AE MTech Curriculum

Core courses → 15 credits
Experimental techniques in aerospace engineering → 1 credit
Aerospace seminar → 1 credit
Math requirement → 3 credits
MTech project dissertation → 20 credits
Electives → 24 credits
Total → 64 credits (minimum)

MTech Dissertation adviser to be chosen by the MTech student at the end of first semester.

Math requirement, all electives, and the independent study course, will be credited by a student in consultation with the MTech dissertation adviser.

Students should register for a minimum of 12 credits per semester

<table>
<tr><th>Semester I</th><th>Semester 2</th><th>Semester 3</th><th>Semester 4</th></tr>
<tr><td>Flight and Space Mechanics</td><td colspan="2">Math requirement
Either 2nd or 3rd semester</td><td>Aerospace Seminar</td></tr>
<tr><td>Fluid Dynamics</td><td>Elective 1</td><td>Elective 5</td><td></td></tr>
<tr><td>Mechanics and Thermodynamics of Propulsion</td><td>Elective 2</td><td>Elective 6</td><td></td></tr>
<tr><td>Flight Vehicle Structures</td><td>Elective 3</td><td>Elective 7</td><td></td></tr>
<tr><td>Navigation, Guidance and Control</td><td>Elective 4</td><td>Elective 8</td><td></td></tr>
<tr><td>Experimental Techniques in Aerospace Engineering</td><td></td><td colspan="2">MTech Dissertation
Distributed over 3rd and 4th semesters</td></tr>
<tr><td>16 credits</td><td colspan="3">48 credits
(Minimum 12 credits per semester)</td></tr>
</table>

Core courses

AE 201 (AUG) 3:0

Flight and Space Mechanics

Basics of flight. Airflow in standard atmosphere. Airplane aerodynamics: Airfoils and finite lifting surfaces, thrust, power, level flight gliding, take-off, landing and basic manoeuvres. Airplane performance, stability and control. Mechanics of launch vehicles and satellites.

Instructor(s) **AE Faculty**

Reference

Anderson, J.D. Jr., Introduction to Flight, Fifth Edition, McGraw Hill Higher Education 2007.

AE 202 (AUG) 3:0

Fluid Dynamics

Properties of fluids, kinematics of fluid motion, conservation laws of mass, momentum and energy, potential flows, inviscid flows, vortex dynamics, dimensional analysis, principles of aerodynamics, introduction to laminar viscous flows.

Instructor(s) **AE Aerodynamics Faculty**

References

Kundu, P.K., Cohen, I.M. and Dowling, D.R., Fluid Mechanics, Academic Press, 2016.

Fay, J.A., Introduction to Fluid Mechanics, Prentice Hall of India, 1996.

Gupta, V. and Gupta, S.K., Fluid Mechanics and its Applications, Wiley Eastern, 1984.

Kuethe, A.M. and Chou, S.H., Foundations of Aerodynamics, Wiley, 1972.

AE 203 (AUG) 3:0

Mechanics and Thermodynamics of Propulsion

Classical thermodynamics, conservation equations for systems and control volumes, one dimensional flow of a compressible perfect gas – isentropic and non-isentropic flows. Propulsion system performance, the gas generator Brayton cycle, zero dimensional analysis of ideal ramjet, turbojet and turbofan cycles, non-ideality and isentropic efficiencies. Performance analysis of inlets and nozzles, gas turbine combustors, compressors and turbines and discussion of factors limiting performance. Chemical rockets - thrust equation, specific impulse, distinction between solid and liquid rockets, maximum height gained analysis, multi-staging, characteristics of propellants.

Instructor(s) **AE Propulsion Faculty**

References

Philip G. Hill and Carl R. Peterson. "Mechanics and thermodynamics of propulsion." Reading, MA, Addison-Wesley Publishing Co., 1992.

Nicholas Cumpsty and Andrew Heyes, Jet propulsion. Cambridge University Press, 2015.

Jack D. Mattingly, Elements of gas turbine propulsion. McGraw-Hill, 1996.

