Course Curriculum for M. Tech.

in

Fluids & Thermal Engineering

(Revised syllabus for students admitted in 2020-21 onwards)

Mechanical Engineering Department

National Institute of Technology Arunachal Pradesh

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COURSE STRUCTURE

Semester I					
Course Code	**Course Title**	**Contact Hours**			**Credit**
		L	**T**	**P**	
MA-501	Advanced Numerical Methods	3	0	0	3
ME-501	Advanced Fluid Mechanics	3	0	0	3
ME-502	Conduction and Radiation	3	0	0	3
ME-503x	Elective-I	3	0	0	3
ME-504x	Elective-II	3	0	0	3
MA-503	Computing Lab	0	0	3	1.5
ME-505	Thermo-Fluid Lab-I	0	0	3	1.5
Total		**15**	**0**	**6**	**18**

Semester II					
Course Code	**Course Title**	**Contact Hours**			**Credit**
		L	**T**	**P**	
ME-521	Computational Fluid Dynamics	3	0	0	3
ME-522	Convective Heat Transfer	3	0	0	3
ME-523	Advanced Thermodynamics	3	0	0	3
ME-524x	Elective-III	3	0	0	3
ME-525x	Elective-IV	3	0	0	3
ME-526	Thermo-Fluid Lab-II	0	0	3	1.5
ME-527	Technical writing and presentation	0	0	3	1.5
Total		**15**	**0**	**6**	**18**

Semester III					
Course Code	**Course Title**	**Contact Hours**			**Credit**
		L	**T**	**P**	
ME-601	Project phase -I	0	0	28	14
Total		**0**	**0**	**28**	**14**

Semester IV					
Course Code	**Course Title**	**Contact Hours**			**Credit**
		L	**T**	**P**	
ME-621	Project phase -II	0	0	30	15
Total		**0**	**0**	30	**15**

List of subjects offered under electives

Elective-I	Elective-II	Elective-III	Elective-IV
Refrigeration and Cryogenics (ME-503A)	Jet propulsion (ME-504A)	Experimental methods (ME-524A)	Finite element analysis (ME-525A)

Gas Turbine Technology (ME-503B)	Micro and Nanoscale Energy Transport (ME-504B)	Fuels and combustion (ME-524B)	Advanced IC engine (ME-525B)
Turbomachinery (ME-503C)	Energy conversion and waste heat recovery (ME-504C)	Aerodynamics (ME-524C)	Two phase flow and heat transfer (ME-525C)
Mechatronics (ME-503D)		Heat Exchanger Design (ME-524D)	Boundary Layer Theory (ME-525D)

Semester-I

MA-501: Advanced Numerical Methods (3-0-0-3)

A. Course Objectives:

The course is designed to meet the objectives of:

1. introducing the basic concepts of round off error, truncation error, numerical stability and condition, Taylor polynomial approximations; to derive and apply some fundamental algorithms for solving scientific and engineering problems: roots of nonlinear equations, systems of linear equations, polynomial and spline interpolation, numerical differentiation and integration, numerical solution of ordinary differential equations.
2. application of computer oriented numerical methods which has become an integral part of the life of all the modern engineers and scientists. The advent of powerful small computers and workstation tremendously increased the speed, power and flexibility of numerical computing.
3. injecting future scope and the research directions in the field of numerical methods.

B. Course Content:

Algebraic and transcendental equations- Definition and sources of errors, solutions of nonlinear equations, Bisection method, Newton's method, fixed point iterations, Regula-Falsi method, convergence analysis, Newton's method for two variables.

Solution of the system of linear equations- Gauss elimination method, Gauss Jordan method, Matrix Inversion, Operations Count, LU Factorization method, Gauss-Jacobi and Gauss-Seidel method, Successive Over Relaxation method

Initial value problems- Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, Predictor-Corrector method, multistep methods and its stability analysis.

Finite difference schemes for partial differential equations- Discretization, Explicit and Implicit schemes, Consistency, Stability and Convergence, Stability analysis by matrix and Von Neumann methods, Lax's equivalence theorem, Finite difference schemes for initial and boundary value problems - FTCS, backward Euler and Crank-Nicolson schemes, ADI methods for Parabolic and Hyperbolic PDEs, Central difference schemes Elliptic PDEs

C. Text Books:

1. *Smith, G. D., "Numerical Solutions to Partial Differential Equations", 3rd edition, 1986, Oxford University Press.*
2. *Morton, K. W. and Mayers, D. F., "Numerical Solution of Partial Differential Equations", 2nd edition, 2005, Cambridge University Press.*
3. *Saha, S. R., "Numerical Analysis with Algorithm and Programming", 1st edition, 2016, CRC Press.*

D. Reference Books:

1. *Kincaid, D. and Cheney, W., "Numerical Analysis: Mathematics of Scientific Computing", 3rd edition, 2002,* AMS.
2. *Atkinson, K. E., "An Introduction to Numerical Analysis", 2nd edition, 1989, Wiley.*
3. *Conte, S. D. and Deboor, C., "Elementary Numerical Analysis - An Algorithmic Approach", 3rd edition, 1981, McGraw-Hill.*
4. *Mathews, J. H., "Numerical Methods for Mathematics Sciences and Engineering", 2nd edition, 2003, Prentice Hall of India, New Delhi.*
5. *Jain, M. K., Iyengar, S. R. K. and Jain, R. K., "Numerical method for Scientific and Engineering Computation", 3rd edition, 1993, New Age International Pvt. Ltd.*
6. *Strikwerda, J. C., "Finite Difference Schemes and Partial Differential Equations", 2nd edition, 2004, SIAM.*
7. *Lapidus, L. and Pinder, G. F., "Numerical Solution of Partial Differential Equations in Science and Engineering", 1982, John Wiley.*

E. Course Outcomes:

Upon Completion of the subject:

1. students will be skilled to do Numerical Analysis, which is the study of algorithms for solving problems of continuous mathematics.
2. students will know numerical methods, algorithms and their implementation in C++for solving scientific problems.
3. students will be substantially prepared to take up prospective research assignments.

ME-501: Advanced Fluid Mechanics (3-0-0-3)

A. Course Objectives:

This course is designed to:

1. Introduce fundamental aspects of fluid flow behaviour.
2. Learn to develop steady state mechanical energy balance equation for fluid flow systems.
3. Estimate pressure drop in fluid flow systems.

B. Course Content:

Introduction- Review of fundamental Concepts, Eulerian and Lagrangian methods of description of fluid flow; Reynolds transport equation, basic equations of motion of fluid flow, Equation of continuity, Navier-Stokes equationsand boundary conditions; Non-dimensionalization of equations and order of magnitude analysis, Euler's equations, Bernoulli's equation, dimensionless parameters and their significance, Exact solution of incompressible Navier-Stokes equations- plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between two concentric rotating cylinders.

Potential flows- Stream and Velocity potential function, Circulation, Irrotational vortex, Source and Sink, Vortex flow, Doublet, Flow past a circular cylinder, Magnus effect; Kutta-Joukowski lift theorem; Concept of lift and drag.

