

M. Tech. in Thermal and Fluids Engineering

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: The graduates will acquire advanced knowledge and concepts of Thermal and Fluids Engineering.	Program Outcome 1: After completion of the M-Tech in Thermal and Fluids Engineering, the students will be able to manage and solve technical problems associated with thermo-fluid systems.
Program Goal 2: To provide the students an opportunity to upgrade their skills and qualifications.	Program Outcome 2: After completion of the M-Tech in Thermal and Fluids Engineering, the students will update their engineering skills for career growth.
Program Goal 3: The graduates will possess the state-of-the art practical, analytical and computational approach for the analysis of thermo-fluid systems.	Program Outcome 3: Possess the computational and analytical expertise required for the analysis of thermo-fluid systems with focus in industrial and research applications.

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	ME5101	Advanced Engineering Mathematics	3	1	0	4
3.	ME5105	Advanced Fluid Mechanics	3	0	0	3
4.	ME5106	Gas Dynamics and Propulsion	3	0	0	3
5.	ME5107	Thermo-Fluid Lab-I	0	0	3	1.5
6.	ME61XX	DE-I	3	0	0	3
7.	ME61XX	DE-II	3	0	0	3
8.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	3	5	24.5

IDE (Inter Disciplinary electives) in the curriculum aims to create multitasking professionals/scientists with learning opportunities for students across disciplines/apptitude of their choice by opting level (5 or 6) electives, as appropriate, listed in the approved curriculum.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	ME5201	Advanced Engineering Software Lab	1	0	4	3
2.	ME5203	Measurement and Instrumentation	3	0	0	3
3.	ME5205	Advanced Heat Transfer	3	1	0	4
4.	ME5206	Thermo-Fluid Lab-II	0	0	3	1.5
5.	MEX2XX	DE-III	3	0	0	3
6.	MEX2XX	DE-IV	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		19	2	7	24.5

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	ME6198	Summer Internship / Mini Project*	0	0	12	3
2.	ME6199	Project I**	0	0	30	15
	TOTAL		0	0	42	18

***Note: Summer Internship (Credit based)**

(i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening summer vacation between Semester II and III. It may be pursued in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

(ii) Further, on return from 60 days internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

**** Note: M. Tech. Project outside the Institute:** A project-based internship may be permitted in industries/academia (outside IITP) in 3rd or 4th semester in accordance with academic regulations. In the IIIrd Semester, students can opt for a semester long M. Tech. project subject to confirmation from an Institution of repute for research project, on the assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC

based on progress report and presentation would be mandatory for a final decision by the competent authority.

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	ME6299	Project II	0	0	42	21
	TOTAL		0	0	42	21

Total Credit from Semester I to IV - 88

ELECTIVE GROUPS

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6101	Multiphase Flow & Heat Transfer	3	0	0	3
2.	ME6102	Computational Fluid Dynamics	3	0	0	3

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6103	Continuum Mechanics	3	0	0	3
2.	ME6104	Refrigeration and Air-Conditioning	3	0	0	3

Department Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6201	Turbulent Shear Flow	3	0	0	3
2.	ME6202	Cryogenics	3	0	0	3
3.	ME6203	Laser Processing of Materials	3	0	0	3

Department Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6204	Aerodynamics	3	0	0	3
2.	ME6205	Advances in IC Engine	3	0	0	3
3.	ME6206	Microfluidics and Microsystems	3	0	0	3

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to students other than ME)

IDE						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6113	Soft Computing Application in Engineering	3	0	0	3

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	ME5101	Advanced Engineering Mathematics	3	1	0	4
3.	ME5105	Advanced Fluid Mechanics	3	0	0	3
4.	ME5106	Gas Dynamics and Propulsion	3	0	0	3
5.	ME5107	Thermo-Fluid Lab-I	0	0	3	1.5
6.	ME61XX	DE-I	3	0	0	3
7.	ME61XX	DE-II	3	0	0	3
8.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	3	5	24.5

Course Number	ME5101
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Advanced Engineering Mathematics
Learning Mode	Lecture
Learning Objectives	Complies with PLOs 1-3 - This course aims to train the students with the basic and advanced mathematical tools required to solve engineering problems. - Showcase the utility of mathematics towards the analysis of real-world engineering problems.
Course Description	This course is designed to fulfil the need for basic and advanced mathematics concepts often used in real-life engineering problems. Prerequisite: NIL
Course Outline	Linear Algebra: Matrix algebra; basis, dimension and fundamental subspaces; solvability of $Ax = b$ by direct Methods; orthogonality and QR transformation; eigenvalues and eigenvectors, similarity transformation, singular value decomposition, Fourier series, Fourier Transformation, FFT. Vector Algebra & Calculus: Basic vector algebra; curves; grad, div, curl; line, surface and volume integral, Green's theorem, Stokes's theorem, Gauss-divergence theorem. Differential Equations: ODE: homogeneous and non-homogeneous equations, Wronskian, Laplace transform, series solutions, Frobenius method, Sturm-Liouville problems; PDE: separation of variables and solution by Fourier Series and Transformations, PDE with variable coefficient. Numerical Technique: Numerical integration and differentiation; Methods for solution of Initial Value Problems, finite difference methods for ODE and PDE; iterative methods: Jacobi, Gauss-Siedel, and successive over-relaxation. Complex Number Theory: Analytic function; Cauchy's integral theorem. Statistical Methods: Descriptive statistics and data analysis, correlation and regression, probability distribution.
Learning Outcome	- This course would enable the students to solve the mathematical governing equations of engineering problems. - The students would be able to realise the connection of Mathematics with Physics and Engineering.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva

Suggested Readings:

Text Books:

1. H. Kreyszig, "Advanced Engineering Mathematics", Wiley, (2006).
2. Gilbert Strang, "Linear Algebra and Its Applications", 4th edition, Thomson Brooks/Cole, India (2006).
3. J. W. Brown and R. V. Churchill, "Complex Variables and Applications", McGraw-Hill Companies, Inc., New York (2004).
4. J. W. Brown and R. V. Churchill, "Fourier Series and Boundary Value Problems", McGraw-Hill Companies, Inc., New York (2009).
5. G. F. Simmons, "Differential Equations with Applications and Historical Notes", Tata McGraw-Hill Edition, India (2003).
6. S. L. Ross, "Differential Equations" 3rd edition, John Wiley & Sons, Inc., India (2004).
7. K. S. Rao, "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd (2005).
8. R. Courant and F. John, "Introduction to Calculus and Analysis, Volume I and II", Springer-Verlag, New York, Inc. (1989).

9. K. Atkinson and W. Han, “Elementary Numerical Analysis” 3rd edition, John Wiley & Sons, Inc., India (2004).
10. R. A. Johnson and G. K. Bhattacharya, “Statistics, Principles and Methods”, Wiley (2008).
11. Michael D Greenberg, “Advanced Engineering Mathematics”, 2nd Edition, Pearson (1998).
12. R.K. Jain and S. R. K. Iyengar, “Advanced Engineering Mathematics” 4th Edition, Narosa; 1st Edition (2002).

