opportunities in different thermal systems
CO2	Outline the methods of energy storage and identify the appropriate methods of energy storage for specific applications
CO3	Understand the energy conversion techniques
CO4	Evaluate the performance of heat recovery system for industrial applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	1	3	3
CO2	1	1	3	1	3	3
CO3	1	1	3	1	3	3
CO4	2	1	3	3	3	3

Syllabus:

INTRODUCTION: Overview of the course; Examination and Evaluation patterns; Basic concepts of energy; Energy and Environment: Global warming, acid rains.

ENERGY STORAGE: Need for energy storage, thermal, electrical, magnetic and chemical energy storage systems.

FUEL COMBUSTION AND GASIFICATION: Fuel Composition and Heating Value; Combustion stoichiometry and calculation; Gaseous product combustion; Coal gasification; Gasification process and gasifiers.

ENERGY CONSERVATION: Introduction; Principles of thermodynamics: Rankine and Brayton cycles; enhancement of efficiency by reheat, regenerative, intercooling; topping, bottoming and combined cycles; concept of tri generation; Boilers :Types, Performance evaluation of boilers, Boiler Water Treatment and blow down, Introduction to FBC Boilers, Mechanism and Operational Features of FBC, Retrofitting FBC system to conventional boilers.

WASTE HEAT RECOVERY: Classification, Advantages and applications, Selection criteria for waste heat recovery technologies, waste heat recovery devices: recuperators, regenerators, economizers, plate heat exchangers, thermic fluid heaters, Waste heat boilers-design aspects; fluidized bed heat exchangers, heat pipe exchangers, heat pumps; Saving potential.

Learning Resources:

Text Books:

1. Energy Storage, J Jensen, Elsevier, 2013

Reference Books:

1. Lee SS EDS, Seagate Subrata, Waste Heat Utilization and Management, Hemisphere, Washington, 1983.
2. Advance Energy Systems, Nikolai V. Khartchenko, Taylor and Francis Publishing, 2013, 2nd Edition.
3. Powerplant Technology, M.M.El-Wakil, Tata McGraw Hill, 20103, Indian Edition

Online Resources:

1. Bureau of Energy Standards Official Website, Link: https://www.beeindia.gov.in

Course Code: ME5174	FLUID AND HEAT TRANSPORT THROUGH POROUS MEDIA	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Comprehend the various terminologies and mathematical modelling aspects of porous media
CO2	Calculate the heat transfer involving forced convection through porous media
CO3	Solve the heat transfer problems comprising of free convection through porous media
CO4	Compute the radiation heat transfer through porous media

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	2
CO3	3	1	3	3	2	2
CO4	3	1	3	3	2	2

Syllabus:

Basic Concepts: Porous Medium, Porosity, Percolation, and Tortuosity .Volume Averaging Procedure

Heat Conduction in Porous Medium: Introduction, First Law of Thermodynamics, Second Law of Thermodynamics, Effective Stagnant Thermal Conductivity, Thermal Dispersion, Local Thermal Non-Equilibrium Model, Transient Heat Conduction in Porous Medium

Fluid Flow through a Porous Medium: Physics of Flow through Porous Media, Extensions of the HDD Model, Permeability and Form Coefficient, Flow Transition

Forced Convection through Porous Medium: Energy Equation with Flow Forced Convection in Porous Medium over a Flat Plate, Forced Convection in Porous Medium Channel, Heat Transfer Enhancement Aspects, Other Forced Convection Configurations, Viscous Dissipation Effects

Natural Convection through Porous Medium: Natural Convection Boundary Layers, Natural Convection with Vertical Thermal Gradient Natural Convection with Horizontal Thermal Gradient, Non-Darcy, LTNE and Heat Generation Effects, Viscous Dissipation

Radiation Heat Transfer in Porous Medium: The Radiative Transfer Equation (RTE), The Energy Equation with Radiation Radiative Property Measurement, Solving the RTE Coupling of RTE with other Heat Transfer Modes

Advanced Topics: Phase Change in Porous Media, Variable Viscosity Porous Medium Flows, Flow and Convection in Bi-disperse Porous Media, Two-phase Flow through Porous Media Combustion in Inert Porous Media