Boundary layer theory- D' Alemberts paradox, Prandtl's boundary layer equations, Von Karman's momentum integral equations, Blasius solution, approximate methods, transition and turbulent flows, turbulent boundary layer, instability and transition.

Compressible flow- Isentropic flow; flow with area change; normal shock waves; oblique shock wave, one and two dimensional compressible flows, compressible viscous flows, compressible boundary layers.

C. Text Books:

1. *Munson, B. R., Young, D. F., Okiish, T. H., "Fundamental of Fluid Mechanics", 6th Ed., 2009, Wiley.*
2. *White, F., "Fluid Mechanics", 8th Ed., 2017, TMH.*

D. Reference Books:

1. *Fox, R. W., McDonald, A. T., Pritchard, P. J., "Introduction to Fluid Mechanics", 6th Ed., 2003, Wiley.*
2. *Anderson, J., Modern Compressible Flow, 3rd Ed., 2017, TMH.*
3. *White, F. M., "Viscous Fluid Flow", 3rd Ed., 2017, McGraw-Hill Education.*
4. *Schlichting, H., "Boundary Layer Theory", 2011, Springer.*

E. Course Outcomes:

Upon completion of the subjects, the student should:

1. Understand the concept of fluid and the models of fluids and the physical meaning of general equations.
2. Develop the concept of stream function and potential function
3. Formulate the equation for viscous flow, including laminar flow and turbulent flow.
4. Apply the compressible flow analysis to a pipe flow and compute the pressure losses due to friction, area change in the system and assess the performance of the system.

ME-502: Conduction and Radiation (3-0-0-3)

A. Course Objectives:

The objectives of the course is:

1. To familiarize the students with the fundamental concepts of heat transfer.
2. To introduce a basic study of the phenomena of conduction and radiation to develop methodologies for solving a wide variety of practical engineering problems, and to provide useful information concerning the performance and design of particular systems and processes.
3. To impart knowledge related to design problem requiring the formulations of solid conduction and the technique of numerical computation.

B. Course Content:

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

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

Numerical method- 2-D conduction problems without and with heat generation.

Introduction to radiation- Recapitulation: Radiative properties of opaque surfaces, Intensity, emissive power, radiosity, Spectral and directional variations, View factors.

Enclosure with transparent medium- Enclosure analysis for diffuse-gray surfaces and non-diffuse, non-gray surfaces, net radiation method.

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

C. Text Books:

1. *Myers, G. E., "Analytical Methods in Conduction Heat Transfer", 1987, McGraw-Hill.*
2. *Modest, M. F., "Radiative Heat transfer", 3^rd^ Ed., 2013, Academic Press.*
3. *Ozisik, M. N., "Heat Conduction", 2^nd^ Ed., 1993, John Wiley & Sons.*

D. Reference Books:

1. *Vedat S. A., "Conduction Heat Transfer", 1987, Addison-Wesley.*
2. *Incropera, F. P., Dewitt, D. P., Bergman, T. L., "Introduction to Heat Transfer", 5^th^ Ed., 2006, John Wiley & Sons.*
3. *Siegel, R. and Howell, J. R., "Thermal Radiation Heat Transfer", 4^th^ Ed., 2002, Taylor & Francis.*

E.Course Outcomes: The course is intended to provide students with the following benefits:

1. Explain problems involving steady and transient heat conduction.
2. Formulate analytical as well as numerical solutions for heat transfer problems.
3. Understanding of basic radiation heat transfer.
4. Investigate radiation heat transfer in transparent and participating media.

MA-503: Computing Lab (0-0-3-1.5)

A. Course Objectives:

The course is designed to meet the objectives of:

1. To increase the Numerical programming skill to solve the various engineering problems,
2. To injecting future scope and the research directions in the field of numerical methods.

B. Experiments:

1. Solution of a system of Linear Equations: Gauss elimination, Gauss Jordan, Matrix Inversion, Jacobi, Gauss Seidel.
2. Find the Roots of Algebraic Equations: Bisection, Regula-Falsi, Newton- Raphson Methods.
3. Solution of Ordinary Differential Equations: Taylor Series, Euler's Method, Runge-Kutta (4th Order).
4. Solution of Partial Differential Equations: FTCS scheme, Crank-Nicolson Scheme, ADI scheme.

C. Books:

1. *Saha, S. R., "Numerical Analysis with Algorithm and Programming", 1st edition, 2016, CRC Press.*
2. *Xavier, C., "C Language and Numerical Methods", 1st edition, 1999, New Age Publisher.*
3. *Press, W. H., Teukolsky, S. A., Vetterling, W. T. and Flannery, B. P., "Numerical Recipes: The Art of scientific Computing", 3rd edition, 2007, Cambridge University Press.*

D. Course Outcomes:

Upon Completion of the subject:

1. Students will be skilled to do Numerical Analysis, which is the study of algorithms for solving problems of continuous mathematics.
2. Students will know numerical methods, algorithms and their implementation in C++for solving scientific problems.
3. Students will be substantially prepared to take up prospective research assignments

ME-505: Thermo-Fluid Lab-I (0-0-3-1.5)

A. Course Objectives:

The course is designed to meet the objectives of:

1. To introduce the student the fundamental theories and the industrial applications of fluid mechanics.
2. This laboratory supports the courses for the graduate studies.
3. This laboratory also supports the advanced research in the area of fluid mechanics.

B. Experiments:

A few experiments under this laboratory courses are:

1. Jet impact on flat and curved surfaces
2. Determination of friction factor as a function of Reynolds number in pipe flow
3. Study of the pressure distribution over smooth and rough cylinder.
4. Flow past bluff and a streamlined bodies and measurement of pressure drag.
5. Flow through converging and diverging nozzles
6. Study of the Pressure distribution over symmetric aerofoil, cambered aerofoil and thin aerofoils.
7. Shock waves and expansion patterns around a two-dimensional model in supersonic flow conditions.
8. Measurement of the velocity profile in laminar and turbulent boundary layers on rough and smooth plates.

C. Books:

1. *Fox, R. W., McDonald, A. T., Pritchard, P. J., "Introduction to Fluid Mechanics", 6th Ed., 2003, Wiley.*
2. *Anderson, J., Modern Compressible Flow, 3rd Ed., 2017, TMH.*
3. *White, F. M., "Viscous Fluid Flow", 3rd Ed., 2017, McGraw-Hill Education.*
4. *Schlichting, H., "Boundary Layer Theory", 2011, Springer.*

D. Course Outcomes:

Upon Completion of the subject:

1. Students should be capable of analysing the physical flow situation of the problem at hand.
2. Estimation of uncertainty in experiments and the so obtained results.

Semester II

ME-521: Computational Fluid Dynamics (3-0-0-3)

A. Course Objectives:

1. Equip students with the knowledge base essential for application of computational fluid dynamics to engineering flow problems.
2. Provide the essential numerical background for solving the partial differential equations governing the fluid flow.