Course Number	ME5105
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advanced Fluid Mechanics
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3. The course aims to enhance the conceptual understanding of fluid motion, with an emphasis on providing the physical and mathematical background needed to solve fluid dynamics problems.
Course Description	The course discusses the integral approach to solve fluid dynamics problems. In addition to exact solutions of Navier-Stokes equation, flow dynamics are analysed in both inviscid and creeping limits. The course also covers boundary layer flows and Micro and nano flow.
Course Outline	Concepts of fluids: Definitions of fluids, concept of continuum, different types of fluid, tensor analysis, governing laws of fluid mechanics in integral form, Reynold's transport theorem, mass, momentum and energy equations in integral form and their applications, differential fluid flow analysis, continuity equation, Navier-Stokes equation and exact solutions. Potential flow analysis: Two-dimensional flow in rectangular and polar coordinates, continuity equation and the stream function, irrotationality and the velocity potential function, complex potential function, vorticity and circulation, flow over immersed bodies and D' Alembert's paradox, aerofoil theory and its application. Viscous flow analysis: Low Reynold's number flow, approximation of Navier-stokes equation, approximate solutions of Navier-Stokes equation, Stokes and Oseen flows, hydrodynamic theory of lubrication, Prandtl's boundary layer equations, Large Reynold's number flow approximation, flow instabilities and onset of turbulence. Micro and nano flow: Physical aspects of micro and nano flows, governing equations, surface tension driven flows, modeling of micro and nano flows.
Learning Outcome	• Students will be able to formulate and solve fluid flow problems using control volume approach. • Ability to obtain solutions to Navier-Stokes equation under laminar regime for different geometries subject to appropriate initial and boundary conditions. • Knowledge of flows in high and low Reynolds number limits. • Basic understanding of transition to turbulence. • Students will have a grasp on the principles of compressible flow through variable area ducts with/without friction or heat transfer.
Assessment Method	Mid Semester Examination, End Semester examination, Quiz, Research/literature-review projects, presentations
Suggested Readings: 1. White, F.M., Viscous Fluid Flow, McGraw-Hill, New York, 3rd edition 2006. 2. Bachelor G. K. An introduction to Fluid Dynamics , Cambridge University Press, 2007. 3. Streeter V.L. and Wylie E. B., Fluid Mechanics , Tata McGraw-Hill, Delhi 2001. 4. Shames I. H., Mechanics of Fluids , Tata McGraw Hill, Delhi, 4th edition 2003. 5. Douglas and Swaffield, Fluid Mechanics , Prentice Hall, 5th edition 2006. 6. Yahya S. M., Fundamentals of Compressible Flow , Tata McGraw Hill, Delhi, 3rd edition 2003. 7. Karniadakis G., Beskok, A., and Narayan A. Microflows and Nanoflows , Springer, 1st edition 2005. 8. Journal of Fluid Mechanics, Cambridge University Press. 9. Physics of Fluids, American Institute of Physics.	

Course Number	ME5106
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Gas Dynamics and Propulsion
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3 The primary focus of this course is to introduce students to the basic principles of gas dynamics and propulsion. Emphasis will be given to the fundamental concepts of compressible flow, shock and expansion waves, nozzle flows and their practical applications. The course further aims to provide understating to students to enable them in carrying out engineering analysis of ramjets and turbine engines along with their separate components.
Course Description	This course discusses the basics of gas dynamics which includes topics such as isentropic relations, normal and oblique shock wave, Rayleigh and Fanno Flows, flows in nozzles and expansion waves. In the later part, the course discusses the basic of propulsions related to various types of Gas turbine engines. The course concludes with the discussion the latest emerging trends in the field of propulsion. Prerequisite: Fluid Mechanics and Thermodynamics or an equivalent course
Course Outline	Gas Dynamics Introduction to Gas Dynamics and Review of Thermodynamics; Basic Governing Equations; Sonic velocity and Mach number, Stagnation state; Normal Shocks: Stationary and Moving Shocks; Rayleigh and Fanno Flows; Quasi 1-D flows; Convergent Nozzles, Convergent-Divergent Nozzles; Oblique shocks: Theta-Beta-M relation, shock reflection and interactions; Expansion fans: Prandtl Meyer Function; Shock Expansion Theory. Propulsion Basic idea in aircraft propulsion: Thrust; Modes of Propulsion; Operation of Basic Gas Turbine Engine; Turbojet, After-burning Turbojet and Turbofan Engine; Detailed analysis of different parts of a Gas Turbine Engine: Intake- Subsonic, Compressor Aerodynamics and Losses, Combustor (Air-Fuel Ratio, Emission, Alternate fuels), Turbine Aerodynamics (Losses and cooling technology); Ramjet and Turboramjet Engine (Supersonic Intakes); Scramjet Engine; Thrust Equation; Thermodynamic Analysis of jet Engines; Thrust Calculations: Turbojet, Turbofan, Ramjet Engine; Emerging Trends with focus on emission reduction
Learning Outcome	At the end of the course, students will have achieved the following learning outcomes: • Understanding of the basic of gas dynamics • Ability to understand the physics behind high-speed flows • Understanding the basic ideas behind aircraft propulsion • Ability to perform thrust calculations for various kinds of aircraft engines
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Term Paper Presentation
Suggested Readings:	

Gas Dynamics

1. H.W. Liepmann, and A. Roshko, Elements of Gas Dynamics, Courier Corporation, 2013
2. J. Anderson, Modern Compressible Flow with Historical Perspective, Fourth Edition, McGraw Hill Education, 2021
3. V. Babu, Fundamentals of Gas Dynamics, Athena Academic Ltd, 2008
4. P.H. Oosthuizen and W.E., Carscallen, Compressible Fluid Flow, McGraw-Hill Education, 1997
5. A. J. Chapman and W.F. Walker, Introductory Gas Dynamics, Holt, Reinhart and Winston, 1971

Propulsion

6. Mattingly, J.D., Elements of Gas Turbine Propulsion, McGraw-Hill Inc., 1996.
7. V. Babu, Fundamentals of Propulsion, ANE Student Edition, 2009
8. P. G. Hill and C. R. Peterson, Mechanics and Thermodynamics of Propulsion, Second Edition, Pearson Education, 2009.
9. G. C. Oates, Aerothermodynamics of Gas Turbine and Rocket Propulsion, Third edition, AIAA Education Series, 1997.
10. G. C. Oates, Aerothermodynamics of Aircraft Engine Components, AIAA Education Series, 1985.
11. R.D. Flack, Fundamentals of Jet Propulsion with Applications, Cambridge University Press, 2005.
12. H. Cohen, G.F.C. Rogers, and H. I. H. Saravanamuttoo, Gas Turbine Theory, 7th Edition Pearson, 2019.

Course Number	ME5107
Course Credit	0-0-3-1.5
Course Title	Thermal Fluid Laboratory-I
Course Learning Objective: • Design, execution, and evaluation of physical experiments in heat transfer and fluid mechanics. Course Learning Outcome: Complies with PLOs 2 and 3. • Hands-on experience in heat transfer and fluid mechanics experiments. • Interpretation and presentation of experimental results. Prerequisite: NIL Syllabus: Fluid Mechanics: measurement of flow through Venturi, orifice, and hot wire anemometer, fluid machinery, and wind tunnel, Conduction: estimation of thermal conductivity and heat capacity, Convection: free and forced convective heat transfer coefficients on different geometries including fins, Heat Exchangers: single phase parallel and cross flow heat exchangers, heat transfer, Radiation heat transfer: Stefan-Boltzmann law, Kirchhoff's law, Lamberts Cosine law, Lamberts law of absorption, inverse square law, view factors, DAQ and Signal Processing: DAQ and its components, feedback temperature control, low pass and high pass filters, spectrum analysis.	

