M.Tech. Program from the Dept. of ME

M. Tech. in Thermal & Fluid Engineering

Semester wise detailed syllabus

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", 2^{nd} Edition, Pearson (1998).
12. R.K. Jain and S. R. K. Iyengar, "Advanced Engineering Mathematics" 4^{th} 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 proving 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

1. 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 Krempl, 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 al 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, Schilieren 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 conduction 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, Colllins 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-Sate 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, 2^{nd} 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 microluidic 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.