B. Course Content:

Introduction to computational fluid dynamics and principles of conservation- Continuity Equation, Navier Stokes Equation, Energy Equation and General Structure of Conservation Equations.

Classification of partial differential equations and physical behaviour- Mathematical classification of Partial Differential Equation, Illustrative examples of elliptic, parabolic and hyperbolic equations, Physical examples of elliptic, parabolic and hyperbolic partial differential equations.

Approximate solutions of differential equations- Error Minimization Principles, Functional involving higher order derivatives, Approximate solution of differential equations through variation formulation, Boundary conditions in the variation form: Primary and secondary variables, Essential and natural boundary conditions, Approximate solutions of differential equations, Properties of variation form, Weighted residual approach: trial function and weighting function, Requirement of trial function and weighting function, Least square method, Point Collocation method, Galerkin's method, Rayleigh-Ritz method.

Fundamentals of discretization- Discretization principles: Pre-processing, Solution, Post-processing, Finite Element Method, 3 Finite difference method, Well posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Transportiveness, Finite volume method (FVM), Illustrative examples: 1-D steady state heat conduction without and with constant source term.

Finite volume method- Some Conceptual Basics and Illustrations through 1-D Steady State Diffusion Problems: Physical consistency, Overall balance, FV Discretization of a 1-D steady state diffusion type problem, Composite material with position dependent thermal conductivity, Four basic rules for FV Discretization of 1-D steady state diffusion type problem, Source term linearization, Implementation of boundary conditions.

Discretization of unsteady state problems- 1-D unsteady state diffusion problems: implicit, fully explicit and Crank-Nicholson scheme.

Finite volume discretization of 2-d unsteady state diffusion type problems- FVM for 2-D unsteady state diffusion problems.

Solution of linear algebraic equation- Basic numerical methods, Direct method, Tri-diagonal Matrix algorithm, TDMA and other iterative methods.

C. Text Books:

1. Chung, T. J., "Computational Fluid Dynamics", 2nd Ed., 2014, Cambridge University Press.
2. Anderson J. D. (Jr)., "Computational Fluid Dynamics: The basic with applications", 2017, McGraw Hill Education.

D. Reference Books:
1. Patankar, S. V., "Numerical Heat Transfer and Fluid Flow", 2017, CRC Press.
2. Versteeg, H. K., Malalasekera, W., "An Introduction to Computational Fluid Dynamics", 2nd Ed., 2007, PHI.
3. Ferziger, J. H. and Peric, M., "Computational Methods for Fluid Dynamics", 3rd Ed., 2002, Springer.

E. Course Outcomes:
Upon completion of this course, the students will be able to:
1. Understand the basic concepts and its solution for aerodynamic flow.
2. Define and setup flow problems within CFD context.
3. Solve Navier-Stokes equations with proper initial and boundary conditions.
4. Use CFD software to model relevant engineering flow problems and analyse the results.

ME-522: Convective Heat Transfer (3-0-0-3)

A. Course Objectives:
The course is design to meet with the following objectives:
1. This is one of the major courses for post graduate students which will help to understand the flow of fluids and heat transfer.
2. The focus of the course is a central theme of modern applied mathematics. Based on mathematical concepts of gradient, divergence, vorticity and tensor, the basic properties normally ascribed to fluids such as density, compressibility and dynamic viscosity will be introduced.
3. Then general equations, including continuous equation, momentum equation and energy equation are derived.
4. Therefore the course is used to model a vast range of physical phenomena and plays a vital role in science and engineering.

B. Course Content:
Introduction- Continuity, Momentum and Energy differential equations in different coordinate systems, Boundary layer Approximations/Scaling Analysis.
Laminar external flow and heat transfer- Blasius solution for flat plate, Pressure gradient flow, von Karman-Pohlhausen method for flows with pressure gradient Integral solutions for flow over an isothermal flat plate, Flat plate with constant heat flux.

Laminar internal flow and heat transfer- Fully developed forced convection in pipes with different wall boundary conditions- Hagen Poiseuille flow, Plane Poiseuille flow, and Couette flow, Graetz solution for forced convection in the thermal entrance region of ducts and channels.

Natural convection heat transfer- Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Similarity solutions for Laminar flow past a vertical plate with constant wall temperature and heat flux conditions.

Turbulent convection- Governing equations for averaged turbulent flow field (RANS), Eddy viscosity and eddy thermal diffusivity, Turbulence Models, Turbulent flow and heat transfer across flat plate and circular tube.

C. Text Books:

1. *Kays, W., Crawford, M. and Weigand, B., "Convective Heat and Mass Transfer", 4th edition, 2017, McGraw Hill Education.*
2. *Burmeister, C., L., "Convective Heat Transfer", 2nd edition, 1993, John Wiley and Sons.*
3. *Bejan, A., "Convection Heat Transfer", 3rd edition, 2006, John Wiley.*

D. Course Outcomes:

Upon Completion of the subjects, the students should:

1. be able to solve industry oriented problems.
2. understand the concept of fluid and the models of fluid flow and heat transfer for flow over external surfaces and duct of different cross-sections.
3. understand the basic physical meaning of general equations.
4. be able to derive the equation for viscous flow, including laminar flow and turbulent flow.

ME-523: Advanced Thermodynamics (3-0-0-3)

A. Course Objectives:

This subject designed to meet the following objectives:

1. To learn about thermodynamic relations, exergy, non-reactive gas mixtures in advanced level.
2. To understand the practical applications of the concepts of thermodynamics.
3. To deal with advanced thermodynamic problems in the practical fields.

B. Course Content:

Thermodynamic relations- Generalized relation for C_p, C_v, K, relations for internal energy and enthalpy, the various Tds equation, clapeyron equation, Helmhotz free energy function, Gibbs free energy function, coefficient of volumetric expansion, isothermal compressibility, differential relation for U, H, G and F-Maxwell relations.

Exergy- Introduction, definition, exergy of closed and open system, exergetic efficiency, exergy analysis of systems and components, entropy generation minimization, finite time thermodynamics, thermo economics.

Non-reactive gas mixtures- introduction, basic definitions for gas mixtures, p-v-t relationship for mixtures of ideal gases, properties of mixtures of ideal gases, entropy change due to mixing, mixtures of perfect gases at different initial pressure and temperatures.

Direct energy conversion- Introduction, thermoelectric converters, thermo-ionic converters, magneto hydrodynamics generators, solar power cells plant, fuel cell hydrogen, hydrogen fuel cells, direct and indirect oxidation fuel cells, biochemical fuel cells.

Statistical thermodynamics- Introduction to statistical thermodynamics

C. Text Books:

1. *Wylen, G. V. and Sontag, R. E., "Fundamentals of Classical Thermodynamics", 4th Ed., 1994,Wiley Eastern Limited, New Delhi.*
2. *Moran, M. J. and Shapiro, H. N., "Fundamentals of Engineering Thermodynamics", 8th Ed., 2014, John Wiley and Sons.*
3. *Sears, F. W. and Salinger, G. L., "Thermodynamics, Kinetic Theory and Statistical Thermodynamics", 1998, Narosa Publishing House, New Delhi.*

D. Course Outcomes:

After studying this course, students will be able to

1. Understand the basic principles of advanced thermodynamics.
2. Apply the exergy concepts in entropy generation.
3. Create pressure, volume and temperature relationships for mixtures of ideal and perfect gases.
4. Identify the latest direct energy conversion systems and also know about statistical thermodynamics.

