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# 2 | Department of Mechanical and Aerospace Engineering

## 2.1 MTech in AE (2020)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| AE5010 | 3 | Introduction to Flight |
| ME5130 | 3 | Finite Element Method |
| AE5020 | 3 | Aerospace Structural Mechanics |
| LAXXXX | 1 | English Communication |
| **Semester 2** | | |
| AE5030 | 3 | Flight Vehicle Aerodynamics |
| ME5700 | 3 | Analysis and Design of Composite Structures |
| MEXXXX | 1 | Seminar |
| MEXXXX | 6 | Department Electives |
| MEXXXX | 1 | Industry Lectures |
| **Semester 3** | | |
| ME6005 | 12 | Thesis Stage-1 |
| **Semester 4** | | |
| ME6505 | 12 | Thesis Stage-2 |
| **Semester-2 Electives** | | |
| ME5610 | 3 | Fracture Mechanics |
| ME5690 | 3 | Advanced FEM |
| AE5040 | 3 | Aeroelasticity |
| ME5723 | 3 | Experimental Solid Mechanics |
| ME6040 | 3 | Machine Learning and Its Applications |
| ME5810 | 3 | Advanced Computational Fluid Dynamics |
| ME5860 | 1 | Introduction to Combustion and Reactor Models |
| ME5870 | 2 | Chemical Kinetics and Modeling in Reacting Flows |
| ME5280 | 3 | Hypersonic and High Temperature Aerodynamics |

## 2.2 MTech in IDM (2020)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| ME5130 | 3 | Finite Element Method |

| Code | Cred. | Course Title |
|---|---|---|
| ME5020 | 1.5 | Elasticity and Plasticity |
| ME5080 | 1.5 | Scaling Laws and Multi-scale Manufacturing |
| ME5210 | 3 | Cad/cam |
| LAXXXX | 1 | English Communication |
| **Semester 2** | | |
| ME5030 | 1.5 | Fluid Mechanics and Heat Transfer |
| ME5040 | 1.5 | Computational Fluid Dynamics Tools |
| ME5421 | 1 | FEM Lab |
| ME5431 | 2 | Integrated Design and Manufacturing Lab |
| MEXXXX | 6 | Department Electives |
| MEXXXX | 1 | Seminar |
| MEXXXX | 1 | Industry Lectures |
| **Semester 3** | | |
| ME6005 | 12 | Thesis Stage-1 |
| **Semester 4** | | |
| ME6505 | 12 | Thesis Stage-2 |
| **Semester-2 Electives** | | |
| ME5200 | 1.5 | Additive Manufacturing |
| ME5220 | 1.5 | Material Removal Processes |
| ME5240 | 1.5 | Metal Forming |
| ME5250 | 1.5 | Design for Manufacturability and Assembly |
| ME5530 | 1.5 | Industry 4.0 |
| ME5720 | 1.5 | Advanced Material Joining Processes |
| ME5690 | 3 | Advanced FEM |
| ME6040 | 3 | Machine Learning and Its Applications |
| ME5440 | 1.5 | Introduction to Machine Vision |

## 2.3 MTech in MAD (2020)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| ME5110 | 3 | Advanced Mechanics of Solids |
| ME5120 | 3 | Dynamics and Vibration |
| ME5011 | 0 | Data Acquisition and Control Lab |
| MEXXXX | 3 | Department Elective |
| LAXXXX | 1 | English Communication |
| **Semester 2** | | |
| MEXXXX | 9 | Department Electives |
| ME5021 | 0 | Vibration Lab |
| MEXXXX | 1 | Seminar |
| MEXXXX | 1 | Industry Lectures |
| **Semester 3** | | |
| ME6005 | 12 | Thesis Stage-1 |
| **Semester 4** | | |
| ME6505 | 12 | Thesis Stage-2 |
| **Semester-1 Electives** | | |
| ME5130 | 3 | Finite Element Method |

| Code | Cred. | Course Title |
|---|---|---|
| **Semester-2 Electives** | | |
| ME7100 | 3 | Advanced Topics in Mathematical Tools |
| ME5610 | 3 | Fracture Mechanics |
| ME5650 | 3 | Engineering Noise Control |
| ME5690 | 3 | Advanced FEM |
| ME5670 | 3 | Vehicle Dynamics and Modeling |
| ME6040 | 3 | Machine Learning and Its Applications |
| ME5723 | 3 | Experimental Solid Mechanics |
| ME5670 | 3 | Vehicle Dynamics and Modeling |
| ME5630 | 3 | Nonlinear Oscillation |
| ME5700 | 3 | Analysis and Design of Composite Structures |

## 2.4 MTech in TFE (2020)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| ME5310 | 3 | Incompressible Fluid Flow |
| ME5320 | 3 | Advanced Heat Transfer |
| LAXXXX | 1 | English Communication |
| MEXXXX | 3 | Core Elective |
| **Semester 2** | | |
| MEXXXX | 9 | Department Electives |
| ME5441 | 1 | CFD Lab |
| ME5971 | 2 | Thermo-fluid Engineering Core Lab II |
| MEXXXX | 1 | Seminar |
| MEXXXX | 1 | Industry Lectures |
| **Semester 3** | | |
| ME6005 | 12 | Thesis Stage-1 |
| **Semester 4** | | |
| ME6505 | 12 | Thesis Stage-2 |
| **Semester-1 Electives** | | |
| ME5020 | 1.5 | Elasticity and Plasticity |
| ME5080 | 1.5 | Scaling Laws and Multi-scale Manufacturing |
| ME5110 | 3 | Advanced Mechanics of Solids |
| ME5120 | 3 | Dynamics and Vibration |
| ME5130 | 3 | Finite Element Method |
| ME5260 | 3 | Continuum Mechanics |
| ME5330 | 3 | Computational Fluid Dynamics |
| ME5340 | 3 | IC Engine Combustion and Pollution |
| ME5480 | 3 | Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization |
| **Semester-2 Electives** | | |
| ME7100 | 3 | Advanced Topics in Mathematical Tools |
| ME5810 | 3 | Advanced Computational Fluid Dynamics |
| ME5830 | 3 | Compressible Flow and Its Computation |
| ME5860 | 1 | Introduction to Combustion and Reactor Models |
| ME5870 | 2 | Chemical Kinetics and Modeling in Reacting Flows |
| ME5270 | 3 | Interfacial Phenomenon |
| ME5280 | 3 | Hypersonic and High Temperature Aerodynamics |

| Code | Cred. | Course Title |
|---|---|---|
| ME5470 | 3 | Introduction to Parallel Scientific Computing |
| ME6040 | 3 | Machine Learning and Its Applications |
| ME5820 | 3 | Turbulence |