AE 204 (AUG) 3:0

Flight Vehicle Structures

Introduction to aircraft structures and materials; introduction to elasticity, torsion, bending and flexural shear, flexural shear flow in thin-walled sections; elastic buckling; failure theories; variational principles and energy methods; loads on aircraft.
Instructor(s) **AE Structures Faculty**
References
Sun, C.T., Mechanics of Aircraft Structures, John Wiley and Sons, New York, 2006.
Megson, T.H.G., Aircraft Structures for Engineering Students, Butterworth-Heinemann, Oxford, 2013.
Lecture notes.

AE 205 (AUG) 3:0
Navigation, Guidance and Control
Navigation: Continuous waves and frequency modulated radars, MTI and Doppler radars; Hyperbolic navigation systems: INS, GPS, SLAM; Guidance: Guided missiles, guidance laws: pursuit, LOS and PN laws, Guidance of UAVs; Control: Linear time invariant systems, transfer functions and state space modeling, analysis and synthesis of linear control systems, applications to aerospace engineering.
Instructor(s) **AE Navigation, Guidance and Control (NGC) Faculty**
References
AE NGC Faculty, *Lecture Notes*.
Skolnik, M. I., *Introduction to Radar Systems,* 2nd edition, McGraw Hill Book Company.
Bose A., Bhat, K. N., Kurian T., *Fundamentals of Navigation and Inertial Sensors*, 1st edition, Prentice-Hall India.
Noureldin, A., Karamat, T. B., and Georgy, J., *Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration*, 1st edition , Springer.
Nise, N.S., *Control Systems Engineering,* 6th edition, John Wiley and Sons Inc.
Shneydor, N. A., *Missile Guidance and Pursuit: Kinematics, Dynamics and Control,* 1st edition, Horwood Publishing.

Non-theory Core Courses

AE 296 (AUG) 0:1
Experimental Techniques in Aerospace Engineering
Experimental techniques in aerospace engineering is a 0:1 credit course that will include demonstrations of experiments in the major sub-disciplines of aerospace engineering. The intent of this course is to give an overview of the experimental facilities and techniques that are commonly used in research in aerospace.
Instructor(s) **AE Faculty**

AE 297 (4th semester) 1 credit
Aerospace Seminar
Aerospace Seminar is a 1 credit course offered in the 4th semester. This course will have lectures by AE faculty as well as lectures by staff from Archives and Publications Cell on best

practices in scientific written and oral communication. Thereafter the MTech students will present a report and seminar during the 4th semester on a topic chosen in consultation with their faculty advisor.

Special topics in Aerospace Engineering

AE 291 and AE 292 (2nd (August) and 3rd semester (January)) 3 credits each
Special Topics in Aerospace Engineering 1 & 2
These 2 electives, one each in the August and January semesters, will be of 3 credits each. These two electives will be of an advanced nature on topics of current research being pursued by AE faculty. These courses will be offered by interested AE faculty. These elective courses will be open to all students in the Institute and pre-requisites for registering for these electives will be with instructor's consent.
Instructor(s) **AE Faculty**

MTech Dissertation

AE 299 (3rd and 4th semester) 20 credits
Dissertation Project
The MTech dissertation project is aimed at training students to analyse independently any problem posed to them. The project may be a purely analytical piece of work, a completely experimental one or a combination of both. In a few cases, the project may also involve a sophisticated design work. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature and analytical and/or experimental or design skill.
Instructor(s) **AE Faculty**

Math requirement

Math requirement can be AE math courses, or courses from Math@IISc, or courses from CDS@IISc.

AE 211 (JAN) 3:0
Mathematical methods for Aerospace Engineers
Ordinary differential equations; Elementary numerical methods; Finite differences; Topics in linear algebra; Partial differential equations.
Instructor(s) **AE Faculty**
References

Erwin Kreysig, Advanced Engineering Mathematics Wiley 2015.