ME-526: Thermo-Fluid Lab-II (0-0-3-1.5)

A. Course Objectives:

The course is designed to meet the objectives:

1. to introduce the student the fundamental theories and the industrial applications of fluid mechanics, heat transfer, I. C engine etc.
2. this laboratory supports the courses for the graduate studies.
3. this laboratory also supports the advanced research in the area of thermal and fluid mechanics.

B. Experiments:

1. Forced Convective Heat Transfer.
2. Boiling Heat Transfer
3. Measurement and Analysis of combustion parameters in I.C. engines.
4. Performance of a vapour compression refrigeration system.
5. Turbine and pump characteristics.
6. Use of softwares: COMSOL, FLUENT (ANSYS).

C. Books:

1. *Fox, R. W., McDonald, A. T., Pritchard, P. J., "Introduction to Fluid Mechanics", 6th edition, 2003, Wiley.*
2. *Burmeister, C., L., "Convective Heat Transfer", 2nd edition, 1993, John Wiley and Sons.*
3. *Dossat, R. J., "Principles of Refrigeration", 4th edition, 2002, Pearson Education.*
4. *V. Ganesan, "Internal Combustion Engines", 2nd edition, Tata McGraw-Hill.*

D. Course Outcomes:

Upon Completion of the subject:

1. Students should be capable of 11nalyzing the physical heat transfer, I. C. engine problem at hand.
2. Estimation of uncertainty in experiments and the so obtained results.

ME-527: Technical writing and presentation (0-0-3-1.5)

Individual students or group of students (maximum of two) are required to choose a topic of their interest preferably from *outside the M.Tech projects* and give a seminar on that topic about 30 minutes. A committee consisting of at least three faculty members including course coordinator shall assess the presentation of the seminar and award marks to the students. Each student/group shall submit two copies of a write up of his / her seminar topic. One copy shall be returned to the student after duly certifying it by the assessing committee and the other will be kept in the departmental library. Internal continuous assessment marks are awarded based on the relevance of the topic, presentation skill, quality of the report and participation.

ELECTIVES

ME-503A: Refrigeration and Cryogenics (3-0-0-3)

A. Course Objectives:

The course is design to meet with the following objectives:

1. To enable students to select alternate new azeotrope and mixed refrigerants based on application in a various refrigeration system.
2. To enable students to analyse low temperature refrigeration systems.
3. To enable students to present design aspects of various refrigeration systems and its components.
4. To enable students to evaluate refrigeration systems to improve the performance.
5. To encourage the dissemination of information concerning low temperature processes and techniques.

B. Course Content:

Refrigeration

Introduction- Review of basic principles of refrigeration, methods of producing cold.

Air refrigeration systems- basic and practical cycles, air craft refrigeration systems, DART.

Vapour compression systems- V-C refrigeration systems- ideal and actual cycles, single and multi- stage systems, cascade systems.

Absorption refrigeration systems- properties of fluid mixtures, simple and practical cycles, NH_3-H_2O and LiBr-H_2O VAR systems.

Refrigerants- Classification, nomenclature, Desirable properties of refrigerants, replacement and selection of refrigerants.

Other refrigeration systems- steam jet, pulse-tube, hilse-tube, piezoelectric refrigeration systems.

Cryogenic

Thermodynamics of gas liquefaction- liquefaction cycles- cryogenic refrigeration systems down to milli Kelvin range. Properties of cryogenic liquids, superfluidity. properties of solids at cryogenic temperatures: mechanical, thermal, electrical and magnetic properties, superconductivity. Storage and transfer of cryogenic liquids, liquid level. Typical applications of refrigeration and cryogenics.

C. Text Books:

1. *Mukhopadhyay, M., "Fundamentals of Cryogenic Engineering", 4th edition, 2010, Prentice Hall India Learning Private Limited.*
2. *Dossat, R. J., "Principles of Refrigeration", 4th edition, 2002, Pearson Education.*

D. Reference Books:

1. *Barron, R. F., "Cryogenic Systems" 2nd edition, 1985, Oxford University Press.*
2. *Stoecker, W. F., "Refrigeration and Air Conditioning", 2nd edition, 2014, Tata McGraw-Hill.*

E. Course Outcomes:

Upon completion of the subject, students should:

1. Select appropriate new eco-friendly refrigerants according to application in various types of refrigeration systems.
2. Design and analyze low temperature refrigeration systems.
3. Design and analyze the refrigeration systems for various applications.
4. Evaluate the refrigeration systems to improve the performance.
5. Describe various methods to produce low temperature and phenomena's at cryogenic temperature.

ME-503B: Gas Turbine Technology (3-0-0-3)

A. Course Objectives:

1. This course is designed to have an advanced understanding of the theory and operation of gas turbine engines.
2. To apply thermodynamic principles to calculate parameters such as pressure and temperature in Gas Turbine Engines as used in aircraft.

B. Course Content:

Fundamentals of turbo machines- Classification, Applications, Isentropic flow, Energy transfer, Efficiency, static and Stagnation conditions, continuity equation, Euler's flow through variable cross sectional area, unsteady flow in turbo machine.

Gas dynamics- Fundamentals, thermodynamic concepts, Isentropic conditions, Mach number and Area – Velocity relation, Dynamic pressure, normal shock relations for perfect gas, supersonic flow, oblique shock waves.

Centrifugal compressors- Elements of compressor stage, Velocity triangles and efficiencies, Blade passage design, Diffuser and pressure recovery, slip factor, Compressor performance - Stall and surge, Performance characteristics.

Axial flow compressors- Flow analysis, work and velocity triangles, Efficiencies, Thermodynamic analysis, stage pressure rise, Degree of reaction, stage loading, Free and forced vortex blades, Effect of axial velocity and incidence on velocity triangles, Performance characteristics.

Axial flow gas turbines- Work done; velocity triangles and efficiencies; thermodynamic flow analysis, degree of reaction, Free-vortex blades, Blade angles for variable degree of reaction, Matching of compressor and turbine.

C. Text Books:
1. *Breeze, P., "Gas-Turbine Power Generation", 2016, Academic Press.*
2. *Ganesan, V., "Gas Turbines", 3^{rd} Ed., 2017, Tata McGraw-Hill.*

D. Reference Books:
1. *Saravanamuttoo, "Gas Turbine Theory", 5^{th} Ed., 2006, Pearson Education.*

E. Course Outcomes:
Students will be able to:
1. Describe the fundamentals of turbo machines as well as flow in turbo machines.
2. Analyse the conditions and concepts of gas dynamics at different levels.
3. Apply the thermodynamics of aircraft propulsion systems, air compressor and gas turbines.
4. Calculate velocity triangles, work done etc. for flow in gas turbine and air compressors.