## 2.5 MTech in IDM (2019)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| ME5130 | 3 | Finite Element Method |
| ME5140 | 1.5 | Process Modeling and Optimization |
| ME5383 | 1 | Soft Computation Lab |
| ME5020 | 1.5 | Elasticity and Plasticity |
| ME5080 | 1.5 | Scaling Laws and Multi-scale Manufacturing |
| ME5090 | 1.5 | Mathematical Elements for Geometrical Modeling |
| ME5100 | 1.5 | Computer Integrated Manufacturing |
| **Semester 2** | | |
| ME5030 | 1.5 | Fluid Mechanics and Heat Transfer |
| ME5040 | 1.5 | Computational Fluid Dynamics Tools |
| ME5421 | 1 | FEM Lab |
| ME5240 | 1.5 | Metal Forming |
| ME5200 | 1.5 | Additive Manufacturing |
| ME5250 | 1.5 | Design for Manufacturability and Assembly |
| ME5230 | 1.5 | Design and Analysis of Welded Joints |
| ME5431 | 2 | Integrated Design and Manufacturing Lab |
| MEXXXX | 3 | Core Electives |
| **Semester 3** | | |
| ME6106 | 1 | Seminar |
| ME6005 | 11 | Thesis (stage1) |
| **Semester 4** | | |
| ME6505 | 12 | Thesis (stage2) |

## 2.6 MTech in MAD (2019)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| ME5260 | 3 | Continuum Mechanics |
| ME5110 | 3 | Advanced Mechanics of Solids |
| ME5120 | 3 | Dynamics and Vibration |
| ME5130 | 3 | Finite Element Method |
| ME5451 | 1 | Computational Mathematics Lab |
| MEXXXX | 1.5 | Core Electives |
| **Semester 2** | | |
| MEXXXX | 12 | Core Electives |
| ME5911 | 2 | Design Engineering Core Lab II |
| **Semester 3** | | |

| Code | Cred. | Course Title |
|---|---|---|
| ME6106 | 1 | Seminar |
| ME6005 | 11 | Thesis (stage1) |
| **Semester 4** | | |
| ME6505 | 12 | Thesis (stage2) |
| **Semester-1 Electives** | | |
| ME5020 | 1.5 | Elasticity and Plasticity |
| ME5030 | 1.5 | Fluid Mechanics and Heat Transfer |
| ME5040 | 1.5 | Computational Fluid Dynamics Tools |
| ME5080 | 1.5 | Scaling Laws and Multi-scale Manufacturing |
| ME5090 | 1.5 | Mathematical Elements for Geometrical Modeling |
| ME5100 | 1.5 | Computer Integrated Manufacturing |
| ME5360 | 1.5 | Planar Multibody Dynamics |
| **Semester-2 Electives** | | |
| ME5610 | 3 | Fracture Mechanics |
| ME5630 | 3 | Nonlinear Oscillation |
| ME5650 | 3 | Engineering Noise Control |
| ME5670 | 3 | Vehicle Dynamics and Modeling |
| ME5690 | 3 | Advanced FEM |
| ME5700 | 3 | Analysis and Design of Composite Structures |
| ME7100 | 3 | Advanced Topics in Mathematical Tools |

## 2.7 MTech in TFE (2019)

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| ME5310 | 3 | Incompressible Fluid Flow |
| ME5320 | 3 | Advanced Heat Transfer |
| ME5451 | 1 | Computational Mathematics Lab |
| MEXXXX | 6 | Core Electives |
| **Semester 2** | | |
| MEXXXX | 12 | Core Electives |
| ME5441 | 1 | CFD Lab |
| ME5971 | 2 | Thermo-fluid Engineering Core Lab II |
| **Semester 3** | | |
| ME6106 | 1 | Seminar |
| ME6005 | 11 | Thesis (stage1) |
| **Semester 4** | | |
| ME6505 | 12 | Thesis (stage2) |
| **Semester-1 Electives** | | |
| ME5020 | 1.5 | Elasticity and Plasticity |
| ME5080 | 1.5 | Scaling Laws and Multi-scale Manufacturing |
| ME5110 | 3 | Advanced Mechanics of Solids |
| ME5120 | 3 | Dynamics and Vibration |
| ME5130 | 3 | Finite Element Method |
| ME5250 | 1.5 | Design for Manufacturability and Assembly |
| ME5260 | 3 | Continuum Mechanics |
| ME5330 | 3 | Computational Fluid Dynamics |
| ME5340 | 3 | IC Engine Combustion and Pollution |

| Code | Cred. | Course Title |
|---|---|---|
| **Semester-2 Electives** | | |
| ME5270 | 3 | Interfacial Phenomenon |
| ME5280 | 3 | Hypersonic and High Temperature Aerodynamics |
| ME5810 | 3 | Advanced Computational Fluid Dynamics |
| ME5820 | 3 | Turbulence |
| ME5830 | 3 | Compressible Flow and Its Computation |
| ME5860 | 1 | Introduction to Combustion and Reactor Models |
| ME5870 | 2 | Chemical Kinetics and Modeling in Reacting Flows |
| ME7100 | 3 | Advanced Topics in Mathematical Tools |

## 2.8 MTech 3Year

- 3-Year M.Tech Curriculum: The course list and the total credits for 3-year MTech will be same as the 2-year MTech counterparts with the following variations:
- (a) Course work must be finished within 5 semesters. The student can plan the course distribution in consultation with the guide.
- (b) The student must be enrolled for at least three credits and at most 12 credits of course-work each semester till the end of his/her course work.
- (c) As the thesis credits are not fixed, but vary across the semesters, the following course numbers can be used for different semesters.

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5915 | (variable) | M.tech (3-year) Thesis (semester-1) |
| **Semester 2** | | |
| ME5925 | (variable) | M.tech (3-year) Thesis (semester-2) |
| **Semester 3** | | |
| ME6915 | (variable) | M.tech (3-year) Thesis (semester-3) |
| **Semester 4** | | |
| ME6925 | (variable) | M.tech (3-year) Thesis (semester-4) |
| **Semester 5** | | |
| ME7915 | (variable) | M.tech (3-year) Thesis (semester-5) |
| **Semester 6** | | |
| ME7925 | (variable) | M.tech (3-year) Thesis (semester-6) |

## 2.9 PhD in Mechanical Engineering

| Code | Cred. | Course Title |
|---|---|---|
| **Semester 1** | | |
| ME5010 | 3 | Mathematical Methods for Engineers |
| MEXXXX | 5 – 8 | Core Electives |
| **Semester 2** | | |
| ME7100 | 3 | Advanced Topics in Mathematical Tools |
| MEXXXX | 2 – 5 | Core Electives |

# 3 | Course Descriptions

## 3.1 Department of Mechanical and Aerospace Engineering

**AE5010** **3**
Introduction to Flight

Aerodynamics of flight vehicles under different speed regimes, Basics of propulsion systems in flight vehicles, Flight vehicle performance in steady and accelerated flight, Systems of axes and notation, Static equilibrium and trim, Equations of motion of flight vehicles, Longitudinal dynamics, Lateral Dynamics, Stability and control

**AE5020** **3**
Aerospace Structural Mechanics

Aircraft structural components and loads, Aircraft materials, Concept of stress and strain in structures, Kinetics and Kinematics of structures, Constitutive behavior of materials, Plane stress/strain problems in elasticity. Three-dimensional beam theory, Euler-Bernoulli beam theory, Timoshenko beam theory, Bending and Torsion of Thin-walled beams. Classical Kirchhoff-Love theory of plate, First order shear deformation plate theory, Introduction to composite laminate theory. Energy and variational methods, Principle of minimum potential energy, Strain energy of beams and plates, Rayleigh-Ritz method, Mixed-variational principles. Structural analysis of beams and plates, Energy formulation of beams and plates, Bending analysis, Buckling analysis.