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6101	Multiphase Flow & Heat Transfer	3	0	0	3
2.	ME6102	Computational Fluid Dynamics	3	0	0	3

Course Number	ME6101
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Multiphase Flow and Heat Transfer
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1-3 1. The student should internalize the meaning of the terminology and physical principles associated with liquid-vapor phase change heat transfer processes. 2. The student should be able to delineate pertinent transport phenomena for any process or system involving phase change heat or mass transfer. 3. The student should be able to use requisite inputs for computing heat transfer rates and/or material temperatures. 4. The student should be able to develop representative models of real processes and systems and draw conclusions concerning process/system design or performance analysis. 5. The student should become familiar with design of multiphase heat transfer experiments and concerning measurement techniques.
Course Description	Liquid-vapor phase change processes play a vital role in many technological applications. The importance of this topic is increasing keeping in view the relevance of topics such as energy and sustainability. This course aims to utilize the fundamentals of thermodynamics, fluid mechanics, and heat transfer processes to help students analyse, model, and predict heat transfer during liquid-vapor phase change processes such as boiling and condensation. Importance of practical consideration on heat transfer is also dealt with.
Course Outline	Fundamentals: Introduction to liquid-vapor phase change fundamentals, kinetic theory, interfacial tension, wettability, boiling, nucleate boiling, critical heat flux and dryout mechanisms, transition boiling, Leidenfrost, film boiling, nucleation theory, convective flow boiling fundamentals, flow patterns and regime map, condensation, film-wise condensation vs. dropwise condensation theory. Devices and applications areas: introduction to devices and application areas, boilers and condensers, nuclear reactor, thermosyphons, heat pipes, and vapor chambers. Practical considerations: effect of non-condensable gas and surface aging. Current trends: Heat transfer coefficient enhancement techniques, heat and mass transfer at microscopic length scales and gravity levels, microchannels, modeling techniques.
Learning Outcome	1. The student should be able to develop representative models of boiling and condensation heat transfer processes and draw conclusions concerning process/system design or performance analysis. 2. The student should be able to design multiphase heat transfer experiments using suitable measurement techniques
Assessment Method	Assignments, Mid-Sem Examination, End-Sem Examination, term paper
Suggested Readings: 1. Van Carey. Liquid-Vapor Phase-Change Phenomena, Taylor and Francis: 2nd Edition, 2007, ISBN: 0-89116-836-2, and 1-56032-074-5 2. Incropera and Dewitt. Fundamentals of Heat and Mass Transfer, Wiley, 6th Edition, ISBN: 9780471457282 3. Leinhard and Leinhard, A Heat Transfer Textbook, Phlogiston Press, 3rd Edition, ISBN: 0- 9713835-2-9	

Course Number	ME6102
Course Credit	L-T-P-C : 3-0-0-3
Course Title	Computational Fluid Dynamics
Learning Mode	Classroom Lecture/Hybrid
Learning Objectives	Complies with PLOs 2-3 This course aims to lay the essential foundations of computational fluid dynamics and enable; (a) understanding of the governing equations of fluid dynamics and their classification, (b) understanding of different discretization methods to solve the governing equations numerically, (c) understanding of different types of grids involved in CFD, (d) understanding of popular CFD algorithms for solving incompressible flows.
Course Description	This course is designed to fulfil the basic concepts of computational fluid dynamics. The course first discusses the general background required for understanding the various numerical methods or discretization techniques involved in CFD. It is followed by a detailed understanding of the two of the popular discretization methods – Finite Difference Method (FDM) and Finite Volume Method (FVM). The course then concludes by providing an overview of other popular CFD methods. Prerequisite: Undergraduate Fluid Mechanics and Heat Transfer course
Course Outline	Concept of Computational Fluid Dynamics: Different techniques of solving fluid dynamics problems, their merits and demerits, governing equations of fluid dynamics and boundary conditions, classification of partial differential equations and their physical behavior, Navier-Stokes equations for Newtonian fluid flow, computational fluid dynamics (CFD) techniques, different steps in CFD techniques, criteria and essentialities of good CFD techniques. Finite Difference Method (FDM): Application of FDM to model problems, steady and unsteady problems, implicit and explicit approaches, errors and stability analysis, direct and iterative solvers. Finite Volume Method (FVM): FVM for diffusion, convection-diffusion problem, different discretization schemes, FVM for unsteady problems. Prediction of Viscous Flows: Pressure Poisson and pressure correction methods for solving Navier- Stokes equation, SIMPLE family FVM for solving Navier-Stokes equation, modelling turbulence. CFD for Complex Geometry: Structured and unstructured, uniform and non-uniform grids, different techniques of grid generations, curvilinear grid and transformed equations. Lattice Boltzman and Molecular Dynamics: Boltzman equation, Lattice Boltzman equation, Lattice Boltzman methods for turbulence and multiphase flows, Molecular interaction, potential and force calculation, introduction to Molecular Dynamics algorithms.
Learning Outcome	After attending this course, the following outcomes are expected:

	1. Ability to classify the partial differential equations involved in fluid mechanics and heat flow and understanding of their physical behaviour. 2. Ability to write CFD codes for the various algorithms covered in this course. 3. Understanding of discretization approach required for the unstructured grids.
Assessment Method	Mid Semester Examination, End Semester examination, Viva, Written and Coding Assignments
Suggested Readings: Text Books: 1. J. D. Anderson, "Computational Fluid Dynamics", McGraw-Hill Inc. (New Edition). 2. S. V. Patankar, "Numerical Heat Transfer and Fluid Flow", Hemisphere Pub. (New Edition) 3. A. Sharma, "Introduction to Computational Fluid Dynamics Development, Application and Analysis", Ane Books, 1st edition 2016 4. K. Muralidhar, and T. Sundarajan, "Computational Fluid Flow and Heat Transfer", Narosa (New Edition) 5. D. A. Anderson, J. C. Tannehill and R. H. Pletcher, "Computational Fluid Mechanics And Heat Transfer", Hemisphere Pub. (New Edition) 6. M. Peric and J. H. Ferziger, "Computational Methods for Fluid Dynamics", Springer (New Edition). 7. H. K. Versteeg and W. Malalaskera, "An Introduction to Computational Fluid Dynamics", Dorling Kindersley (India) Pvt. Ltd. (New Edition). 8. C. Hirsch, "Numerical Computation of Internal and External Flows", ButterworthHeinemann, (New Edition). 9. J. M. Jaile, "Molecular Dynamics Simulation: Elementary Methods", Willey Professional, (New Edition). 10. A. A. Mohamad, "Lattice Boltzman Method: Fundamentals and Engineering Applications with Computer Codes, Springer (New Edition).	

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6103	Continuum Mechanics	3	0	0	3
2.	ME6104	Refrigeration and Air-Conditioning	3	0	0	3

Course Number	ME6103
Course Credit	L-T-P-C: 3-0-0-3
Course Name	Continuum Mechanics
Pre-requisites	Mechanics of Solids and Mechanics of Fluids
Learning Mode	Classroom lecture
Course Objectives	
Complies with PLOs 2 and 3 This course targets students of solid and fluid mechanics, aiming to familiarize them with the fundamentals of continuum mechanics by enhancing their problem-solving skills for engineering problems like structural mechanics, fluid dynamics and heat transfer.	
Course Content	
1. Mathematical Preliminaries Introduction to Tensors: Vectors and second order tensors; Tensor operation; Properties of tensors; Invariants, Eigenvalues and eigenvectors of second order tensors; Tensor fields; Differentiation of tensors; Divergence and Stokes theorem. 2. Kinematics of Deformation Continuum hypothesis, Material (Lagrangian) and Spatial (Eulerian) descriptions of motion, Displacement field, Deformation gradient, Stretch ratios, Polar decomposition of deformation gradient, Velocity gradient, Rate of deformation, Vorticity, Length, area and volume elements in deformed configuration; Material and spatial time derivatives - velocity and acceleration, Cauchy stress tensor, state of stress, concept of first and second Piola-Kirchoff stress tensors. 3. Fundamental Laws in Continuum Mechanics: Material derivatives of Line, Surface and Volume Integrals, Conservation of mass, continuity equation, Conservation of linear and angular momentum, Conservation of energy; Continuum Thermodynamics: Basic laws of thermodynamics; Energy equation; Entropy; Clausius-Duhem inequality. 4. Constitutive Relations and Material Models: Constitutive Assumptions; Ideal Fluids; Elastic Fluids, Hyperelastic Material; Notion of Isotropy; Isothermal Elasticity - Thermodynamic Restrictions, Material Frame Indifference, Material Symmetry; Hooke's law, Stokes problem, Newtonian and Non-Newtonian fluids.	
Learning Outcomes: - The students will understand the various theoretical elements of continuum mechanics, and how these elements apply to solids and fluids. - The students will be able to derive and apply the equations of continuum mechanics in the following areas: stress and strain analysis, deformation, work and energy, theory of elasticity, viscoelasticity, theory of plasticity, fluid mechanics, and the basis for constitutive equations. - The students will be able to use continuum theory descriptions in their research work. Furthermore, it will also be helpful for them to understand research or scientific articles with continuum formulations.	
Assessment Method Mid semester examination, End semester examination, Class test/Quiz, Assignments	
Reference Books Mase, G. T., and Mase, G. E., Continuum Mechanics for Engineers, CRC Press, 2nd Edition, 1999.	