ME-503C: Turbomachinery (3-0-0-3)

A. Course Objectives:
The course is designed to:
1. Provide a thorough understanding of the principles and applications of turbomachinery in modern industry.
2. Analyse a useful tool for designing and researching on turbomachinery instruments.

B. Course Content:
Centrifugal fans and blowers - Types- stage and design parameters-flow analysis in impeller blades-volute and diffusers, losses, characteristic curves and selection, fan drives and fan noise.

Centrifugal compressor - Construction details, impeller flow losses, slip factor, diffuser analysis, losses and performance curves.

Axial flow compressor - Stage velocity diagrams, enthalpy-entropy diagrams, stage losses and efficiency, work done simple stage design problems and performance characteristics.

Axial and radial flow turbines - Stage velocity diagrams, reaction stages, losses and coefficients, blade design principles, testing and performance characteristics.

C. Text books:
1. *Yahya, S. M., "Fundamentals of Compressible Flow", 6^{th} Ed., 2018, New Age International (P) Limited.*
2. *Stepanoff, A.J., "Turboblowers", John Wiley & Sons.*

D. Reference Books:
1. *Church, A. H., "Centrifugal pumps and blowers", 1944, John Wiley and Sons.*
2. *Dixon, S. L. and Hall, C. A., "Fluid Mechanics and Thermodynamics of turbomachinery", 7^{th} Ed., 2014, Pergamon Press.*

E. Course Outcomes:

Upon completion of the subject, the students should:

1. Understand the concept of fluid mechanics and thermodynamics in turbomachinery.
2. Describe the basic characteristics of radial and axial pumps, compressors, turbines and fans with different kinds of working mediums.
3. Determine performance of compressor and turbine.
4. Analyse the fluid mechanics responsible for limits of turbomachinery operability and stability, particularly, stall, surge, cavitations, and choke.

ME-503D: Mechatronics (3-0-0-3)

A. Course Objectives:

1. Generate conceptual design for Mechatronics systems based on potential customer requirements.
2. Selection of appropriate sensors and transducers and devise an instrumentation system for collecting information about processes, control systems.
3. Design a control system for effective functioning of Mechatronics systems using digital electronics, microprocessors, microcontrollers and programmable logic controllers.
4. Selection of appropriate actuators for physical systems.
5. Study design of robot as case study.

B. Course Content:

Introduction: Introduction to Mechatronics, need and applications, Philosophy and approach; Systems and Design: Mechatronic approach, Integrated Product Design, Modeling, Analysis and Simulation, Man Machine Interface; , role of mechatronics in automation, manufacturing and product development.

Sensors and transducers: characteristics, classification, working principles, Development in Transducer technology, Opto-electronics Shaft encoders, strain, velocity , Acceleration, LVDT, temperature Sensors, Vision System, etc.

Drives and Actuators: Hydraulic and Pneumatic drives, Electrical Actuators such as servo motor and Stepper motor, Drive circuits, open and closed loop control; Embedded Systems: Hardware Structure, Software Design and Communication, Programmable Logic Devices, Automatic Control and Real Time Control Systems;

Smart materials: Shape Memory Alloy, Piezoelectric and Magnetostrictive Actuators, Micro-sensors, Micro-actuators;

Application: Case studies based on the application of mechatronics in manufacturing, Machine Diagnostics, Road vehicles and Medical Technology, bionics and avionics. Industrial robotics, types of Industrial robots, classification based on work envelope, Generations configurations and control loops, co-ordinate systems, need for robot, basic parts and functions, specifications.

C. Text Books:

1. *Bolton, W., "Mechatronics, Electronic control systems in mechanical and electrical engineering", 5th Ed., 2011, Pearson Education.*
2. *Alcaiatore, G.D., Michel B. H., "Introduction to Mechatronics and Measuring Systems", 3rd Ed., 2006, Mc. Graw Hill International.*
3. *Robert H. B., "The Mechatronics Handbook", 2nd Ed., 2007, CRC Press.*

D. Reference Books:

1. *Stenersons, J., "Fundamentals of Programmable Logic Controllers Sensors and Communications", 3rd Ed., 2004, Pearson Education.*
2. *Kuttan K. A., "Introduction to Mechatronics", 2007, Oxford University Press.*

A. Course Outcomes:

Students who successfully fulfil the course requirements will:

1. Be able to identify the need of mechatronics and integrated product design procedure and role of mechatronics in various engineering fields.
2. Have basic understanding of various types of sensors and transducers including modelling
3. Study and select appropriate actuators and drivers along with design of control system and modelling.
4. Have case studies and design of robotic systems and application of mechatronic in system design.

ME-504A: Jet Propulsion (3-0-0-3)

A. Course Objectives:

1. This course is designed to teach the principles of jet propulsion.
2. The primary focus of the course is on the teaching of thermodynamics and Gas dynamics in aircraft engines.
3. The course will provide information that will enable the engineering analysis of ramjets and turbine engines and its separate components including inlets, nozzles, combustion chambers, compressors.

B. Course Content:

Basic theory of Jet propulsion devices and historical development. Types of various jet propulsion plants like air screw, turboprop, turbojet, Ram jet, pulse jet, rocket propulsion, etc. and their comparative study.

Performance study of various jet propulsion devices from ideal and practical consideration. Study and design considerations of main components of jet propulsion plants. Thrust augmentation devices and their thermodynamic analysis.
Combustion performance, products of combustion and their properties.
Recent advances in jet propulsion devices.

C. Text Books

1. *Flack, R. D., "Fundamentals of Jet Propulsion with Applications", 2011, Cambridge University Press.*
2. *Hill, P. and Carl, P., "Mechanics and Thermodynamics of Propulsion", 2nd edition, 2009, Pearson Education.*
3. *Mattingly, J. D., "Jet Propulsion", 2006, McGraw Hill Inc.*

D. Reference Books:

1. *Roy, B., "Aircraft Propulsion", 1st edition, Elsevier (India).*
2. *Ahmed, E. A., "Aircraft Propulsion and gas Turbine Engines", 2nd edition, 2017, CRC press.*

E. Course Outcomes:

Students successfully completing this course will get:

1. a basic understanding of thermodynamic cycles of jet engines.
2. a basic understanding of the compressible fluid flow in inlets and compressors and turbines.

3. a basic understanding of the combustion physics in combustion chambers.
4. a basic understanding of the rational behind several types of jet engines. The ability to analyze jet engines; determine propulsion efficiency and design inlets and nozzles.

ME-504B: Micro and Nanoscale Energy Transport (3-0-0-3)

A. Course Objectives:

The course is designed to meet with the following objectives:
1. Gain an understanding of the fundamental elements of solid-state physics and quantum mechanics.
2. Develop skills to derive continuum physical properties from sub-continuum principles.
3. Apply statistical and physical principles to describe energy transport in modern small-scale materials and devices.