**AE5030** **3**
Flight Vehicle Aerodynamics

Flow characteristics in subsonic, transonic, supersonic and hypersonic flow regimes, Estimation of aerodynamic coefficients and derivatives for flight vehicles, Quasi-1D analysis of compressible flow, Introduction to numerical methods for aerodynamics, Basics of experimental aerodynamics

**AE5040** **3**
Aeroelasticity

Review of Mechanics fundamentals, Structural dynamics, Static aeroelasticity of wind-tunnel models, Aeroelasticity of uniform lifting surface, Aileron reversal, Divergence, Aeroelastic tailoring, Classical flutter analysis, Flutter analysis using assumed modes, Introduction to numerical simulation of aeroelasticity

**ME5010** **3**
Mathematical Methods for Engineers
▷see syllabus

Vectors, operations and operators, identities; Cartesian tensors: definition, notation, transformation matrix, orthogonal properties, order of a tensor, operations, contraction, quotient rule, vector identities and theorems in tensor form.
First and second order ODEs, linear ODEs with constant coefficients; Laplace transforms; Second order linear homogenous differential equations and their solutions; Sturm-Liouville problem; orthogonal functions; Gram-Schmidt procedure
PDEs: Classification of PDEs, analytical solution of linear PDEs, Fourier series, and Fourier transforms transformation of PDEs between different coordinate systems.
Linear algebraic equations: matrix form, matrix operations, determinants, Cramer's rule, Inverse, singularity, inconsistent equations, Gauss elimination, Gauss-Seidel, LU decomposition, finding inverses, echelon form, general solution for under-determined systems, generalized inverses, least-squares solution for over-determined systems, eigen-values and eigenvectors, orthogonalization, singular value decomposition (without proof)
Introduction to Integral equations, classifications, solution methodology. Function, functional and an introduction to integral of calculus, Euler-Lagrange equation.
Pre-Req: The student should have done GATE level Math courses in his/her undergraduate

**ME5011** **0**
Data Acquisition and Control Lab

List of Experiments: (1) Elevator control using PLC (2) Conveyor belt control and object categorization using PLC (3) Unipolar and bipolar stepper motor actuation using Arduino board (4) On/Off temperature control using Arduino board (5) Introduction to LabView (6) Unipolar and bipolar stepper motor actuation using LabView

**ME5020** **1.5**
Elasticity and Plasticity
▷PG Only

Elastic and Plastic Behaviour of Metals; Stress: Introduction, Invariants, Deviatoric stress and equilibrium equations; Strain: Introduction, Compatibility, Strain Invariants and Deviatoric Tensor; Stress and Strain Relations (Elastic and Plastic); Yield and Flow: Yield

| | |
|---|---|
| | Condition, Isotropic Yield Criteria (von-Mises, Tresca and Hill), Experimental Verification of Yield Criteria, Anisotropy and Anisotropic Yield Criteria. |
| **ME5021** **0**<br>Vibration Lab | Exp1: Vibration Fundamental Trainer ; Exp2: Damping Measurement using Oberst Beam Method ; Exp3: Whirling of Shaft ; Exp4: Experimental Modal Analysis ; Exp5: Shaft Alignment |
| **ME5030** **1.5**<br>Fluid Mechanics and Heat Transfer<br>▷PG Only | Introduction to Fluid flow; Lagrangian and Euler frames of reference; Material derivative; streamlines, streamlines and path lines; velocity potential and stream function; Conservation of mass and momentum; continuity equation; potential flows; Elliptic equations; boundary conditions; Euler equations; Newton's law of viscosity; Navier-Stokes equations; boundary conditions; Boundary layers; Turbulence; Turbulence modelling; Heat conduction; transient and steady heat conduction equation; Natural convection; Forced Convection; Non-dimensionalization, and non-dimensional parameters; Turbulent convection. |
| **ME5040** **1.5**<br>Computational Fluid Dynamics Tools<br>▷PG Only | Introduction to Navier Stokes equation, basics of discretization methods, finite volume formulation of convection-diffusion equation, pressure-velocity coupling, boundary condition implementation, mesh generation techniques in CFD, CFD applications in manufacturing processes through examples - heat removal during machining process, laser welding process, casting, spray coating process. |
| **ME5050** **1.5**<br>Material Science and Material Selection<br>▷PG Only | Phase and Phase diagrams, Diffusion in Solids, Fundamentals of dislocations and strengthening mechanisms, Mechanical behavior of materials. Materials and design, Evolution of Engineering Materials and their Properties, Materials selection charts, Selection of Engineering materials and their Shape, Selection of Manufacturing Processes, Examples and Case studies. |
| **ME5080** **1.5**<br>Scaling Laws and Multi-scale Manufacturing | Introduction to Macro and micro-manufacturing, Importance of Scaling Laws. Scaling Laws in Mechanics, fluids , thermodynamics, Electromagnetism, tribology and Examples. Trimmer force scaling vector. Micro-Fabrication - Fundamentals of Micro-fabrication and Materials, Micro Manufacturing Processes (Additive, Formative and Removal) and their scientific and technological details, Applications. Sensing (measurement) and Control. |
| **ME5090** **1.5**<br>Mathematical Elements for Geometrical Modeling | Introduction to computer aided design, fundamentals of computer graphics; geometric modelling of synthetic curves: Hermite, Bezier, B-spline, NURBS. Parametric representation of surfaces: plane, ruled, revolution; Part modelling techniques: wireframe, surface and solid modelling, data representation and exchange formats, geometry and topology. Three-dimensional transformations and projections. |
| **ME5100** **1.5**<br>Computer Integrated Manufacturing<br>▷ME5090 | Current developments in CAD- feature based modeling, design by feature, function, feature linkages, application of feature based models, parametric modeling; Computer Aided Manufacturing: fundamentals of part programming, path generation, post processing and verification; Group Technology, Computer aided process planning (CAPP), computer aided inspection and reverse engineering, manufacturing process simulation, virtual and distributed manufacturing, computer integrated manufacturing. |
| **ME5110** **3**<br>Advanced Mechanics of Solids | Introduction; Stress definition and stress-traction relations; Deformation, strain definition, strain-displacement relation; Constitutive equations; Equilibrium and compatibility equations; Two dimensional problem solutions – Plane stress and Plane strain; Advanced two dimensional problems – Plate with a hole, Rotating disk, Disk under diametral compression; Axisymmetric problems; Torsion – Prandtl stress function; membrane analogy; Special problems – Wedge with boundary tractions, concentrated force on half plane. |
| **ME5120** **3**<br>Dynamics and Vibration | Analytical dynamics, degrees of freedom, equations of motion using Newton's laws and Lagrange equations, constrained motion, free and forced vibration of single degree of freedom damped and undamped systems, vibration isolation, Jeffcott rotor, free and forced vibration of multi-degree of freedom systems, modal decoupling, free and forced vibrations of continuous systems (vibrations of rods, strings, beams, and plates). |
| **ME5130** **3**<br>Finite Element Method | Theory and implementation of finite element methods for solving boundary value problems in solid mechanics. Mathematical foundations (Calculus of Variation), review of energy theorems, theory and implementation of 1D, 2D, and 3D elasticity problems. Introduction to FEM softwares. |
| **ME5140** **1.5**<br>Process Modeling and Optimization | Introduction to Processes and Variation, Probability Models of Manufacturing Processes, Statistical modeling and control in manufacturing processes, Sampling Distributions and Statistical Hypotheses, Statistical Process Control. Design of Experiments, ANOVA. Use of experimental design and response surface modeling to understand manufacturing processes. Multi criteria optimization. Case studies. |