2. Malvern, L. E., Introduction to the Mechanics of a Continuous Medium, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1969.
3. Rudnicki, J. W., Fundamentals of Continuum Mechanics, John Wiley & Sons, 2015.
4. Lai, W. M., Rubin, D., and Krepl, E., Introduction to Continuum Mechanics, Butterworth-Heinemann, 4th edition, 2015.
5. Reddy, J.N., An introduction to continuum mechanics, Cambridge University Press, 2013.
6. Jog, C.S., Foundations and applications of mechanics: Volume I: Continuum mechanics, Narosa Publishing House, 2007.

Course Number	ME6104
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Refrigeration and Air Conditioning
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1-3 Students will be able to: (a) comprehend the nomenclature of refrigerants, their physical, chemical, thermodynamic requirements and the environmental concerns, (b) analyse various types of refrigeration and air conditioning systems (c) design different components of vapour compression refrigeration system (d) perform cooling and heating load calculations for a building, and (e) design air distribution system
Course Description	This course is designed to impart the necessary knowledge of the processes and components involved in refrigeration and air conditioning systems.
Course Outline	Refrigeration Refrigeration systems: Vapour compression, vapour absorption and air refrigeration system, Thermo- electric refrigeration, Cryogenics. Refrigeration Hardware: Refrigerant compressors, refrigerant condensers, refrigerant evaporators, receiver, expansion devices, filter-drier, moisture indicator etc. Refrigeration Controls: HP/LP cut-out, Solenoid valve, evaporator pressure regulator, Accumulators, Suction pressure regulator. Capacity control techniques: Hot gas by-pass scheme, Cylinder loading scheme, suction gas throttling scheme Refrigerants: Classification and nomenclature, desirable properties of refrigerants, common refrigerants, environmental issues-Ozone depletion and global warming Alternative refrigerants: low GWP and zero ODP newer refrigerants. Applications of Refrigeration: Industrial refrigeration, Transport refrigeration, food preservation (cold storage) Air-conditioning Review of Basic psychrometry: Sensible cooling/heating processes, humidification /dehumidification processes on psychrometric chart etc. Classification of air-conditioners: unitary systems (Window type/self-contained/single-package unit), split-unit and Central air conditioning system Cooling/Heating load calculations: Transmission load, Solar heat gain, Occupancy load, Equipment load, Infiltration and ventilation load. Duct Design: Design considerations and procedures. Air Conditioning controls: basic elements, types of control systems
Learning Outcome	The course training will enable students to achieve the learning objectives: (a) Selection of an appropriate refrigerant for a given application taking into account the physical, chemical, and thermodynamic requirements and the environmental concerns (b) Analysis of various refrigeration and air conditioning systems,

	(c) Designing of different components of vapour compression refrigeration system (d) Performing air conditioning load calculations and estimating quantity of dehumidified air required according to the calculated load (e) Designing of air conditioning duct which allows required quantity of air to be delivered to different rooms in a building,
Assessment Method	Mid Semester Examination, End Semester examination, Assignments, Quiz, and Seminar
Suggested Readings: 1. Dossat R.J., 2008. Principles of Refrigeration, Pearson Education (Singapore) Pte. Ltd. 2. Stoecker W., 1982. Refrigeration and Air Conditioning, Tata McGraw-Hill Publishing Company Limited, New Delhi. 3. Arora C.P., 2005. Refrigeration and Air Conditioning, Tata McGraw-Hill Publishing Company Limited, New Delhi. 4. Ameen A., 2006. Refrigeration and Air Conditioning, Prentice Hall of India Private Limited, New Delhi. 5. American Society of Heating Refrigerating and Air Conditioning Engineers Inc, 2013 ASHRAE Handbook- Refrigeration Fundamentals. 6. American Society of Heating Refrigerating and Air Conditioning Engineers Inc, 2011 ASHRAE Handbook- HVAC Applications.	

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	ME5201	Advanced Engineering Software Lab	1	0	4	3
2.	ME5203	Measurement and Instrumentation	3	0	0	3
3.	ME5205	Advanced Heat Transfer	3	1	0	4
4.	ME5206	Thermo-Fluid Lab-II	0	0	3	1.5
5.	MEX2XX	DE-III	3	0	0	3
6.	MEX2XX	DE-IV	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		19	2	7	24.5

Course Number	ME5201
Course Credit	L-T-P-C: 1-0-4-3
Course Title	Advanced Engineering Software Laboratory
Learning Mode	Classroom Lectures and Practical
Learning Objectives	Complies with PLOs 1-3. Exposure to industrial software used in Mechanical Engineering practices.
Course Description	This course is designed to make students understand commercial software along with the understanding of numerical techniques.
Course Outline	CAD/CAM: 2D and 3D geometric transformation, Composite Transformation, Projections; Curves: Cubic, Bezier, Splines; Surfaces: Quadric, Coons patch, Super Quadric, Bezier, B-Splines. Process planning, CL data generation, Automatic CNC code generation. FEM: Solid model creation, different types of elements, chunking of model, meshing, mesh quality, different kinds of analysis: static, dynamic, transient, thermal, electro-magnetic, acoustics, sub- structuring and condensation, Error and convergence. Non-linear static and dynamic analysis, contact analysis, multi-physics problem, rigid body analysis of flexible element. CFD: Different types of CFD techniques, various stages of CFD techniques (i) pre-processor: governing equations, boundary conditions, grid generation, different discretization techniques (ii) processor: solution schemes, different solvers (iii) post-processing: analysis of results, validation, grid independent studies etc. Developing codes using commercial/open source software for solving few problems of laminar and turbulent flow with heat transfer applications. Engineering software's related to CAD/CAM, FEM, CFD, with both GUI and script like languages, are to be used for laboratory assignments.
Learning Outcome	At the end of the course, students will be able to use the industrial software for simulating industrial and research problems related to solid and fluid mechanics. A mature understanding of various numerical techniques and their advantages and disadvantages will develop with respect to the software used in the class.
Assessment Method	Class test & quiz, Assignment, Class Performance and Viva, Practical Exam
Suggested Readings: 1. D. F. Rogers and J. A. Adams, "Mathematical Elements for Computer Graphics", McGraw- Hill, 1990 2. M. Groover and E. Zimmers, "CAD/CAM: Computer-Aided Design and Manufacturing", Pearson Education, 2009. 3. Saxena and B. Sahay, "Computer Aided Engineering Design", Springer, 2007. 4. J. N. Reddy, "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill, 2005. 5. J. Fish, and T. Belytschko, "A First Course in Finite Elements", 1st Ed., John Wiley and Sons, 2007. 6. J. D. Anderson, "Computational Fluid Dynamics", McGraw-Hill Inc. (1995). 7. H. K. Versteeg and W. Malalaskera, "An Introduction to Computational Fluid Dynamics", Dorling Kindersley (India) Pvt. Ltd. (2008). 8. S. Biringen and C Chow, An Introduction to Computational Fluid Mechanics by Example.	