Electives

Aerodynamics
(Course numbers in the range AE 221 - AE 239; AE 321 - AE 339)
Aerospace Propulsion
(Course numbers in the range AE 241 - AE 249; AE 341 - AE 349)
Aerospace Structures
(Course numbers in the range AE 251 - AE 269; AE 351 - AE 369)
Navigation, Guidance, and Control
(Course numbers in the range AE 271 - AE 279; AE 371 - AE 379)

Aerodynamics
(Course numbers in the range AE 221 - AE 239; AE 321 - AE 339)

AE 221 (JAN) 3:0
Aerodynamics
Prerequisite **AE 202**
Introduction to aerodynamics, potential flows, conformal mapping and Joukowski airfoils, Kutta condition, thin airfoil theory, viscous effects and high-lift flows, lifting line theory, vortex lattice method, delta wings, compressibility effect, supersonic flows, unsteady aerodynamics.
Instructor **O N Ramesh or N Balakrishnan**
References
Houghton, E.L. and Carpenter, P.W., Aerodynamics for Engineering Students, Butterworth-Heinemann, 2003.
Katz, J. and Plotkin, A., Low-speed Aerodynamics, Cambridge, 2001.
Bertin, J.J. and Smith, M.L., Aerodynamics for Engineers, Prentice-Hall, 1989.

AE 222 (JAN) 3:0
Gas Dynamics
Prerequisite **AE 202**
Fundamentals of thermodynamics, propagation of small disturbances in gases, normal and oblique shock relations, nozzle flows, one-dimensional unsteady flow, small disturbance theory of supersonic speeds, generation of supersonic flows in tunnels, supersonic flow diagnostics, supersonic flow over two-dimensional bodies, shock expansion analysis, method of characteristics, one-dimensional rarefaction and compression waves, flow in shock tube.
Instructor **G Jagadeesh or Srisha Rao or J Mathew**
References
Liepmann, H.W. and Roshko, A., Elements of Gas Dynamics, John Wiley, 1957.
Becker, E., Gas Dynamics Academic Press, New York, 1968.

Anderson, J.D., Modern Compressible Flow, McGraw Hill, 1990.
Zucrow, M.J. and Hoffman, J.D., Gas Dynamics, Vols. 1-2, Wiley, 1976.
Zucker, R.D. and Biblarz, O., Fundamentals of Gas Dynamics, Wiley, 2002.

AE 223 (AUG) 3:0
Hypersonic Flow Theory
Prerequisites **AE 202, AE 222**
Characteristic features of hypersonic flow, basic equations boundary conditions for inviscid flow, shock shapes over bodies, flow over flat plate, flow over a wedge, hypersonic approximations, Prandtl-Meyer flow, axisymmetric flow over a cone. Hypersonic small disturbance theory, applications to flow over a wedge and a cone, blast wave analogy, Newtonian impact theory, Busemann centrifugal correction and shock expansion method, tangent cone and tangent wedge methods. Introduction to viscous flows, hypersonic boundary layers, non-equilibrium high enthalpy flows. High enthalpy impulse test facilities and instrumentation. Computational fluid mechanics techniques for hypersonic flows, methods of generating experimental data for numerical code validation at hypersonic Mach numbers in hypervelocity facilities.
Instructor **G Jagadeesh**
References
Cherynl, C.G., Introduction to Hypersonic Flow, Academic Press, 1961.
Hayes, W.D. and Problein, R.F., Hypersonic Flow Theory, Academic Press, 1959.
Cox, R.N. and Crabtree, L.P., Elements of Hypersonic Aerodynamics, London, 1965.

AE 224 (JAN) 3:0
Advanced Fluid Dynamics
Prerequisites **AE 202 or equivalent**
Viscosity, stress tensor, Navier-Stokes equations, boundary conditions. Parallel flows in ducts, Stokes/Rayleigh problems, laminar boundary layers, viscous compressible flow. Nature of turbulent flows, Reynolds decomposition and equations, turbulence modelling and computation, free shear and wall-bounded flows, DNS/LES.
Instructor **J Mathew**
References
White, F.M., Viscous Fluid Flow, McGraw-Hill, 2005.
Kundu, P.K., Cohen, I.M. and Dowling, D.R., Fluid Mechanics, Academic Press, 2016.
Pope, S.B., Turbulent Flows, Cambridge, 2000.