**ME5150** **1.5**
Computational Intelligence

Function approximation and Pattern recognition: Statistical modelling, Neural Network, Fuzzy system and Classification, Principal Component Analysis; Evolutionary computation: Genetic algorithms; Meta-heuristic methods: Simulated annealing, Ant colony optimization, Tabu search; Monte-Carlo simulation, Design and analysis of experiments.

**ME5190** **2**
Manufacturing Processes

Classification, operating parameters, and throughputs of manufacturing processes - Generative, Additive, and Removal Processes; Conventional and Non-conventional process; Contact and Non-contact processes; Hybrid manufacturing processes. Characterization of manufactured products: Form and Surface features, Residual stress, Mechanical properties, Corrosion resistance; Process control and feedback: Electrical, hydraulic, pneumatic, and optical sensors; open and closed loop control.

**ME5200** **1.5**
Additive Manufacturing
▷PG Only

Overview of Rapid Product Development: Product Development Cycle, virtual prototyping, physical prototyping, Solid Modelling: Data formats, conversion, checking, repairing and transmission. Synergic integration technologies, Part slicing and Build Orientation, Area-filling strategies, applications and limitations of RPM. Classification of RPM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, Direct Energy Deposition. Popular RPM processes. Selection of rapid prototyping, tooling and manufacturing systems based on product requirements.

**ME5230** **1.5**
Design and Analysis of Welded Joints

Modern welding process: GMAW (Robotic, CMT, and STT), Micro plasma welding, EBW, LBW, Diffusion bonding, Ultrasonic welding, Pulsed current welding, Friction stir welding, Magnetic Pulse welding. Analysis of heat sources for material joining, 2D and 3D heat flow in welds, Residual stress analysis. Weldment design for static and fatigue loading, Failure of welds, NDT of welds, Welding symbols.

**ME5240** **1.5**
Metal Forming
▷ME5020

Overview of Plasticity; Metal Forming- Bulk Processes: Rolling, Extrusion, Drawing and Forging (Each Process will be analysed using Force Equilibrium, Slip-line and Upper Bound Methods), Tool Design, Defects and Remedies; Sheet Metal Forming: Shearing, Bending, Deep Drawing (all its variants) and other processes; Hydro Forming, Explosive Forming, Electro-Magnetic Forming, Electro-Plasticity. Scaling laws in Plasticity, Micro-Forming; Analysis of Forming Processes including defects using Finite Element Analysis.

**ME5250** **1.5**
Design for Manufacturability and Assembly
▷ME2030, ME3010, ME3040, ME3050

Introduction to design for manufacturing concepts; importance of product specification and standardization, selection of materials and shapes, design rules for various manufacturing processes, design for assembly, design for reassembly, design for automated assembly, design for ergonomics, design for quality and reliability, design for X concepts. Materials selection charts, Selection of Engineering materials and their Shape, Selection of Manufacturing Processes, Examples and Case studies.

**ME5260** **3**
Continuum Mechanics

Tensor Algebra and Analysis - Review properties of a vector space. Tensors as linear transformations. Tensor product of vectors. Symmetric tensor related to dot product. Scalar and regular product of tensors. Trace, Determinant, Inverse, Orthogonality, Positive Definiteness. Eigen vectors/values and Spectral theorem, Cayley-Hamilton theorem and principal invariants, Polar decomposition. Derivatives as a linear map. Compute derivative by this definition. Derivative of determinant/ square root/ simple functions. Product rule and Chain rule. Gradient/Divergence/Curl. Divergence theorem, Stokes' theorem.
Kinematics - Body as a subset of a Euclidean space. Motion, deformation, deformation gradient, Polar decomposition. Lagrangian and Eulerian descriptions. Properties of deformation gradient and left/right stretch tensors. Examples of deformation: homogeneous, isochoric, rotations. Assumptions of small deformation. Motion, Velocity, Acceleration, Material time derivative, velocity gradient. Transport theorem
Balance Laws - Conservation of mass, linear and angular momenta. Global and local statements. Cauchy's theorem and its proof. Surface/body forces. Principle of virtual work. States of stress: tensile, shear, hydrostatic etc. Examples of various stress tensors.
Constitutive Modelling - Motivation of the general constitutive law s=g(n). Hyperelasticity and energy-density function. Material symmetry and various symmetry groups. Invariance on change of observer. Special consequences of isotropy.

**ME5270** **3**
Interfacial Phenomenon
▷ME5310

Introduction to interfacial flows - Governing equations and boundary conditions - Laplace Pressure - Minimal surfaces - Young's law - Fluid statics - Hydrodynamics of Interfaces: Thin films, Rayleigh-Taylor instability, Plateau-Rayleigh instability, Drop oscillations, coating flows, Marangoni effects - Contact line hysteresis - Dynamic wetting phenomenon.