Course Number	ME5203
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Measurement and Instrumentation
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3. The course aims to provide a basic understanding of the mechanical measurement systems and statistical analysis of experimental data.
Course Description	The course contains the generalized configuration and functional elements of measuring systems, static and dynamic characteristics of measuring instruments. The course also includes the instrumentation for displacement, strain, velocity, force, torque, power, pressure, sound, flow and temperature measurement.
Course Outline	Module-1 Basic concepts of measurement, functional elements of instruments, classification of measuring instruments, methods of correction for interfering and modifying inputs, static characteristics of measuring instruments Module-2 Static characteristics of measuring instruments, loading effect and impedance matching, statistical analysis, Chi-square test, least square method, Curve Fitting, Uncertainty analysis and error propagation Module-3 Generalized model of a measuring system, zero and first order system, second order system. First order system- ramp response, impulse response, frequency response, Second order system- step response, ramp response, impulse and frequency response, higher order systems, compensation, transducers Module-4 Flow measurement (hot wire anemometer, PIV systems, coriolis flow meter, etc.), temperature measurement (thermocouple, RTD, Infra thermography etc.), heat flux sensors. Optical Methods- Shadowgraph, Schlieren and Interferometer. Module-5 Strain gauges, piezoelectric transducers pressure measurement, force and torque measurement, displacement and acceleration measurement Module-6 Sound measurement, thermophysical properties measurement, flow visualization, air pollution sampling and measurement, pollutants-Gas Chromatography.
Learning Outcome	- Students will be able to analyze and behavior and characteristics of various measuring instruments and record data - Students will be able to analyze and interpret the experimental data - Students will be able to perform uncertainty analysis in the measured and derived quantities.
Assessment Method	Mid Semester Examination, End Semester examination, Quiz, assignments seminar
Textbook 1. E.O. Doebelin, Measurement Systems: Application and Design. Reference books 2. E.G.R. Eckert and R.G. Goldstein, Measurement Techniques in Heat Transfer. 3. T.P. Holeman, Experimental Methods for Engineers. 4. H.D. Young, Statistical Treatment of Experimental Data.	

Course Number	ME5205
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Advanced Heat Transfer
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1 and 2. To impart a deep fundamental understanding of the underlying concepts of heat transfer using simple to advanced analytical techniques.
Course Description	The course develops the governing equations for the different modes of heat transfer, viz. conduction, convection and radiation along with various solution strategies applicable to a variety of heat transfer problems.
Course Outline	Conduction: Equations and boundary conditions in different coordinate systems; Analytical Solutions: separation of variables, Laplace Transform, Duhamel's theorem; Non-impulse initial conditions; Numerical Methods: Finite difference and flux conservation; Interfacial heat transfer. Convection: Conservation equations and boundary conditions; Heat transfer in laminar developed and developing boundary layers: duct flows and external flows, analytical and approximate solutions, effects of boundary conditions; Heat transfer in turbulent boundary layers and turbulent duct flows; Laminar and turbulent free convection, jets, plumes and thermal wakes, phase change. Radiation: Intensity, radiosity, irradiance, view factor geometry and algebra; formulations for black and non-black surfaces, spectrally-selective surfaces (solar collectors); Monte Carlo methods for radiation exchange; The radiative transfer equation, extinction and scattering properties of gases and aerosols, overview of solution methods and applications. Interaction between conduction, convection and radiation: Coupled problems; Examples in manufacturing and electronic cooling applications; Micro channels and micro fins.
Learning Outcome	• Students will be equipped with the analytical tools to analyse the thermo-fluid phenomena encountered in research/engineering problems. • Ability to physically interpret the theoretical solutions to heat transfer problems. • Ability to analytically solve conduction equation for multi-dimensional problems of engineering interest. • Development of numerical codes for solving simple conduction heat transfer problems. • To be able to solve internal and external laminar flows with heat transfer. • Basic knowledge of turbulence modelling. • Applying the principles of radiation heat transfer to practical problems such as design of solar collectors.
Assessment Method	Mid Semester Examination, End Semester examination, Quiz, Homework assignments, Mini-projects, presentations
Suggested Readings: 1. M N Ozisik, Heat Conduction, 2nd ed, John Wiley & Sons, 1993 2. Kakaç, S., Yener, Y., Heat Conduction, 3rd edition, Taylor & Francis, 1993. 3. F P Incropera and D P Dewitt, Introduction to Heat Transfer, 3rd ed, John Wiley & Sons, 1996 4. W. M. Kays and E. M. Crawford, Convective Heat and Mass Transfer, Mc Graw Hill, 1993. 5. Adrian Bejan, Convective Heat Transfer, John Wiley and Sons, 1995. 6. M F Modest, Radiative Heat Transfer, McGraw-Hill, 1993 7. R Siegel and J R Howell, Thermal Radiation Heat Transfer, 3rd ed, Taylor & Francis, 1992	

ME5206	Thermal Fluid Laboratory-II	(0-0-3-1.5)
Course Learning Objective: Complies with PLOs 2 and 3. - Design, execution, and evaluation of physical experiments in heat transfer and fluid mechanics. Course Learning Outcome: - Hands-on experience in heat transfer and fluid mechanics experiments. - Interpretation and presentation of experimental results. Prerequisite: NIL Syllabus: Change Heat Transfer: pool boiling, Leidenfrost, flow boiling, dropwise condensation, film wise Condensation, Surface Tension and Capillarity: wettability and contact angles on hydrophilic, hydrophobic and super-hydrophobic surfaces using a micro-goniometer, Wilhelmy plate method, capillarity, droplet impingement on hydrophilic, hydrophobic and super-hydrophobic surfaces, Turbulence: jet and plumes, Solar Thermal: solar intensity measurement using a Pyranometer, estimation of emissivity using heat source, metal plates and IR camera, evaluation of a solar flat-plate collector system in thermosyphonic and forced flow modes at different radiation levels, inlet water temperature, wind speeds, flow rate, Flow Visualization and Analysis: smoke and dye based flow visualization, e-PIV, μ-PIV.		