B. Subject Matter:

Transport phenomena applied to micro-nano scale, basic heat transfer and kinetic theory, transport phenomena, photons, electrons, phonons, energy carriers, energy transport, heat transport, energy levels, statistical behavior, internal energy, waves and particles, scattering, heat generation,Quantum statistics, Bose – Einstein statistics, Fermi – Dirac statistics, Boltzmann equation, Classical laws, Fourier, Newton, Ohm, thermoelectric effect, Brownian motion, surface tension, van der Waals potential.

C. Text Books:

1. *Chen, G., "Nanoscale energy transport and conversion", 1st edition, 2005, Oxford University Press.*
2. *Sobhan, C. B. and Peterson, G. P., "Microscale and Nanoscale Heat Transfer", 1st edition, 2008, CRC press.*
3. *Zhang, Z. M., "Nano/Microscale Heat Transfer", 1st edition, 2007, McGraw-Hill.*

D. Reference Books:

1. *Tien, C. L., Majumdar, A., and Gerner, F. M., "Microscale energy Transport", Illustrated edition, 1998, Taylor & Francis.*
2. *Faghri, M., and Sunden, B., "Heat and Fluid Flow in Microscale and Nanoscale Structures", Illustarted edition, 2003, WIT Press.*

E. Course Outcomes:

Upon completion of the subject, the students should learn:
1. the recent developments in thermal science and engineering related to micro/nanoscale technologies.
2. the fundamentals of nano/microscale heat transfer and thermophysics as applied to emerging technologies, as well as methodology for solving practical problems in small dimensions and/or short time periods.
3. the microscopic descriptions and approaches in thermal science, including the equilibrium statistics, Boltzmann transport equation, and nanoscale heat conduction and radiation.

ME-504C: Energy Conversion and Waste Heat Recovery (3-0-0-3)

A. Course Objectives:

1. To impart knowledge in the domain of energy conservation
2. To bring out Energy Conservation Potential and Business opportunities across different user segments under innovative business models.
3. To inculcate knowledge and skills about assessing the energy efficiency of an entity/ establishment.
4. To understand and analyze the present and future energy demand of world and nation and techniques to exploit the available renewable energy resources such as, solar, bio-fuels, wind power, tidal and geothermal effectively.

B. Course Content:

Introduction- Introduction to energy conversion technologies, Waste Heat, Importance of Waste Heat Recovery.

Energy Economics.

In Power plant cycles- Energy Cascading, Combined Cycles, Cogenerations, Bottoming Cycle options for WHR.

In refrigeration- Vapor Absorption Refrigeration, Ejector Refrigeration.

Heat exchangers for waste heat recovery- Recuperator, Regenerator, Special Heat Exchanger Devices, Heat pipes & Vapor Chambers, Prime movers, Heat Recovery from Incinerators.

Energy conversion technologies- Thermoelectric Generators, Thermoionic conversion, Thermo-PV, MHD and others.

Energy storage techniques- Pumped hydro, Compressed Air, Flywheel, Superconducting Magnetic storage etc., Chemical, Thermal, electrical, magnetic and chemical storage systems.

Energy economics

C. Text Books:

1. *Harlock, J. H., "Combined Heat and Power", Pergaman Press.*
2. *Kreith, F. and West, R. E., "Energy Efficiency", 1st edition, 1996, CRC Press.*

D.Reference Books:

1. *Kays, W. M. and London, A. L., "Compact Heat Exchangers", 3rd edition, 1998, McGraw-Hill.*

E. Course Outcomes:

1. Obtain knowledge about energy conservation policy, regulations and business practices.
2. Analyse energy systems from a supply and demand perspective.
3. Recognize opportunities for enabling rational use of energy.
4. Apply knowledge of Energy Conservation Opportunities in a range of contexts.
5. Develop innovative energy efficiency solutions and demand management strategies.

ME-524A: Experimental Methods (3-0-0-3)

A. Course Objectives: The course is design to meet with the following objectives:

1. To learn basic concept of experimental methods.
2. To learn techniques involve in measurement and its principles.

3. To familiar with different measuring instruments related to fluid flow and heat transfer.
4. To learn methods of measurement of physical quantities and uncertainty analysis.

B. Course Content:

Introduction- Importance of measurement and experimentation, Basic issues in measurements, Signal flow diagram of measurement system.

Principles of measurement- Causes and types of errors in measurement, Error analysis and method for error estimate, Propagation of errors, Regression analysis, Calibration, Curve fitting and quality of curve fitting, zero order, first order, second order systems, Inputs and their methods of correction - broad category of methods for measuring field and derived quantities, Design of experiments, control systems, PID, LVDT, data acquisition.

Pressure measurement- Manometers, Electric pressure transducers, Bourdon tube pressure gage, Diaphragm gage.

Flow rate measurement- Positive displacement flow meters, venture, orifice, impact tube, flow nozzle, sonic nozzle, rotameter, pitot static tube, hot-wire anemometer, laser Doppler anemometer, flow visualization techniques – shadowgraph, Schlieren and interferometer.

Thermometry- Hg-in-glass thermometer, RTD, thermocouple, optical pyrometer, Effect of heat transfer on temperature measurement, errors of system/sensor interaction.

Thermal conductivity measurement- Guarded hot plate apparatus, heat flux meter.

Uncertainty analysis.

C. Text Books:

1. *Holman, J. P., "Experimental Methods for Engineers", 7th Ed., 2017, McGraw Hill Education.*
2. *Beckwith, T.G., Lienhard, J. H. and Marngoni, V. R. D., "Mechanical Measurements", 6th Ed., 2013, Pearson Education.*

D. Reference Books:

1. *Dally, J. W., Riley, W. F. and McConnel, K. G., "Instrumentation for Engineering Measurements", 2nd Ed., 1993, John Wiley & Sons.*
2. *Doebelin, E.O. "Measurement systems, Application and Design", 2nd Ed., 1990, Tata McGraw-Hill.*

E. Course Outcomes:

Upon completion of the subject, students will be able to:
1. Understand the basics of errors in measurement and its importance.
2. Describe mathematical and experimental techniques involved in measurement of different physical quantities.
3. Analyse calibration of measuring instruments.
4. Evaluate uncertainty in measured and derived quantities.

ME-524B: Fuels and Combustion (3-0-0-3)

A. Course Objectives:
1. To understand solid, liquid and gaseous fuel properties, analysis, process and handling
2. To know the stoichiometry relations and combustion process
3. To learn about features of different types of burners.
4. To understand about emissions.

B. Course Content:

Introduction: History of Fuels, classification, properties, Production, present scenario and consumption pattern of fuels.

Solid Fossil fuel (Coal): Definitions and properties, classification, Analysis- Proximate and ultimate, composition, preparation, combustion techniques, liquefaction, Gasification.

Liquid Fossil fuel (Petroleum): exploration, evaluation, Refining of Petroleum, cracking, Synthesis of Gasoline-Fischer-Tropsch process. And Bergius process, distillation, Hydro-treatment, dewaxing, deasphalting, Refining of Petroleum.

Gaseous Fuels: Natural gas, LPG, Producer gas, Water gas, Hydrogen, Acetylene and Other fuel gases.