**ME5280** **3**
Hypersonic and High

(1) Review of fundamental gas dynamics, introduction to hypersonic flow regimes; (2) Inviscid hypersonic flows: applicability, hypersonic shock and expansion relations,

| | |
|---|---|
| Temperature Aerodynamics | surface pressure distribution relations, hypersonic aerodynamic theory, numerical solution techniques (3) Viscous hypersonic flows: Navier Stokes and boundary layer equations, Friction drag and aerodynamic heating, hypersonic-viscous interactions, numerical modelling of viscous hypersonic flows, shock-boundary layer interactions in hypersonic flows, numerical modelling of viscous hypersonic flows. (4) High Temperature Gas Dynamics: Introduction to high temperature flows, thermodynamics of reacting gases, Statistical thermodynamics and Boltzmann distribution, kinetic theory of gases, energy, mass and momentum transport, chemical and vibrational reaction rates, inviscid high temperature flows, viscous high temperature flows, radiative gas dynamics. Applications. |
| **ME5290** **1**<br>Stability of Time Delayed Systems | Stability theory of ordinary differential equations, Stability of maps, introduction to delay differential equations (DDEs), quasi-polynomials, method of semi-discretization, Galerkin approximation, Floquet theory, stability of DDEs with time periodic delays and time periodic coefficients |
| **ME5300** **2**<br>Variational Methods in Mechanics | Introduction to functional; simple fixed end point variational problem and its Euler equation; generalized variational problem; Legendre transformation; Noether's Theorem; Principle of least action and conservation laws; Second variation and sufficient condition for extremum; application to continuous mechanical systems. |
| **ME5310** **3**<br>Incompressible Fluid Flow | Tensors, Lagrangian and Euler frames of reference; Material derivative; Newton's law of viscosity; velocity potential and stream function; Derivation of continuity equation; potential flows; Euler equations; Derivation of Navier-Stokes equations; Elliptic and Parabolic equations; boundary conditions; Analytical solutions of NS equations; Boundary layer Theory; Similarity solutions; Approximate methods; Turbulence; RANS equations; Introduction to Turbulence modelling; Non-dimensionalization, and non-dimensional parameters. |
| **ME5320** **3**<br>Advanced Heat Transfer<br>▷ME3110 | Introduction - Review of fundamentals of heat transfer. Conduction: General heat conduction equation, Analytical solutions of two dimensional steady state heat conduction; Transient conduction. Convection: Governing equations, boundary layer equations, Forced convection over external surfaces and internal ducts; Similarity solutions. Free and Mixed convection flows, Conjugate heat transfer analysis. Radiative Heat Transfer: Thermal radiation, Emissive Power, Solid Angles, Radiative Intensity, Heat Flux, Pressure and Characteristics, Radiative transport equation. |
| **ME5330** **3**<br>Computational Fluid Dynamics | Introduction to numerical solutions of PDEs; importance of CFD; various methods; Taylor Series; Finite-difference of first, second and third derivatives; Order of accuracy; finite-differences on non-uniform grids; time-stepping; explicit and implicit time-stepping of 1D unsteady heat conduction equation; Boundary and Initial conditions; tri-diagonal solver; Explicit and Implicit schemes for 2D unsteady heat conduction equation; Gauss-seidel method; Convergence; iterative vs direct methods; Types of PDEs, and their IC and BCs; the well-posed problem; Methods of Elliptic PDE; False-transient method; Hyperboilc PDEs; 1st order wave equation: characteristics; Methods: Lax, McCormack etc; modified equation; dissipative and dispersive errors; systems of hyperbolic equations; diagonalization; Finite-volume method; Convection-Diffusion equation; Convective schemes: Upwind, 2nd upwind, Quick, etc; Vorticity-stream function formulation: Explicit, Implicit and Semi-Implicit schemes; coupled temperature equation; segregated and coupled solution methods; SMAC method for Navier-Stokes equations. |
| **ME5340** **3**<br>IC Engine Combustion and Pollution | Introduction: Engine types and their operation, Engine design and operating parameters, Thermochemistry of fuel-air mixtures; Combustion in Spark-Ignition Engines: Essential features of process, Thermodynamic analysis of SI engine combustion, Flame structure and speed, cyclic variations in combustion, partial burning and misfire, Spark ignition, Abnormal combustion: Knock and surface Ignition; Combustion in Compression-Ignition Engines: Essential features of process, Types of Diesel combustion Systems, Phenomenological model of CI engine combustion, Analysis of cylinder pressure data, Fuel spray behavior, Ignition delay, Mixing-controlled combustion; Modeling real engine flow and combustion processes: Purpose and classification of Models, Governing equations for open thermodynamic system, Intake and exhaust flow models, Thermodynamic-based In-Cylinder models, Fluid-mechanics based multidimensional models; Pollutant formation and control: Nature and extent of problem, Nitrogen oxides, Carbon monoxide, unburned hydrocarbon emissions, Particulate emissions, Exhaust gas treatment; Nonconventional Engines: Common rail diesel injection, Dual fuel and multi-fuel engine, Free piston engine, Gasoline direct injection engine, Homogenous charge compression ignition engine, Lean burn engine, Stirling engine, Stratified charge engine, Variable compression ratio engine, Wankel engine. |

**ME5350** **1.5**
Introduction to Hydrodynamic Stability

Introduction to hydrodynamic stability theory - relevance and applications - Linear Inviscid stability analysis - Rayleigh's stability equation - temporal stability analysis and spatial stability analysis - convective and absolute instabilities - Initial value problems - Viscous stability analysis - Orr Sommerfeld and Squire's equation - Stability of density and thermally stratified flows - Capillary instabilities - Solve stability problems with Matlab.

**ME5360** **1.5**
Planar Multibody Dynamics

Introduction to kinematics and dynamics of planar rigid bodies - vector and matrix notation - degrees of freedom, constraint equations and constraint forces, kinematic joints - formulation of kinematics in body coordinates, joint coordinates, and point coordinates; formulation of dynamics in body coordinates, joint coordinates, and point coordinates; kinematic analysis - forward dynamic analysis - inverse dynamic analysis.

**ME5370** **2**
Impact Mechanics
▷ME3150 or ME5110 or ME5020

Propagation of 1D stress pulse, coaxial collision of bars, reflection and superposition, review of continuum mechanics, dilatational and shear waves, Rayleigh and Lamb waves, longitudinal, torsional and flexural vibrations of rods, Pochhammer equations for cylindrical bars, design of a split hopkinson bar for high strain rate characterization, propagation of 1D stress pulse in elasto-plastic material, Taylor impact test, one dimensional impact on metal foams, plastic deformation of beams subjected to impact.

**ME5380** **2**
Robot Manipulators: Kinematics and Dynamics

Introduction to robot manipulators – common kinematic arrangements of manipulators – rigid motion and homogeneous transformations – forward kinematics – inverse kinematics – velocity kinematics – Jacobian – singularities; Dynamics – Euler-Lagrange formulation – Newton-Euler formulation

**ME5400** **2**
Sustainable Energy Technology 1: Energy Sources

(a) Introduction:- Review of thermodynamics; Energy Demand and Supply Outlook; Climate Change: projections and risks (b) Non-renewable Energy sources (Coal, Oil, Natural Gas, Nuclear) and their impact on the environment (climate change , atmospheric pollution, radioactive waste); (c) Renewable Energy Sources - Wind, Solar PV, Solar-Thermal, Geo-thermal, Hydropower – technology and deployment; (d) Carbon Neutral Fuels – biomass to fuel conversion, biofuel combustion technology, hydrogen as fuel, CO2 to fuel conversion, fuel cell technology;

**ME5410** **1**
Sustainable Energy Technology 2: Energy Efficiency, Storage and Optimization

(a) Energy Storage Technology – chemical storage and battery technology, electro-mechanical storage, thermal storage; (b) Energy Efficiency and Emission Reduction – Use of Exergy to optimize energy use, Clean Combustion Technology, Carbon Capture and Storage, Energy efficient buildings, Life Cycle Assessment (LCA), Distributed and Smart Grid systems.