Department Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6201	Turbulent Shear Flow	3	0	0	3
2.	ME6202	Cryogenics	3	0	0	3
3.	ME6203	Laser Processing of Materials	3	0	0	3

Course Number	ME6201
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Turbulent Shear Flows
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3 The primary focus of this course is to introduce students to the basic and advanced concepts of turbulent flows. To get familiar with the different statistical methods employed for turbulent calculations. Understanding the turbulent flows and their calculation related to wall-bounded and free shear flows.
Course Description	This course discusses first discussed flow instability and how turbulent flows are onset. Then it discusses methods of identifying a turbulent flow and the governing equation related to the same. Thereafter different statistical tool to study turbulent flows are explained. The turbulent flow calculations related to various fundamental types of shear flows are discussed. Students who may find this course useful: PhD, M. Tech., and 3rd/4th–year B. Tech. Students from Mechanical, Civil and Chemical Engineering Departments. Prerequisite: Fluid Mechanics or an equivalent course
Course Outline	1. Flow instability and transition to turbulence 2. Nature of turbulence 3. Indicial notation for tensors 4. Fourier transforms and Parseval's theorem 5. Governing equations of turbulence 6. Eulerian Lagrangian and Fourier descriptions of turbulence 7. Statistical description of turbulence (Reynolds-averaged Navier-Stokes and Reynolds stress evolution equations) 8. Kolmogorov's hypotheses 9. Filtered description of turbulence (Bridging methods and large eddy simulation) 10. Boundary layer flow and other important turbulent shear flows (wake, jet, channel flow, etc.) 11. Development of turbulence closure models (Boussinesq approximation and Reynolds-stress evolution equation closures) 12. Rapid distortion theory (RDT) of turbulence Turbulence processes (Cascade, dissipation, material element deformation, mixing, etc.)
Learning Outcome	At the end of the course, students will have achieved the following learning outcomes: • Understanding of flow instabilities which leads to turbulent flows • Ability to distinguish a turbulent flow from laminar flow • Understanding of various statical tools required for study of turbulent flows • The concepts behind RANS, LES and DNS computations • Understating of boundary layer flow and other important turbulent shear flows
Assessment Method	Mid Semester Examination, End Semester examination, Assignment, Term Paper Presentation
Suggested Readings:	

Text Books:

1. Pope, S. B., Turbulent Flows, Cambridge University Press, 2000.
2. Wilcox, D.C., Turbulence Modeling for CFD, D.C.W. Industries, 3rd Edition, 2006.
3. White, F.M., Viscous Fluid Flow, TATA McGraw Hill, 2011
4. Tennekes, H. and Lumley, J.L., A First Course in Turbulence, The MIT Press, 1972.

Course Number	ME6202
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Cryogenics
Pre-requisite	Basic and Applied Thermodynamics
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1-2 • To present an introductory knowledge of Cryogenic Engineering. • To develop an Intuitive understanding of Liquefaction process, gas separation process, thermophysical and mechanical properties of materials at cryogenic temperature. • To encourage creative thinking and understanding of Cryogenic Engineering.
Course Description	This course is designed to impart the necessary knowledge of the processes and components involved in Cryogenic technology.
Course Outline	Introduction to Cryogenics and its applications Properties of materials at cryogenic temperature: T-s diagram of a cryogenic fluid, Properties of cryogenic fluids: Argon, Nitrogen, Oxygen, Neon, Hydrogen (ortho/para), Helium (He^3 and He^4), Liquid He-I and He-II (superfluid He) and its applications. Mechanical, Thermal, Electrical and Magnetic properties of materials (metals and nonmetals) at cryogenic temperature, Structure of metals and plastics. Gas Liquefaction and Refrigeration Systems: Basics of refrigeration/Liquefaction, Production of low temperatures, Ideal thermodynamic temperature cycle, Various liquefaction cycles. J-T expansion of real gas, adiabatic expansion, Ideal thermodynamic cycle. Linde-Hampson system, Precooled Linde-Hampson system, Effect of Heat exchanger effectiveness on Linde-Hampson system, some other liquefaction cycles such as Claude Cycle, Kapitza cycle, Collins cycle, etc. Gas Separation, storage, transportation: Basics of gas separation, Ideal gas separation system, Principles of gas separation, Rectification and plate calculations. Introduction to Cryocoolers, Cryogenic heat pipes: Cryocoolers classification and basics, Applications, Stirling cryocooler, Comparison of GM, Stirling and Pulse tube cryocooler. Introduction to Cryogenic engines. Cryogenic Insulations: Types of insulation, Vacuum, evacuated powder, opacified powder, Multilayer insulation. Vacuum Technology: Need of vacuum in cryogenics, Vacuum fundamentals, Various types of Vacuum pumps. Instrumentation in Cryogenics: Need of cryogenic instrumentation, Measurement of Thermo-physical properties, Various Sensors. Safety in Cryogenics: Need for safety, Basic Hazards, Protection from hazards
Learning Outcome	Graduates will be able to • do thermodynamic analysis of different liquefaction plants and choose a suitable method of liquefaction • choose suitable materials for cryogenic systems

	• perform research in the area of cryogenics • design safe and efficient cryogenic systems • display new contemporary methods and tools to carry out thermo-physical and mechanical investigations, analysis, and processing of cryogenic machines, plants and equipment.
Assessment Method	Quiz, Seminar, Mid & End semester examinations
Reference books 1. Randall F. Barron, “Cryogenics Systems”, Second Edition, Oxford University Press, New York (1985). 2. Timmerhaus Flynn, “Cryogenic Process Engineering”, Plenum Press, New York (1989). 3. Pipkov, "Fundamentals of Vacuum Engineering", Mir Publishers, Moscow. 4. Thomas M. Flynn, “Cryogenic Engineering”, second edition, CRC press, New York (2005). 5. G.M Walker. “Cryocooler- Part 1: Fundamentals” Plenum Press, New York (1983). 6. G.M Walker. “Cryocooler- Part 2” Plenum Press, New York (1983). 7. Mamata Mukhopadhyay, “Fundamentals of Cryogenic Engineering”, PHI Learning Pvt. Ltd, New Delhi (2010).	

Course Number	ME6203
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Laser Processing of Materials
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 2 and 3 This course aims to (a) Understand the fundamentals of laser, laser-material interactions, and physics involved in the laser processing of materials. (b) Understand and analyze various laser machining processes used in manufacturing from macro-scale to micro-scale. (c) Understand and analyze various laser joining processes and surface modification techniques. (d) Understand laser-based 3D manufacturing techniques. (e) Acquainted with recent developments in the field of laser material processing.
Course Description	This course is designed to impart the necessary basic knowledge of laser, laser-material interaction, and a wide range of applications of laser material processing.
Course Outline	Module-I : Laser Fundamentals Stimulated Emission, Population Inversion and Amplification; Laser Beam Characteristics: Wavelength, Coherence, Polarization, Mode and Beam Diameter; Industrial Lasers: Solid-State Lasers, Gas Lasers, Semiconductor Lasers, Liquid Dye Lasers, etc; Laser Materials Interactions: Absorption of Laser Radiation, Absorption Characteristics of Materials; Thermal Effects - Heating, Melting, Vaporization and Plasma Formation; Time scales. Module-II: Laser Machining Laser Drilling: Melt Expulsion During Laser Drilling, Analysis of Laser Drilling Process, Laser Drilling Applications. Laser Cutting: Evaporative Laser Cutting, Laser Fusion Cutting, Reactive Laser Cutting, Controlled Fracture Technique; Underwater Cutting. Laser Micromachining: Laser Ablation, Laser-Assisted Chemical Etching; Laser Micromachining Techniques - Direct Writing Technique, Mask Projection Technique. Laser Micromachining Applications. Module-III: Laser Fabrication Laser Welding: Process Mechanisms - Keyholes and Plasmas, Analysis of Laser Welding Process. Laser Surface Modification: Heat Treatment, Rapid Solidification, Alloying and Cladding, Surface Texturing. Laser Rapid Prototyping: Classification of RP Processes, Laser Based RP Processes, Applications. Mathematical Modeling. Module-IV: Special Topics