Power alcohol and Biodiesel: Production of ethanol, Production of biodiesel, Flue Gas Analysis.

Combustion Technology: Fundamentals of thermochemistry, Combustion air calculation, Calculation of calorific value of fuels, Adiabatic flame temperature calculation, Mechanism and kinetics of combustion, Flame-premixed and diffusion flames, Flame Properties, Combustion devices-Burners, Furnaces, Gasifiers, IC Engines, Nuclear Reactors.

Emissions: Emission index, corrected concentrations, control of emissions for premixed and non-premixed combustion.

C. Text Books:
1. *Turns, S., An Introduction to Combustion: Concepts and Applications, 3rd Ed., 2017, McGraw-Hill.*
2. *Sarkar, S., Fuels and Combustion, 3rd Ed., 2009, Universities Press.*

D. Reference Books:
1. *Glassman, I., Combustion, 3rd Ed., 1997, Academic Press.*
2. *Griswold,J., Fuels Combustion and Furnaces, 2006, Mc-Graw Hill.*

E. Course Outcomes:

The student will be able to:
1. Identify the types of fuels (solid, liquid and gas).
2. Understand design considerations of burners.
3. Develop the mechanism and kinetics of combustion principles.
4. Analyse exhaust and flue gases.

ME-524C: Aerodynamics (3-0-0-3)

A. Course Objectives:

1. Formulate and apply appropriate aerodynamic models to predict the forces on and performance of realistic three-dimensional configurations;
2. Assess the applicability of aerodynamic models to predict the forces on and performance of realistic three-dimensional configurations and estimate the errors resulting from their application;

B. Course Content:

Aircraft and Aerodynamic Forces and Moments, Fluids and Forces in Fluids, Kinematics of fluid motion, Velocity with specified extension and vorticity, Vorticity Distribution, Velocity without expansion and vorticity Navier - Stokes Equation, Conservation of Energy and Energy Equation, Equations of Motions, Exact Solution for Simple Problems, Non-dimensional Form of the Equations and Possible Simplifications, High Reynolds Number Approximation, Conditions fior Incompressibility, Potential Flow-Combination of Basic Solutions.

C. Text Books:

1. *Anderson, J., "Fundamentals of Aerodynamics" 5th edition, 2011, TMH.*

D. Course Outcomes:

1. Define basic aerodynamic forces acting on an aircraft
2. Define aerodynamic devices on an aircraft
3. Explain the changes in the characteristics of compressible and incompressible flows through variable-area sections using mathematical relations.

ME-524D: Heat Exchanger Design (3-0-0-3)

A. Course Objectives:

The objective of this course is to exhibit how real components are desigend in industry following the principles outlined here.

B. Course Content:

Introduction- Types of heat exchangers, shell and tube heat exchangers, regenerators and recuperators, Temperature distribution and its implications, Parts description.

Process design of heat exchangers- Heat transfer correlations, Overall heat transfer coefficient, analysis of heat exchangers, LMTD and effectiveness method. Sizing of finned tube heat exchangers, U tube heat exchangers, Design of shell and tube heat exchangers, fouling factors, pressure drop calculations.

Stress analysis- Stress in tubes, types of failures, buckling of tubes, flow induced vibration.

Compact and plate exchanger- Types, Merits and Demerits, Design of compact heat exchangers, plate heat exchangers, performance influencing parameters, limitations.

Condensers and cooling towers- Design of surface and evaporative condensers, cooling tower, performance characteristics.

C. Text Books:

1. *Shah, R. K. and Sekulic, D. P., "Fundamentals of Heat Exchanger Design", 2012, John Wiley & Sons.*

D. Reference Books:

1. *Cengel, Y. A., "Heat transfer: A Practical Approach", 2006, McGraw Hill*
2. *Kakac, A. and Liu, H., "Heat Exchangers", 3rd edition, 2012, CRC Press.*
3. *Kays, W. M. and London, A. L., "Compact Heat Exchangers", 2016, Krieger Pub Co.*

E. Course Outcomes:

1. Analyze heat exchanger performance by using the method of log mean temperature difference.
2. Students will be able to design various heat exchanger like shell & tube heat exchanger, plate heat exchanger.

ME-525A: Finite Element Analysis (3-0-0-3)

A. Course Objectives:

1. To apply vector mechanics as a tool for problem solving
2. To Understand the need in Design for the Finite Element Method
3. To understand mechanical engineering design concepts to use the Finite Element Method software correctly and efficiently
4. To analyze a physical problem, develop experimental procedures for accurately investigating the problem, and effectively perform and document findings.
5. To understand forces associated with different parts of a machine

B. Course Content:

Overview of engineering systems- Continuous and discrete systems Energy methods: Variational principles and weighted residual techniques (least square method, collocation, sub-domain collocation, Galerkin method) for one-dimensional equation, Rayleigh-Ritz Formulation, development of bar and beam element, application to truss and frames.

Finite elements for two-dimensions- Equivalence between energy formulation and Galerkin approach, discretization concepts, choice of elements, derivation of element shape functions (Lagrangian and Hermite) in physical coordinates, Iso-parameteric mapping, numerical integration, Assembly procedure, solution techniques.

Introduction to finite element programming- Applications to problems in engineering: plane elasticity, heat conduction, potential flow and Transient problems. Computer implementation.

C. Text Books:

1. *Bathe, K. J., "Finite element procedures", 2006, Prentice Hall, Indian edition.*
2. *Fish, J. and Belytschko, T., "A first course in finite elements", 2007, Wiley, USA.*
3. *Cook, R. D., Malkus, D. A., Plesha, M. E., Witt, R. J., "Concepts and Applications of finite element analysis", 4th edition, 2002, John Wiley & Sons.*

D. Reference Books:

1. *Szabo, B. and Babuska, I., "Introduction to finite element analysis", 2011, John Wiley & Sons, UK.*
2. *Zienkiewicz, O. C. and Taylor, R. L., "The finite element method", Volume 1 & 2, 5th edition, 2000, Butterworth Heinemann, New Delhi.*

E. Course Outcomes:

Student will be able to:

1. understand the numerical methods involved in Finite Element Theory
2. understand the role and significance of shape functions in finite element formulations and use linear, quadratic, and cubic shape functions for interpolation
3. understand direct and formal methods for deriving finite element equations
4. understand global, local, and natural coordinates
5. understand the formulation of one-dimensional elements (truss and beam)
6. understand the formulation of two-dimensional elements (triangle and quadrilateral continuum and shell elements)
7. understand the formulation of three-dimensional elements (tetrahedral and brick elements)

ME-525B: Advanced IC Engine (3-0-0-3)

A. Course Objectives:

1. To understand the underlying principles of operation of different IC engines and components.
2. To understand the combustion process in SI engine and CI engine and emissions formation during the combustion cycle and their treatment.
3. To provide knowledge on pollutant formation, control, alternate fuel.

B. Course Content:

Spark ignition engines- Mixture requirements, Fuel injection systems, Single point, Multipoint & Direct injection, Stages of combustion, Normal and Abnormal combustion, Knock, Factors affecting knock, Combustion chambers.