**ME5420** **1**
Aerial Robotics: Dynamics of Drones

3D rigid body kinematics – representation of rotation – rotation matrix – Euler angles – Tait-Bryan angles – Euler parameters – axis-angle representation – quaternions – rigid body dynamics – angular momentum – moment of inertia tensor – equations of motion – under-actuated motion

**ME5421** **1**
FEM Lab
▷ME5020, ME5130

Finite element methods for solving boundary value problems in solid mechanics. Introduction, Spatial Modelling, Geometric discretization, Element Library, Material Modelling, Loading and Boundary Conditions, Constraints, Surface/Interfaces modelling, Step and job handling and Post-processing. FEA Implementation and Visualization of 1D Problems, Truss Problem, Beam bending, Plane and axisymmetric Problems and 3D problems. Various analysis such as, Static, Transient, Harmonic, Modal, Dynamics and Multi Physics (Thermomechanical, etc).

**ME5431** **2**
Integrated Design and Manufacturing Lab

Job preparation using CNC machining, Robotic welding, 3D printing, EDM, Injection molding. Measurements of parts using CMM; Form measurement; Digitization using 3D scanner, surface roughness testing. Deep drawing using forming machine. Cutting force measurement using dynamometer. Sample preparation and characterization using Optical Microscope. Lab project.

**ME5440** **1.5**
Introduction to Machine Vision

Overview, cameras and selection, lenses and selection, illumination, image acquisition, sampling, quantization and digitization, transforms, filtering, image restoration and enhancement, image segmentation techniques, object identification, application to automatic inspection and identification, optical character recognition, bar code, robot guidance

**ME5441** **1**
CFD Lab

Mesh generation techniques, experiment using commercial CFD solver - turbulent mixing and heat transfer, external flow, combustion, two-phase flow, turbo-machines.

**ME5451** **1**
Computational Mathematics

Introduction to MATLAB - variables, structures, arrays, operators, conditional statements, loops; root finding using Newton-Raphson method, optimization, solving ODEs and

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| Lab | PDEs, event detection; graphics; simulink based simulations. |
| **ME5470** **3**<br>Introduction to Parallel Scientific Computing | Almost all computing devices today employ multiple processing units that work at the same time (in parallel). As a result, parallel programming finds application in several engineering domains. This course will introduce parallel programming as applied to a subset of scientific computing applications, focused on solving partial differential equations. Parallel algorithms for sparse and dense linear solvers and fast Fourier transforms will be discussed. Basics of parallel thinking, measures of parallelism and parallel performance will be introduced. Shared memory (using OpenMP) and distributed memory (using MPI) paradigms will be described. The need to understand hardware aspects to achieve scaling will be emphasized. Students will get experience with practical aspects of building, debugging, and profiling parallel applications through exercises. Since the examples used will focus on solution of partial differential equations, this course will be beneficial for students in Mechanical and Aerospace, Civil, and Chemical Engineering departments. Ideally, students taking this course should have some exposure to implementing (serial) numerical algorithms. This course will be useful to students using scientific computing for their research needs as well as to those aspiring to work in industry focused on numerical algorithms. |
| **ME5480** **3**<br>Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization | Introduction:- Review of thermodynamics; Energy Demand and Supply Outlook; Climate Change: projections and risks. Non-renewable Energy sources (Coal, Oil, Natural Gas, Nuclear) and their impact on the environment (climate change , atmospheric pollution, radioactive waste); Renewable Energy Sources - Wind, Solar PV, Solar-Thermal, Geo-thermal, Hydropower – technology and deployment; Carbon Neutral Fuels – biomass to fuel conversion, biofuel combustion technology, hydrogen as fuel, CO2 to fuel conversion, fuel cell technology; Energy Storage Technology – chemical storage and battery technology, electro-mechanical storage, thermal storage; Energy Efficiency and Emission Reduction – Use of Exergy to optimize energy use, Clean Combustion Technology, Carbon Capture and Storage, Energy efficient buildings, Life Cycle Assessment (LCA), Distributed Energy and Smart Grid systems. |
| **ME5505** **3**<br>Special Topics in Manufacturing | This is a project oriented course where the students are expected to work on a research subject with the guidance of the individual faculty. This will be accompanied by regular assessment of the progress through weekly presentation/seminars. |
| **ME5510** **1.5**<br>Industrial Automation and Robotics | Automation principles and strategies, basic elements of an automated system, levels of automation, sensors, actuators, and control system components; automation in manufacturing processes, material handling, inspection and assembly.<br>Robotics fundamentals - workspace, forward kinematics, inverse kinematics, dynamics and control algorithms |
| **ME5520** **1.5**<br>Measurement Science and Techniques | Introduction to Measurement, Errors in Measurement, Calibration and Basic Statistics, Displacement Measurement: Intrusive and non-Intrusive methods, Measurement of Temperature: Contact and non-contact, Measurement of Pressure: Various principles of measurement, Different gauges, Vibration and Acoustic Measurement: Velocity and Acceleration Measurement, Sound pressure level measurement, Measurement of Force Torque and Power: Load cells, Torque cells, Dynamometers, Stress Strain Measurements using Strain gauges |
| **ME5530** **1.5**<br>Industry 4.0 | [1] Introduction to Industry 4.0: The various industrial revolutions; Comparison of industry 4.0 factory and today's factory; Trends of industrial big data and predictive analytics for smart business transformation; Drivers, enablers, compelling forces for Industry 4.0. [2] Concepts of the factory of the future: Flexible production; Crowdsourcing; Interoperability of data; movement from mass production to mass customization; integration of enterprise IT and operations technology. [3] Local Initiatives and Case-Studies: US- Industrial Internet of Things (IIoT), Japan- e-Factory, Germany- Industrie 4.0, China- Intelligent Manufacturing; case studies. [4] Enabling Technologies: Machine-to-machine communication; Cloud-based application infrastructure and middleware; Data analytics; Integrated product-production simulation; Additive manufacturing/3D printing. |
| **ME5610** **3**<br>Fracture Mechanics | Review of elements of solid mechanics, analysis of stress-strain-constitutive equations, introduction to fracture mechanics, crack growth mechanisms, fracture mechanism, Inglis solution, Griffith's realization, energy principles, energy release rate, linear elastic fracture mechanics, stress intensity factor, SIF for general cases - analytical/numerical/experimental, multi-parameter stress field equation, elastic plastic fracture mechanics, J-integral definition, fatigue crack propagation and evaluation of |

testing standards.

**ME5620** **3**
Mechatronic Systems

Overview of mechatronic systems - mathematical modeling of systems - introduction to control - sensors and transducers - signal conditioning - amplification, filtering, analog-to-digital converters and digital-to-analog converters - data presentation systems - actuators - electrical, mechanical, pneumatic, hydraulic - analog electric circuits, operational amplifiers - digital logic circuits, microprocessors, microcontrollers, DSPs, Programmable Logic Controllers - programming in assembly and C - communication interfaces - RTOS - machine vision systems - robotics.