Learning Resources:

Text Books:

1. Essentials of Heat and Fluid Flow in Porous Media, Arunn Narasimhan, CRC Press, 2012, 1st Edition
2. Principles of Heat Transfer in Porous Media, M. Kaviany, Springer-Verlag New York Inc., 1995, 2nd Edition

Reference Books:

1. Convection in Porous Media, Adrian Bejan and Donald A. Nield, Springer-Verlag New York, 2013, 4th Edition
2. Transport Phenomena in Porous Media, D.B. Ingham, I. Pop (Eds.), Pergamon Press, Danvers, 1998, 1st Edition
3. Handbook of Porous Media, K. Vafai (Ed.), Marcel Dekker, 2000, 2nd Edition
4. Dynamics of fluids in porous media, Jacob Bear, Dover Publications Inc.,1989

Online Resources:

1. Course on Flow through Porous media by Prof. Somenath Ganguly, NPTEL Course [Link: https://nptel.ac.in/courses/103/105/103105160/#]

Course Code: ME5561	FUEL CELL TECHNOLOGY	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand fuel cell fundamentals
CO2	Analyse the performance of PEM fuel cell system
CO3	Demonstrate the operation of different fuel cells
CO4	Apply the modelling techniques for fuel cell systems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	2	2	1
CO2	2	2	2	3	3	2
CO3	1	2	3	3	3	1
CO4	1	2	3	3	2	1

Syllabus:

Overview of Fuel Cells: Description of fuel cell, brief history, classification, working principle, Fuel cell basic chemistry and thermodynamics of fuel cell and performance.

Fuel Cell Thermodynamics: Thermodynamic Potentials, Heat Potential of a Fuel: Enthalpy of reaction, Reaction Enthalpies, Work Potential of a Fuel: Gibbs Free Energy, Relationship between Gibbs Free Energy and Electrical Work, Computing Reversible Voltages, Reversible Voltage Variation with Temperature, Reversible Voltage Variation with pressure, Reversible Voltage Variation with concentration: Nernst Equation, Fuel Cell Efficiency-Ideal and real fuel cell efficiency.

Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents. **Fuel Cell Modeling:** A Basic Fuel Cell Model, 1-D PEM Fuel Cell Model.

Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others. hydrogen generation and storage; limitations, recent advances.

Overview of fuel cell types: Phosphoric acid fuel cell (PAFC), Polymer electrolyte membrane fuel cell (PEMFC), Alkaline fuel cell (AFC), Molten carbonate fuel cell (MCFC), Solid-oxide fuel cell (SOFC) and other fuel cells.

PEM Fuel cell components: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, flow field plate design, Fuel cell operating conditions: pressure, temperature, flow rates, humidity. **Direct methanol**

fuel cell, active and passive DMFC, methanol cross over and techniques to reduce, current collectors.

Fuel Cell Vehicles: Basic of fuel cell vehicle, Fuel cell hybrid vehicles, etc.

Main components of solid-oxide fuel cells, Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modelling.
Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal , Using renewable fuels for SOFCs.

Learning Resources:

Text Books:

1. Fuel Cell Fundamentals, Ryan O′Hayre, Suk-Won Cha Whitney Colella, second edition, John Wiley & Sons, 2018.
2. PEM Fuel Cells: Theory and Practice, Franno. Barbir, 2nd Ed. Elsevier/Academic Press, 2013.

Reference Books:

1. Fuel Cells and Their Applications, Karl Kordesch & Gunter Simader, VCH Publishers,2001.
2. Fuel Cell Technology Hand Book, Hoogers G., CRC Press, 2010.

Course Code: ME5564	HYBRID ELECTRIC VEHICLES	Credits 3-0-0: 3

Prerequisites: Nil

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the need for hybrid electric vehicles and classify based on configuration
CO2	Identify power sources for hybrid electric vehicles
CO3	Analyse plug-in hybrid systems with different energy storage devices.
CO4	Evaluate the HEV configurations with battery, hybrid and fuel cell electric vehicles

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	3	2
CO2	1	2	3	3	3	2
CO3	1	2	3	3	3	1
CO4	2	1	2	2	2	1

Syllabus:

Introduction: Sustainable Transportation - Population, Energy, and Transportation - Environment - Economic Growth – Emissions regulations and norms- impact of modern drive-trains on energy supplies-New Fuel Economy Requirement Emergence of Electric Vehicles- Basics of the EV - Constituents of an EV -Vehicle and Propulsion Loads.