Compression ignition engines- Diesel Fuel Injection Systems, Stages of combustion, Knocking, Factors affecting knock, Direct and Indirect injection systems, Combustion chambers, Fuel Spray behaviour, Spray structure and spray penetration, Air motion, Introduction to Turbocharging.

Pollutant formation and control- Pollutant, Sources, Formation of Carbon Monoxide, Unburnt hydrocarbon, Oxides of Nitrogen, Smoke and Particulate matter, Methods of controlling Emissions, Catalytic converters, Selective Catalytic Reduction and Particulate Traps, Methods of measurement, Emission norms and Driving cycles.

Alternative fuels- Alcohol, Hydrogen, Compressed Natural Gas, Liquefied Petroleum Gas and Bio Diesel, Properties, Suitability, Merits and Demerits, Engine Modifications.

Recent trends- Air assisted Combustion, Homogeneous charge compression ignition engines, Variable Geometry turbochargers, Common Rail Direct Injection Systems, Hybrid Electric Vehicles, NOx Adsorbers, Onboard Diagnostics.

C. Text Books:

1. *Ganesan, V., "Internal Combustion Engines", 4th edition, 2017, Tata McGraw-Hill.*
2. *Smith, D., "Auto Fuel Systems", 2nd edition, 1992, The Good Heart Willcox Company, Inc.*

D. Reference Books:

1. *Mathur. R.P. and Sharma, M. L., "Internal Combustion Engines", 2014, Dhanpat Rai & Sons.*
2. *Ramalingam, K. K., "Internal Combustion Engine Fundamentals", Scitech Publications.*
3. *Chowenitz, E., "Automobile Electronics", SAE Publications.*

E. Course Outcomes:

The student will be able to explain

1. design parameters like fuel-air mixtures and cycle analysis
2. gas exchange processes and motion of charge in the cylinder and its effects on combustion process in SI and CI engines and control the pollutant formation
3. flow in carburetor and Intake manifolds
4. future internal combustion engine technology

ME-525C: Two-phase Flow and Heat Transfer (3-0-0-3)

A. Course Objectives:

The course is designed to meet with the following objectives:

2. To provide a rudimentary exposure to the thermo-fluid transport phenomena in one of the simplest multiphase systems: two-phase.
3. To formulate and solve problems associated with two-phase flow phenomena.
4. Design heat transfer equipment in which phase change (boiling or condensation) takes place.

B. Course Content:

Introduction- Basic definitions; Review of one-dimensional conservation equations in single phase flows; Governing equations for homogeneous; pressure gradient components; flow patternsmaps for horizontal and vertical systems; Simplified treatment of stratified, bubbly, slug and annular flows, Pressure Drop in Two-Phase Flow, brief discussion on Critical Flow.

Basic flow models- Homogeneous flow model, pressure gradient, twophase friction factor for laminar flow and turbulent flow, two phase viscosity, modeling of two phase flow.

Boiling- Evaporation, nucleate boiling, convective boiling; bubble formation and limiting volume; boiling map; nucleation and dynamics of single bubbles, critical boiling conditions; static and dynamic instabilities;empirical correlations in two phase flow, critical heat flux and interfacial phenomena, rohsenow correlation for nucleate boiling, pool and boiling crisis.

Condensation- Types of condensation, Nusselt theory, deviations from Nusselt theory, practical equations, condensation of flowing vapors; introduction to boiling and condensation in small passages.

C. Text Books:

1. *Ghiaasiaan, S. M., "Two-Phase flow, Boiling, and Condensation", 2nd edition, 2017, Cambridge UniversityPress.*

2. *Brennen, C.E., "Fundamentals of Multiphase Flow", 1st edition, 2009, Cambridge University Press.*

D. References

1. *Collier, J. G. and Thome, J. R., "Convective Boiling and Condensation", 3rd edition, 1996, Oxford UniversityPress.*
2. *Tong, L. S. and Tang, Y. S., "Boiling Heat Transfer and Two-Phase Flow", 2nd edition, 1997, CRC Press.*

E. Course Outcomes:

Upon completion of the subject, the students should:

1. describe the most important phenomena and principles of two-phase flow in engineering applications.
2. apply the basic two-phase models and flow pattern maps to calculate the pressure drops of two-phase flow at various conditions.
3. apply the models of critical flow and flooding to analyze limiting flow of engineering processes.
4. explain the main points of boiling and condensation, heat transfer, and their enhancement methods.
5. describe the concept boiling crisis (e.g., DNB - departure from nucleate boiling, and dryout) and its modelling.

ME-525D: Boundary Layer Theory (3-0-0-3)

A. Course Objectives:

The course is design to meet with the following objectives:

1. An understanding of fluid mechanics fundamentals, including concepts of mass and momentum conservation.
2. Knowledge of laminar and turbulent boundary layer fundamentals.
3. An exposure to recent developments in fluid mechanics, with application to aerospace systems.

B. Course Content:

Introduction- A general review of basic concepts, physics and mathematical descriptions of viscous flow; BL parameters; Prandtl Laminar BL equations.

Navier-stokes equation and its application- Navier-Stokes equations and some of the exact solutions; Understand the boundary layer model and different analytic methods.

Solution to boundary layer- Flat plate at zero angle of incidence, method of exact solution Blassius solution to boundary layer problems, Approximate solutions - Vonkarman solution to boundary layer flows over the flat plate, flow with pressure gradient, flow over a cylinder, plane Couette flow, flow between parallel plates.

Thermal boundary layers- Heat transfer from heated surface. Heat transfer from cold surface, thermal boundary layer growth over the hot and cold surface, flow over the flat plate with different flow conditions with heat transfer, exact and approximate solutions to thermal boundary layer flows relation between thermal and hydrodynamic boundary layer theories, Reynolds analogy and Colburn analogy, non-dimensional numbers governing boundary layer flows.

Boundary layer control- Need of boundary layer control, causes of boundary layer separation, flow over the cylinder and aerofoil for different flow conditions leads separation, Advanced Boundary layer Theory-

Similarity solutions to the BL equations (other than a flat plate); Similarity solutions to thermal BL; Energy Equation in thermal BL.

C. Text Books:

1. *Schlichting, H. and Gersten, K., Boundary Layer Theory, 8th edition, 2000, Springer.*
2. *Panton, R. L., Incompressible Flow, 3rd edition, 2006, Wiley,*

***D.* Reference Books:**

1. *White, F., "Fluid Mechanics", 8th edition, 2017, TMH.*
2. *Munson, B. R., Young, D. F., Okiish, T. H., "Fundamental of Fluid Mechanics", 7th edition, 2012, Wiley.*

E. Course Outcomes:

Upon completion of the subject, students will have the:

1. knowledge of basic fluid dynamics.
2. knowledge of control volume analysis.
3. ability to use differential equations to understand pressure and velocity variations.
4. knowledge of dimensional analysis.
5. ability to determine "losses" in flow systems.

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