**ME5630** **3**
Nonlinear Oscillation

Review of dynamical systems, solution methodology, phase space and different stability analysis, different types of nonlinear systems and its classification based on the nature of nonlinearity, modeling of single/multi-degree of freedom dynamical systems with single/multiple inputs, evolution equations obtained from continuous systems, existence of nonlinear resonances, regular perturbation, singular perturbation methods, multiple scales method, equilibrium stability vs orbital stability of periodic and quasiperiodic systems, local bifurcation theory and center manifold theorem, application of techniques to do nonlinear analysis of mechanical systems under external/parametric excitation.

**ME5640** **3**
Multibody Dynamics

Review of kinematics and dynamics of point mass and rigid body - types of constraints - constraints for revolute joints, translational joints, composite joints - formulation of planar multi-body systems, kinematics and dynamics in point coordinates, body coordinates, and joint coordinates - numerical methods for solution - analysis of planar multi-body systems, kinematic analysis, inverse dynamic analysis, forward dynamic analysis, constraint stabilization - case studies, McPherson strut suspension, Double A-arm suspension, planar robot manipulator - Spatial multi-body systems.

**ME5650** **3**
Engineering Noise Control

Introduction to noise control: definition of sound, acoustic wave equation, sound level and spectra, octave and 1/3 octave bands, weighting networks (a, b, c and linear), hearing, psychological response to noise, loudness interpretation, NC curves, masking, sound propagation, plane wave, spherical wave, sound power, its use and measurement, sound power and sound pressure level estimation procedure, characteristics of noise sources, source ranking, passive noise control methods, sound absorption coefficient measurement, transmission loss, room acoustics, sound in enclosed spaces, basics of muffler design, lined plenum absorption, pipe wrapping, vibration isolation, vibration damping.

**ME5660** **3**
Applied Micro and Nanomechanics in Engineering

Review of different physical domains and their coupling in the design of micro and nanomechanics based senors and actuators. Scaling laws - length and time scale. Inter and intra-molecular forces, constitutive relationships in solids and fluids. Electrostatic potential, and capacitance, pull-in phenomena, static and dynamic analysis. Application of the numerical techniques through standard multidomain analysis softwares such as COMSOL multiphysics/Intellisuite/Coventorware/ANSYS, etc.

**ME5670** **3**
Vehicle Dynamics and Modeling

Vehicle Mechanics - Forces under static and dynamic equilibrium. Free body diagram of different vehicle components. Simple linearized rigid models of different components. Dynamic stability and the vehicle performance under different operating conditions such as understeering, neutral steering, and oversteering. Concept of vehicle ride comfort. Vehicle stability controls. Driveline models, Performance characteristics of a comfortable vehicle ride. Introduction to the development of vehicle model using different software such as MATLAB Simulink, MAPLESIM, System Modeller, ADAMS, CarSIM.

**ME5680** **1.5**
Fatigue and Damage Tolerance Evaluation

Introduction to fatigue of structures and material; fatigue phenomenon in material; stress intensity factors; fatigue properties; fatigue strength of notched specimens; fatigue crack growth - analysis and predictions; fatigue testing; fatigue tolerant structure.

**ME5690** **3**
Advanced FEM
▷ME5130

Theory and implementation of finite element methods for solving non-linear boundary value problems in solid mechanics. Review of fem and continuum mechanics, nonlinear bending of beams and plates, nonlinear analysis of time dependent problems, material non-linearity, and solution procedures for linear and nonlinear algebraic equations.

**ME5700** **3**
Analysis and Design of Composite Structures

Introduction to composite materials, Concepts of isotropy vs. anisotropy, Micro-mechanics of composite lamina, Macro-mechanics of composite laminate, Classical Lamination Plate theory (CLPT), Failure criteria, Bending and buckling analysis of laminated composite plates, Inter-laminar stresses, First Order Shear Deformation Theory (FSDT), Delamination models, Composite tailoring and design issues.

**ME5720** **1.5**
Advanced Material Joining Processes

Modern welding process: GMAW (Robotic, CMT, and STT), Micro plasma welding, EBW, LBW, Diffusion bonding, Ultrasonic welding, Pulsed current welding, Friction stir welding, Magnetic Pulse welding. Analysis of heat sources for material joining, 2D, 3D

heat flow in welds, residual stress analysis, Arc physics.

**ME5723** **3**
Experimental Solid Mechanics

Introduction to stress analysis; Optical Methods for whole field measurement; Strain gauges – Principle, measurement; Introduction to Interferometry technique; Photoelasticity - Principle, measurement; Moiré - Principle, measurement; Holography - Principle, measurement; Speckle pattern interferometry - Principle, measurement; Digital Image Correlation - Principle, measurement; Recent advancements in experimental techniques; Sensitivity and data interpretation; Practical measurements using photoelasticity, strain gauges, DIC including specimen preparation, testing and analysis.

**ME5750** **3**
Micro-mechanics of Defects
▷ME5110

Review of Elasticity, Theory of Eigen strains, the theory of elastic inclusions (Isotropic and Cubic), the theory of cracks and dislocation. Interaction of defects. Review of plasticity, Theory of elastoplastic inclusions.

**ME5810** **3**
Advanced Computational Fluid Dynamics

Finite-volume method; pressure problem for incompressible Navier-Stokes equations; Pressure-velocity decoupling; Staggered and collocated grids; semi-explicit (SMAC) method on staggered grids; Convective schemes; Implicit SIMPLE method; higher-order accuracy implementations; Non-orthogonal grids: problems with staggered grids; collocated grid; implementation of semi-explicit and implicit schemes on rectangular collocated grids; generalization to collocated non-rectangular hexahedral grids; Boundary conditions and their implementation; adaptation of schemes to tetrahedral grids, general hybrid grids; advanced linear equations solvers; algebraic multigrid methods.

**ME5820** **3**
Turbulence

Turbulence: Introduction, nature, origin, length and time scales in turbulent flows, Kolmogorov energy spectrum. RANS equations, Closure problem, Turbulent transport of momentum and heat. Dynamics of Turbulence: Kinetic energy of the mean flow, Kinetic energy of turbulence, Vorticity dynamics, Dynamics of temperature fluctuations. Free-shear flows, Wall bounded shear flows. CFD modelling of Turbulence: Algebraic models, One-equation models, Two-equation models: Wall bounded flows; Wall functions and Low Reynolds number effects, Beyond RANS for turbulence modelling; LES and DNS.