HEV Fundamentals: Classification- Hybridization of the Automobile-Mild Hybrids, Full Hybrids, Plug-In Hybrids and Electric Vehicles with Range Extender Hybrids- Architectures of HEVs - Series HEVs Parallel HEVs - Series–Parallel HEVs - Complex HEVs - Diesel and other Hybrids - Other Approaches to Vehicle Hybridization Basics of the HEV-Importance of HEV-Constituents of an HEV –Vehicle Model - Vehicle Performance - HEV Powertrain Component Sizing - Series Hybrid Vehicle - Parallel Hybrid Vehicle - Electrically Peaking Hybrid Concept - Gradeability Requirement -Selection of Gear Ratio from ICE to Wheel - Wheel Slip Dynamics.

Plug-In Hybrid Electric Vehicles: Basics of Plug-In Hybrid Electric Vehicle (PHEV) - Constituents of a PHEV - Comparison of HEV and PHEV - Basics of Fuel Cell Vehicles (FCVs) - Constituents of a FCV-Some Issues Related to Fuel Cells-Introduction to PHEVs - PHEVs and EREVs - Blended PHEVs - Electricity for PHEV Use -PHEV Architectures - Equivalent Electric Range of Blended PHEVs - Fuel Economy of PHEVs - Well-to-Wheel Efficiency - PHEV Fuel Economy - Utility Factor - Power Management of PHEVs -Vehicle-to-Grid Technology(V2G) - PHEV Battery Charging - Impact of G2V - The Concept of V2G- Advantages of V2G - Case Studies of V2G.

Electric Machines and Drives in HEVs: Introduction - Induction Motor Drives - Principle of Induction Motors - Equivalent Circuit of Induction Motor - Speed Control of Induction Machine

- Variable Frequency, Variable Voltage Control of Induction Motors - Efficiency and Losses of Induction Machine - Permanent Magnet Motor Drives - Basic Configuration of PM Motors - Basic Principle and Operation of PM Motors - Unsaturated Motor -Saturated Motor.

Electric Energy Sources and Storage Devices: - Introduction - Characterization of Batteries - Battery Capacity - Energy Stored in a Battery - State of Charge in Battery (SOC) and Measurement of SOC - SOC Determination - Direct Measurement - Amp-hr Based Measurement - Some Better Methods - Initialization Process - Depth of Discharge (DOD) of a Battery - Specific Power and Energy Density - Ampere-Hour (Charge and Discharge) Efficiency - Number of Deep Cycles and Battery Life - Some Practical Issues About Batteries and Battery Life- Battery Management Implementation - Comparison of Energy Storage Technologies.

Fundamentals of Regenerative Braking: Braking Energy Consumed in Urban Driving - Braking Energy versus Vehicle Speed - Braking Energy versus Braking Power
Braking Power versus Vehicle Speed - Braking Energy versus Vehicle Deceleration Rate - Braking Energy on Front and Rear Axles - Brake System of EV, HEV, and FCV.

Special Hybrid Vehicles: Brief Introduction of Hydraulic Hybrid Vehicles - Regenerative Braking in HHVs-Off-Road HEVs - Hybrid Excavators - Hybrid Excavator Design Considerations - Diesel HEVs Electric or Hybrid Ships- Locomotives.

Learning Resources:

Text Books:

1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.
2. Hybrid Electric Vehicles Principles and Applications with Practical Perspectives, Chris Mi, M. Abul Masrur John Wiley & Sons, Inc.,2018, II Edition.

Reference Books:

1. Electric vehicle technology explained, John Lowry and James Larmine, John Wiley and Sons, 2012.
2. Electric and Hybrid Vehicles: Design Fundamentals, Iqbal Hussein, CRC Press, 2003.