AE 225 (JAN) 3:0
Boundary Layer Theory
Prerequisites **AE 202 or equivalent**
Discussions on Navier-Stokes equation and its exact solutions, boundary layer approximations, two-dimensional boundary layer equations, asymptotic theory, Blasius and Falkner Skan solutions, momentum integral methods, introduction to axisymmetric and three-dimensional boundary layers, compressible boundary layer equations, thermal boundary layers in presence of heat transfer, higher-order corrections to the boundary layer equations, flow separation -

breakdown of the boundary layer approximation and the triple deck analysis, transitional and turbulent boundary layers - introduction and basic concepts.

Instructor **Sourabh S Diwan**

References

Schlichting, H., Boundary Layer Theory, McGraw-Hill, 1968.

Rosenhead (ed.), Laminar Boundary Layers, Clarendon Press, 1962.

van Dyke, M., Perturbation Methods in Fluid Mechanics, Academic Press, 1964.

Recent Literature.

AE 226 (JAN) 3:0

Turbulent Shear Flows

Prerequisite **AE 202 or equivalent**

Origin of turbulence, laminar-turbulent transition, vortex dynamics, statistical aspects of turbulence, scales in turbulence, spectrum of turbulence, boundary layers, pipe flow, free shear layers, concepts of equilibrium and similarity, basic ideas of turbulence modeling, measurement techniques.

Instructor **O N Ramesh or J Mathew**

References

Tritton, D.J., Physical Fluid Dynamics, Oxford University Press.

Tennekes, H. and Lumley, J., A First Course in Turbulence, M.I.T. Press.

Townsend, A.A., The Structure of Turbulent Shear Flow, Cambridge Univ. Press.

AE 227 (JAN) 3:0

Numerical Fluid Flow

Prerequisite **AE 202 or equivalent**

Introduction to CFD, equations governing fluid flow, hyperbolic partial differential equations and shocks, finite difference technique and difference equations, implicit difference formula, time discretization and stability, schemes for linear convective equation, analysis of time integration schemes, monotonicity, schemes for Euler equations, finite volume methodology. Introduction to unstructured mesh computations.

Instructor **N Balakrishnan**

References

Charles Hirsch, Numerical Computation of Internal and External Flows, Vols.1-2, Wiley-Interscience publication, 1990.

AE 228 (AUG) 2:1

Computation of Viscous flows

Prerequisite **AE 227**

Review of schemes for Euler equations, structured and unstructured mesh calculations, reconstruction procedure, convergence acceleration devices, schemes for viscous flow discretization, positivity, turbulence model implementation for unstructured mesh calculations, computation of incompressible flows. Introduction to LES and DNS.

Instructor **N Balakrishnan**

AE 229 (JAN) 3:0
Computational Gas Dynamics
Prerequisites **AE 202, AE 222, courses in Numerical Analysis/Numerical Methods, and any programming language.**
Governing equations of compressible fluid flows, classification of partial differential equations, analysis of hyperbolic conservation laws, basics of discretization, finite difference and finite volume methods, numerical diffusion, numerical methods for scalar and vector conservation laws, central and upwind discretization methods, flux splitting methods, Riemann solvers, kinetic (Boltzmann) schemes, relaxation schemes.
Instructor **S V Raghurama Rao**
Laney, B., Computational Gas Dynamics.
Toro, E.F., Riemann Solvers and Numerical Methods for Fluid Dynamics.
Godlewski, E., and Raviart, P., Numerical Approximation of Hyperbolic System of Conservation Laws.