	Laser Interference Processing; Laser Shock Processing; Biomedical Laser Processes, etc.
Learning Outcome	The course training will enable students to achieve the following learning objectives: (a) Basics of laser and laser parameters for various laser-based manufacturing processes. (b) The advantages and limitations of laser-based manufacturing processes with physical insights. (c) The effects of various process parameters in laser material processing. (d) Basic foundation knowledge and analytical skills to perform research on laser material processing.
Assessment Method	Mid Semester Examination, End Semester Examination, Assignments, Quiz, and Seminar.
Suggested Readings: 1. W. M. Steen and J. Mazumder, Laser Material Processing, 4'th Edition, Springer, 2010. 2. N. B. Dahotre and S P Harimkar, Laser Fabrication and Machining of Materials, Springer, 2008. 3. E. Kannatey-Asibu, Principles of Laser Materials Processing, , Wiley, 2009. 4. M. von Allmen and A . Blatter, Laser-Beam Interactions with Materials, 2'nd Edition, Springer, 1998. 5. John C. Ion, Laser Processing of Engineering Materials, Elsevier, 2005. 6. J. F. Ready (Editor), LIA Handbook of Laser Materials Processing, Springer, 2001. 7. Selected Journal Papers	

Department Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6204	Aerodynamics	3	0	0	3
2.	ME6205	Advances in IC Engine	3	0	0	3
3.	ME6206	Microfluidics and Microsystems	3	0	0	3

Course Number	ME6204
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Aerodynamics
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3 The primary focus of this course is to introduce students to the basic principles of aerodynamics. The course emphasis will be on the fundamental concepts related to theoretical calculations related to incompressible flow over airfoils and wings. A brief understanding of compressible flows over airfoil will also be given. Finally, students will be familiarized with the modern-day applications of aerodynamics.
Course Description	This course broadly covers the following topics: • Review of Fluid Mechanics concepts related to aerodynamics. • Incompressible Flow Applications (airfoils and wings) • Compressible Flow Applications (airfoils) • Advanced Applications in the field of aerodynamics Prerequisite: Fluid Mechanics, Thermodynamics, Heat Transfer or an equivalent course
Course Outline	Review of Fluid Mechanics: Navier-Stokes equations, Potential flows, Concepts of lift and drag, Boundary layer theory, Application of potential flow and boundary layer theory in design of airfoils, Turbulence, Compressible flows, Shock and expansion waves Incompressible Flow Applications: Incompressible flow over airfoils: Kutta condition, Kelvin's circulation theorem, Classical thin airfoil theory, Incompressible flow over finite wings: Prandtl's classical lifting line theory, Three-dimensional incompressible flows, Panel methods and numerical techniques, Wind tunnel experimentation, Dynamic stall, Delta wings. Compressible Flow Applications: Introduction to subsonic compressible flow over airfoils, Supercritical Airfoil, Supersonic flows. Advanced Applications: Aerodynamics of wing-fuselage system and control surfaces, Helicopters, Aerodynamics of birds/insects, Micro-air Vehicle
Learning Outcome	At the end of the course, students will have achieved the following learning outcomes: • Understanding of the basic of aerodynamics • Ability to perform theoretical calculation for aerodynamic forces related to airfoils and wings. • Understanding the aerodynamics of key flying objects which one encounters in modern day life
Assessment Method	Mid Semester Examination, End Semester examination, Assignment, Term Paper Presentation
Suggested Readings: Text and References: 1. J. D. Anderson, Fundamentals of Aerodynamics, McGraw-Hill Inc. (Indian Edition), 6th Edition.	

2. Josep Katz and Allen Plotkin, Low-speed aerodynamics, Cambridge University Press, 2001.
3. Wei Shyy, Yongsheng Lian, Jian Thang, Dragos Viieru and Hao Liu, Aerodynamics of Low Reynolds Number Flyers, Cambridge University Press, 2009.
4. Holt Ashley and Landhall. M. Aerodynamics of Wings and Bodies. Addison-Wesley 1965.
5. Jones.R.T. Wing Theory. Princeton University Press 1990.

Course Number	ME6205
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advances in IC Engines
Learning Mode	Class room lecturer
Learning Objectives	Complies with PLOs 1 and 2 • To understand the fundamental Principles of IC engines. • To explore recent advancements in combustion technologies • To analyze the impact of alternative fuels on engine performance and emissions • To investigate strategies for improving engine efficiency and reducing environmental impact. • To understand the generation of undesirable exhaust emissions • To understand the Optical diagnostics in I C Engines • To examine the integration of hybrid and electrification technologies with I C engines
Course Description	This course is designed to impart the knowledge of advanced concepts in Internal combustion engine such as alternative fuels, emission control, optical diagnostics, Hybrid and electric vehicles etc.
Course Outline	Introduction: Basic Introduction to SI and CI engine, Engine Performance Parameters. Conventional fuels & Alternative fuels: Energy Scenario, Transport Fuel, Petroleum Based Liquid Fuel and Their Characteristics, Straight vegetable oils, Biodiesels, Emulsified Fuels, Methanol, Ethanol, and higher versions of alcohols. Gaseous fuels include CNG, LPG, LNG, DME, hydrogen, and ammonia. Combustion in SI and CI Engines: Combustion in SI engines, Ignition Process and Limit, Spark Plug, Spark and Flame Propagation, Stages of Combustion in SI engines, Flame Front Propagation, Effects of Engine variables on Ignition Lag, and Factors Influencing the Flame Speed. Combustion in CI engine, Stages of CI engine combustion. Knocking in SI and CI engine, Effect of Engine Variables on Knock, Comparison of knocking in SI & CI engine, Factors Affecting Detonations. Stoichiometric Combustion of Fuels, Adiabatic Flame Temperature. Advances in the combustion process Combustion chambers in SI and CI engines, Important Factors Considered in Combustion Chamber Design, Modern developments in IC Engines such as EGR, MPFI, GDI, HCCI and Turbocharging. Engine Ignition cooling and Lubrication system Different Ignition Systems and Working, Components of battery Ignition System, Parameter Affecting Engine Heat Transfer, Engine Friction and Types, Factors affecting Mechanical Friction, Lubrication and its mechanism, Different Lubrication System (Mist, Wet Sump, Dry Sump) Fuel Injection System:

	Electronic Fuel in Injection (EFI) System, Components of an EFI system, Fuel Injectors, Types of Injection, Electronic control of engines, Requirement of Diesel Injection System, Types of Injection system for CI engine, Fuel Pump, Nozzles. Importance of ECU. Measurement and Testing of Engine Performance Parameters: Measurement of Speed, Fuel Consumption Measurement, Volumetric type flowmeters, Measurement of Air consumption, Types of the dynamometer, Measurement of Brake Power, Frictional Power, and Indicated Power, Endurance test of I C Engine as per Indian standard Air Pollution and its Control Exhaust Emissions, Effect of Various Parameter on Exhaust Emissions, Exhaust Emissions from SI and CI Engines, Working of NDIR System, Flame Ionization Detector, Schematic and Working of FID system, Chemiluminescence Analyzer, Smoke opacimeters, Principle and working of emission reduction technologies Diesel Oxidation catalyst (DOC), Diesel Particulate Filter (DPF), Selective Catalytic Reduction (SCR) and Lean NOX trap (LNT) etc. Indian emission standards for SI and CI engines. Comparison between US, European and Bharat stage emission standards Optical Diagnostics in IC Engines: Spray and combustion measurements in the optical engine and constant volume combustion chamber, Application of optical techniques such as High-speed imaging, Schlieren imaging, PIV, PLIF, Diffused back Illumination (DBI), Phase Doppler Anemometry (PDA), Combustion Luminosity Imaging, etc. Hybrid and Electric vehicles History of electric vehicles, Vehicle Power Plant and Transmission Characteristics, Basic architecture of Hybrid Drive trains, Power flow in HEVs.
Learning Outcome	By the end of this course, mechanical engineering undergraduate students should be able to: • Understand advanced concepts in Internal Combustion Engines. • Understand the application of alternative fuels in I.C. Engine and their implications for future engine design and operation. • Able to identify and explain the function of various engine components and systems, such as fuel injection systems, ignition systems, and exhaust after-treatment systems. • Understand the advanced techniques for reducing emissions from I.C. engines. • Understand the concepts of optical diagnostic techniques in I.C. Engine and use them in real-life experiments. • Understand the technologies of hybrid and electric vehicles.
Assessment Method	Mid Semester Examination, End Semester Examination, Assignments, Quiz, and Seminar.
Suggested Readings: Text Books: 1. IC Engine Fundamentals: John B. Heywood, 2nd Edition, Mc Graw Hill, 2018 2. Fundamentals of IC Engines: P. W. Gill and James Smith, Fourth Revised Edition, Oxford IBH, 1959	

3. Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design Lino Guzzella and Antonio Sciarretta, , CRC Press, 2nd Edition, 2009
4. Electric Vehicle Technology Explained: James Larminie and John Lowry, Wiley, 1st Edition, 2003

Reference Books:

1. Introduction to Internal Combustion Engines: Richard Stone, SAE Inc., 1999
2. IC Engines Combustion and Emissions, B. P. Pundir, Narosa Publications, 2010
3. IC Engine Fundamentals: V. Ganesan, Tata Mc Graw Hill
4. The Internal combustion Engine in theory and practice: C F Taylor, 2nd Edition, MIT Press, Cambridge, 1985.
5. Hydrogen Fuel for Surface Transportation: Joseph Norbeck, SAE Publications, 1996.

Course Number	ME6206
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Microfluidics and Microsystems
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3 • Equip the students with basics of fluid mechanics at microscale, unique phenomenon dominant at microscale and their benefits for real life. • To understand this interdisciplinary science of microfluidics which uses knowledge from fluid mechanics at microscale, chemistry, Electrostatics, Micro-electromechanical systems (MEMS) and Biology to help humanity by designing novel microsystems such as point of care diagnostic devices.
Course Description	Microfluidics is the research discipline dealing with transport phenomena and fluid-based devices at microscopic length scales of microns. This course aims to fulfil the need of basic understanding about fluid flow at microscale. Further, it introduces the students with electrostatics and its utility towards design of new microfluidic systems such as electroosmotic pump and Knudsen pump. In the later part, distinct types of microfabrication techniques are explained. The last chapter introduces many modern techniques related to biomedical engineering and medical science such as DNA sequencing, micropumps and point of care diagnostic devices. Prerequisite: NIL
Course Outline	Introduction: Origin, Definition, Fluid quantity, Benefits, Challenges, Commercial activities. Scaling laws: Scaling in nature, Scaling of physical systems, Trimmer's vertical bracket notation, limitations. Micro-scale flows: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations, Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects, Liquid film flow in an inclined plane, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Couette flow with slip, Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel. Capillary flows: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect. Electrokinetics: Electrohydrodynamics fundamentals, Electro-osmosis, Dielectrophoresis, Electro-capillary effects, Continuous electro-wetting, Direct electro-wetting, Electro-wetting on dielectric. Microfabrication: Materials, Clean room, Silicon crystallography, Miller indices, Oxidation, Photolithography- mask creation, spin

	coating, exposure and development, Etching, Bulk micromachining, Wafer bonding, Polymer microfabrication: PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnection. Microfluidics Components: Micropumps, Microvalves, Microflow Sensors, Micromixers, Droplet Generators, Microparticle Separators, Microreactors, DNA sequencers, Point of Care Devices.
Learning Outcome	At the end of the course, students will have achieved the following learning objectives: • Design a microfluidic network to meet the need of a microfluidic system by minimizing the overall drag reduction. • Be capable of understanding the design of existing microfluidic systems such as micropumps, Micro-reactors, DNA sequencer and other point of care devices. • To be equipped to design and develop new microfluidic systems.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Term Paper Presentation
Suggested Readings: Text/Reference Books: 1. Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002. 2. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008. 3. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002. 4. Tabeling, P., Introduction to microfluidics, Oxford University Press Inc., 2005. 5. Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010. 6. Colin, S., Microfluidics, John Wiley & Sons, 2009.	

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan. Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods. Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation. Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.). Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet

	research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to students other than ME)

IDE						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	ME6113	Soft Computing Application in Engineering	3	0	0	3

Course Number	ME6113
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Soft Computing Application in Engineering
Pre-requisite	NIL
Learning Mode	Classroom Lecture
Learning Objectives	• Introduce students to soft computing concepts and techniques and foster their abilities in designing and implementing soft computing based solutions for real-world and engineering problems. • Introduce students to fuzzy systems, fuzzy logic and its applications. • Explain the students about Artificial Neural Networks and various categories of ANN. • Integrating traditional and nontraditional optimizing algorithm to build robust soft computing tool for various applications
Course Description	This course is designed to fulfil the requirement of systems per se considering the inevitable nonlinearity in the system, which is usually ignored in analyzing system dynamics. Chaos and Hyper Chaos are frequently observed in systems and in general unattended.
Course Outline	Chapter-I: FUZZY Modeling Fuzzy Sets: Basic Definition and Terminology, Set-theoretic Operations: Member Function Formulation and Parameterization, Fuzzy Rules and Fuzzy Reasoning, Extension Principle and Fuzzy Relations: Fuzzy If-Then Rules – Fuzzy Inference Systems – Mamdani, Sugeno and Tsukamoto Fuzzy Models – Input Space Partitioning and Fuzzy Modeling. Chapter-II: NEURAL NETWORKS Supervised Learning Neural Networks – Perceptrons - Adaline – Backpropagation Mutilayer Perceptrons – Radial Basis Function Networks – Unsupervised Learning Neural Networks – Kohonen Self-Organizing Networks – Hebbian Learning, The Hopfield Network, Competitive Learning Networks – ART networks Adaptive Neuro-Fuzzy Inference Systems – Architecture – Hybrid Learning Algorithms Chapter-III: OPTIMIZATION Classical techniques: The Method of Steepest Descent, Classical Newton's Method, Advanced optimization techniques: Genetic Algorithms, Simulated Annealing, Particle swarm optimization Chapter-IV: Applications Manufacturing, Image Processing, Stock Marketing
Learning Outcome	After successful completion of this course, student will be able to

	• Understand soft computing techniques and their role in problem solving. • Conceptualize and parameterize various problems to be solved through basic soft computing techniques. • Analyze and integrate various soft computing techniques in order to solve problems effectively and efficiently.
Assessment Method	Mid Semester Examination (25%), End Semester examination (35%), Class test & quiz (30%), Assignment (10%)

Text Books:

1. J.S.R.Jang, C.T.Sun and E.Mizutani, “Neuro-Fuzzy and Soft Computing”, PHI, 2004, Pearson Education, New Edition
2. Haykin S., Neural networks a comprehensive foundation, Prentice Hall, NJ, USA, New edition.
3. Arnold Kaufmann and Madan M Gupta, Introduction to fuzzy arithmetic theory and application, International Thomson computer press, New Edition
4. Optimization in Engineering Design - Kalyanlmoy Deb, PHI, New Edition
5. Davis E.Goldberg, “Genetic Algorithms: Search, Optimization and Machine Learning”, Addison Wesley, N.Y., New Edition.

Reference Books:

6. S. Rajsekharan and G. A. Vijayalakshmi Pai, Neural networks, Fuzzy Logic, and Genetic algorithms synthesis and applications, New Delhi, PHI Publication, New Edition
7. Ham F. and Kostanic I., Principles of Neurocomputing for Science and Engineering, New York, Mcgraw-Hill, New Edition
8. Optimization methods - S. S.Rao, Wiley-Interscience, New Edition
9. J. S. Arora, Introduction to Optimum Design, Academic Press, New Edition
10. Timothy J.Ross, “Fuzzy Logic with Engineering Applications”, McGraw-Hill, New Edition.