Online Resources:

1. Introduction to Hybrid and Electric vehicles by Dr. Praveen Kumar and Prof. S. Majhi (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/108/103/108103009/)

Course Code: ME5469	OPTIMIZATION METHODS FOR ENGINEERING DESIGN	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Formulate a design task as an optimization problem
CO2	Identify constrained and unconstrained optimization problems and solve using corresponding methods
CO3	Solve discontinuous optimization problems using special methods
CO4	Solve nonlinear optimization problems with evolutionary methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	1	2
CO2	2	2	3	3	2	2
CO3	3		3	3	3	2
CO4	3		3	3	3	2

Syllabus:

Introduction to Optimization in Design: Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

Multiple-variable Optimization: Optimal criteria, Direct search methods (Box's, Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, Sensitivity analysis, Direct search methods for constrained optimization, quadratic programming, GRG method, Formulation and Case studies.

Specialized algorithms: Integer programming (Penalty function and branch-and- bound method), Geometric programming.

Evolutionary Optimization algorithm: Genetic algorithms, simulated annealing, Anti-colony optimization, Particle swarm optimization.

Multi-objective Optimization: Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

Case studies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

Learning Resources:

1. Introduction to Optimum Design, Jasbir Arora, Academic Press, 2004
2. Optimization For Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, 2004.
3. Multi-Objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, Wiley, 2001.

Course Code: ME5368	INDUSTRY 4.o and IIoT	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Explore how Industry 4.0 will change the current manufacturing technologies and processes by digitizing the value chain
CO2	Understand the drivers and enablers of Industry 4.0
CO3	Learn about various IIoT-related protocols
CO4	Build simple IIoT Systems using Arduino and Raspberry Pi

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	1	2	
CO2	2		2	2	1	
CO3	2		3	3		
CO4			3	3	1	2

Syllabus:

Introduction to Industry 4.0: Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Mass Customization, Smart and Connected Business Perspective, Smart Factories, Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.

Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

IIoT Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. Case Studies: IoT case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Learning Resources:

Text Books:

1. Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy,

Anandarup Mukherjee, CRC Press, 2020.
2. A Hands on Approach”, Vijay Madisetti, Arshdeep Bahga, Ïnternet of Things, University Press, 2009.
3. Introduction to Internet of Things: A practical Approach”, Dr. SRN Reddy, Rachit Thukral and Manasi Mishra, ETI Labs,2010
4. The Internet of Things: Enabling Technologies, Platforms, and Use Cases”, Pethuru Raj and Anupama C. Raman, CRC Press, 2012
5. Designing the Internet of Things”, Adrian McEwen, Wiley, 2015

Reference Books:

1. Internet of Things: Architecture and Design, Raj Kamal, McGraw Hill., 2005.
2. Getting Started with the Internet of Things, Cuno Pfister, O Reilly Media, 2007.

Online Resources:

1. NOC:Introduction to internet of things by Prof. Sudip Misra (IIT Kharagpur), NPTEL Course [Link: https://nptel.ac.in/courses/106/105/106105166/]

Course Code: ME5370	PROJECT MANAGEMENT	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand the importance of projects and its phases.
CO2	Analyze projects from marketing, operational and financial perspectives.
CO3	Evaluate projects based on discount and non-discount methods.
CO4	Develop network diagrams for planning and execution of a given project.
CO5	Apply crashing procedures for time and cost optimization.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		2	2		2
CO2	3	1	2	2		2
CO3	2	1	2			2
CO4	2	1	2	2	2	2
CO5	2	1	2	2		2

Syllabus:

Introduction: Introduction to Project Management, History of Project Management, Project Life Cycle.

Project Analysis: Facets of Project Analysis, Strategy and Resource Allocation, Market and Demand Analysis, Technical Analysis, Economic and Ecological Analysis.

Financial Analysis: Financial Estimates and Projections, Investment Criteria, Financing of Projects.

Network Methods in PM: Origin of Network Techniques, AON and AOA differentiation, CPM network, PERT network, other network models.

Optimization in PM: Time and Cost trade-off in CPM, Crashing procedure, Scheduling when resources are limited.

Project Risk Management: Scope Management, Work Breakdown Structure, Earned Value Management, Project Risk Management.