**ME5830** **3**
Compressible Flow and Its Computation

Basics: Introduction and review of Thermodynamics; Integral form of conservation equations; One-dimensional Flow - Area-Velocity Relations and Isentropic Relations, Wave Propagation, Speed of Sound, Shock Waves, Normal Shock Waves; Flow Through Nozzles and Duct, Flow with Heat addition and friction; Two - dimensional Compressible Flow: Oblique Shocks, Expansion Waves, Shock Interactions, Detached Shocks, Shock-Expansion Technique; Unsteady Wave Motion; Analytic Methods: Method of Characteristics;
Computation: Mathematical nature of Euler equations: Various forms of Euler equations; Hyperbolic Equations; Riemann Problem. Basic Numerical Methods: Centred and upwind discretisation. Artificial Viscosity, CFL condition and Numerical stability. Brief Historical Evolution of the computational methods for compressible flow and their classification. Central Schemes, First and Second order upwind scheme. Roe and MacCormack methods. Flux-Vector Splitting, Godunov Methods, High Resolution Schemes: TVD and Flux-limiters. Boundary Conditions: Treatments for physical and numerical Boundary Conditions. Modern Compressible Flow and Current Research; Numerical Methods available in commercial and open source software.

**ME5840** **1**
Introduction to Open CFD

Open source CFD software distribution; Meshing, Initialization, Boundary conditions, Selecting models, Mesh conversion; Examples - Incompressible Flows, Compressible Flows, Multiphase flows; Post-processing tools and visualization, Running in parallel, Programming new transport and turbulence models.

**ME5850** **1**
Introduction to Molecular Solvers

Introduction to Continuum and Molecular Theories, Direct Simulation Monte Carlo Method, Open source molecular solvers with applications to hypersonic, rarefied and microscale gas flows; external aerodynamics; Molecular Dynamics Method, Applications to nano liquidics.

**ME5860** **1**
Introduction to Combustion and Reactor Models

Combustion background; 1st and 2nd law of thermodynamics applied to chemical reaction, Gibbs free Energy, equilibrium temperature and composition; Arrhenius law, reaction rate for single step and multistep reactions; PSR, PFR, const. pressure and const. volume reactor models and their applications to simulate practical combustion systems.

**ME5870** **2**
Chemical Kinetics and Modeling in Reacting Flows

Chemical Kinetics - elementary and global reactions, collision theory, rate of reaction in multistep mechanisms, chemical time scales and partial equilibrium; Simplified conservation equations applied to reaction systems, concept of conserved scalar; Laminar flames - premixed and diffusion; Turbulent flames - premixed and diffusion; detonations and deflagration, liquid and solid fuel combustion reaction modeling.

**ME5880** **3**

Detailed review of optical diagnostic techniques - PIV, PLIF, CARS, Raman and Rayleigh

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| Combustion and Flow Diagnostics | | scattering, interferometry, schlieren and shadowgraph; experimental applications to flow field diagnostics; liquid fuel spray atomization characterization, combustion and pollutant formation; optical measurements in direct injected diesel and gasoline engines; advanced developments - Infrared laser-induced fluorescence imaging, novel flow-tagging velocimetry approach, new diode laser sources for combustion diagnostics and control, CO2 interferences in engine diagnostics. |
| **ME5911** Design Engineering Core Lab II | **2** | Experimental stress analysis lab: Strain measurement involving strain gages for tensile, torsion and bending applications,Thick cylinder under internal pressure, Gage factor determination for a strain gage, Introduction to photoelasticity, Material stress fringe value determination, Tardy method of compensation for fringe order determination, Photoelasticity applications, Beam under four point bending, Bending study of a diaphragm under pressure load Vibration Lab: Vibration Fundamental Trainer, Whirling of Shaft, Experimental Modal Analysis, Laser alignment system Mechatronics Design Lab: Traffic control using Programmable Logic Controller, Magnetic levitation system, Stepper motor control through digital input/output (DIO) using Labview, Temperature measurement through ADC using LabView. |
| **ME5971** Thermo-fluid Engineering Core Lab II | **2** | Introduction about Subsonic Wind tunnel; Measurement of static and dynamic pressure; Calibration of pressure transducers; Measurement of aerodynamic forces and flow characteristics: Cylinder, flat plate, symmetric and asymmetric airfoils.<br>Thermal conductivity of fluids: water and air; Fluidized bed heat transfer; Pool boiling and Condensation. |
| **ME6010** Mechanics of Composite Materials<br>▷ME5110 | **2** | Introduction to composite materials, Concepts of isotropy vs. anisotropy, Micro-mechanics of composite lamina, Macro-mechanics of composite laminate, Classical Lamination Plate theory (CLPT), Failure criteria, Bending and buckling analysis of laminated composite plates, Inter-laminar stresses, First Order Shear Deformation Theory (FSDT), Delamination models, Composite tailoring and design issues. |
| **ME6020** Theory of Dislocations | **2** | Introduction to Dislocations and Disclinations. Glissile dislocations: Velocity of dislocations, Glide, Climb, and Plastic strain due to dislocation movement. Elastic Properties of Dislocations (Straight and curved): Stress fields, Strain Energy, Dislocation Interactions (with other dislocation, crack, free surface and grain boundary). Dislocations in FCC: Full and Partial dislocations, Stacking faults. Dislocations in other structures: BCC, HCP, Polymer crystals and Graphene. Intersection of dislocations. Nucleation of dislocations: Sessile dislocations, Homogenous nucleation, in-homogenous nucleation. Dislocation Arrays and Crystal Boundaries and twinning: Plastic deformation, recovery and Recrystallization. Plasticity and Dislocation Dynamics: Strain rate dependence of the flow stress, Peierls stress lattice resistance, Work hardening, flow stress for random array of obstacles, dislocation fracture. |
| **ME6040** Machine Learning and Its Applications | **3** | Overview, supervised learning – linear regression, logistic regression and classification, regularization; feedforward neural network and backpropagation training algorithm; Support Vector Machines; unsupervised learning – clustering, dimensionality reduction; anomaly detection; advanced concepts in machine learning; application case studies |
| **ME6106** Seminar | **1** | Thesis writing, research paper writing, delivering technical seminars, group discussion, technical interview, text processing using LaTeX. |
| **ME7100** Advanced Topics in Mathematical Tools<br>▷ME5010 | **3** | Classical Optimization, stochastic optimization, Neural and Fuzzy system, FFT, Wavelets, monte carlo simulations, design of experiments, Taguchi method. Introduction to linear and nonlinear dynamical system, fixed points and stability, phase plane analysis, Limit cycles, Bifurcations in 1D and 2D of systems, Lyapunov stability, Deterministic chaos, Strange attractors, Regular and singular perturbation, Boundary layer theory, Matched asymptotic expansions, and Method of multiple scales. |
| **ME7110** Introduction to Impact Mechanics | **1** | Elastic impact: Propagation of 1D stress pulse, coaxial collision of bars, reflection and superposition, Navier's equations, dilatational and shear waves, Rayleigh and Lamb waves.<br>Plastic impact: lower and upper bound theorems of plasticity, applications to static plastic deformations in beams, propagation of 1D stress pulse in elasto-plastic material, Taylor impact test, one dimensional impact on metal foams, plastic deformation of beams subjected to impact, dynamic buckling of beams. |