Learning Resources:

Text Books:

1. Project: A Planning Analysis, Prasanna Chandra, Tata McGraw Hill Book Company, New Delhi, 4th Edition,2009.
2. Project Management, Cleland, Gray and Laudon, Tata McGraw Hill Book Company, New Delhi, 3rd Edition, 2007.
3. Larson Project Management , Clifford F. Gray, Gautam V. Desai, Erik W., Tata McGraw-Hill Education, 2010

Course Code: ME5371	ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR MECHANICAL SYSTEMS	Credits 3-0-0: 3

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand the core concepts of Mechanical Systems in the context of Industry 4.o
CO2	Apply AI, ML and Deep Learning concepts on Various Mechanical Systems
CO3	Apply the statistical and optimization techniques on Mechanical Systems
CO4	Evaluate the Mechanical System performance using simulation and experimental analysis

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3		3	3
CO2			3	3		3
CO3	3	3	3	3		3
CO4		3		3	3	3

Syllabus:

Introduction to Mechanical Systems evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.

Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, centre limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.

Artificial Intelligence: Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.

Machine Learning: Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.

Introduction to Raspberry Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes -

Simulink, Mechanical Systems implementation: From features to software components, Mapping software components to ECUs.

Learning Resources

Text Books:

1. Rajkumar, Dionisio De Niz ,and Mark Klein, Cyber-Physical Systems, Wesley Professional.
2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
3. Robert Levine et al., “A Comprehensive guide to AI and Expert Systems”,McGraw Hill Inc, 1986.
4. E. A. Lee and S. A. Seshia, “Introduction to Embedded Systems: A Cyber-Physical Systems Approach”, 2011.
5. C. Cassandras, S. Lafortune, “Introduction to Discrete Event Systems”, Springer 2007.
6. Constance Heitmeyer and Dino Mandrioli, “Formal methods for real-time computing”, Wiley publisher, 1996.
7. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.

Course Code: ME6147	COMPREHENSIVE VIVA - VOCE	Credits 02

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Comprehend the knowledge gained in the course work.
CO2	Identify principles of working of thermal energy systems.
CO3	Demonstrate the ability in problem solving and to communicate effectively.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	2		3
CO2	3		3	3	2	3
CO3	3		3	3	3	3

Course Code: ME6149	DISSERTATION PART - A	Credits 12

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify a topic in advanced areas of Thermal Engineering.
CO2	Review literature to identify gaps and define objectives and scope of the work.
CO3	Employ the ideas from literature and develop research methodology.
CO4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	1		3
CO2	3	2	3	1		3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3

M. Tech Dissertation Rubric Analysis:

Task	Description
I	Selection of Topic
II	Literature Survey
III	Defining the Objectives and Solution Methodology
IV	Performance of the Task
V	Dissertation Preparation
VI	Review (Presentation & Understanding)
VII	Viva-Voce
VIII	Publications /Possibility of publication

Task-CO Mapping:

Task (% Weightage)	CO1	CO2	CO3	CO4
I (10%)	X			
II (20%)		X		
III (30%)			X	
IV (40%)				X

Course Code: ME6199	DISSERTATION PART - B	Credits 20

Prerequisites: NIL

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Identify the materials and methods for carrying out experiments/develop a code.
CO2	Execute the research methodology with a concern for society, environment and ethics.
CO3	Analyse, discuss and justify the results/trends and draw valid conclusions.
CO4	Prepare the report as per recommended format and present the work orally adhering to stipulated time.
CO5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3	3	2	3
CO2	2		3	3	2	3
CO3	3		3	3	2	3
CO4	3	3	3	3	3	3
CO5	3	3	3			3

M. Tech Dissertation Rubric Analysis:

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IV	Performance of the Task
V	Dissertation Preparation
VI	Review (Presentation & Understanding)
VII	Viva-Voce
VIII	Publications /Possibility of publication

Task-CO Mapping:

Task (% Weightage)	CO1	CO2	CO3	CO4	CO5
IV (40%)	X	X			
V (20%)				X	
VI (10%)			X		
VII (20%)				X	
VIII (10%)					X

NOTE: Refer to the following link for the guidelines to prepare dissertation report: https://www.nitw.ac.in/main/PGForms/NITW/