AE 230 (JAN) 3:0
Numerical Grid Generation and Flow Computations
Basics of fluid dynamics, gas dynamics, governing equations of fluid dynamics, various levels of approximation, partial differential equations, basics of discretization, finite difference, finite volume methods, mesh-less methods, space marching and time marching approaches, geometrical complexities for mesh generation, methods of mesh generation, examples of simple flow computations
Instructor **Prakash S Kulkarni**
Tannehill, J.C., Anderson, D.A. and Fletcher, R.H., Computational Fluid Mechanics and Heat Transfer.
Anderson, Computational Fluid Dynamics - Basics and applications.
Joe Thompson, Numerical Grid Generation.

AE 231 (AUG) 3:0
Aerodynamic Testing Facilities and Measurements
Prerequisite **AE 202 or equivalent**
Aerodynamic testing in various speed regimes, requirements of aerodynamic testing, design aspects of low speed wind tunnels, flow visualization methods, measurement methods for flow variables. Wind tunnel balances, elements of computer-based instrumentation, measurements and analyses methods. Elements of high speed wind tunnel testing: design aspects to supersonic and hypersonic wind-tunnels, other high speed facilities like shock tube shock tunnels, free piston tunnels, ballistic ranges and low density tunnels, special aspects of instrumentation for high speed flows.
Instructors **Duvvuri Subrahmanyam, Sourabh S Diwan, and Srisha Rao**
References
William H Roe Jr., and Alan Pope, Low Speed Wind Tunnel Testing Wiley and Sons, 1984.

Pankhrust, R.C., and Holder, D.W., Wind-Tunnel technique, Sir Isaac Sons Ltd., London, 1968.
Lukasiewicz, J., Experimental methods of Hypersonic, Marcel Dekker in New York, 1973.
Alan Pope and Kenneth L Going, High-Speed Wind Tunnel Testing, Wiley and Sons, 1965.

AE 321 (JAN) 3:0
Hydrodynamic Stability
Prerequisite **AE 202 or equivalent and consent of Instructor.**
Hydrodynamic stability theory for laminar-turbulent transition. Linearized flow equations, normal mode analysis, the eigenvalue problem (EVP) and instability criteria: Rayleigh equation, discussion of Kelvin- Helmholtz and other instabilities. Boundary layer stability: Orr-Sommerfeld equations, Tollmien-Schlichting waves, dual role of viscosity. Introduction to spatio-temporal, absolute and convective instabilities, secondary instability theories. Weakly non-parallel shear flow instability: parabolized stability equation (PSE) methods, extensions to include nonlinearity. Global stability theory, non-parallel two and three-dimensional flow with multiple inhomogeneous directions. Nonmodal treatment of hydrodynamic stability as an initial value problem (IVP), optimal perturbations.
Instructor **Arnab Samanta**
References
Schmid, P. and Henningson, D., Stability and transition in shear flows, Springer, 2001.
Drazin, P.G. and Reid, W.H., Hydrodynamic stability, Cambridge University Press, 2004.
Recent Literature.

AE 322 (JAN) 3:0
Aeroacoustics
Pre requisite **AE 202 or equivalent and consent of instructor.**
Review of classical acoustics: linearized equations of motion; classical wave equation: plane and spherical waves, wave propagation in homogeneous and inhomogeneous media; models for acoustic sound sources: point sources, monopoles, dipoles and quadrupoles, Green's function solutions for wave equations, Kirchhoff-Helmholtz theorem for rigid boundaries. Aeroacoustic sources: Lighthill's acoustic analogy, integral solutions and far-field approximations; effect of solid surface: Curle's theory and Ffowcs Williams-Hawkings' equation. Computational approaches: numerical aspects; direct methods: Reynolds-averaged Navier-Stokes equations (RANS), direct numerical simulations (DNS), application of large eddy simulations (LES); hybrid methods: flow-sound separation, numerical evaluation of Lighthill's integral.
Instructor **Arnab Samanta**
References
Pierce, A.D., Acoustics, Acoustical Society of America, 1989.
Howe, M.S., Theory of Vortex sound, Cambridge, 2003.
Crighton, D.G., Basic principles of aerodynamic noise generation, Prog. Aerospace Sci., 16(1), 1975, pp. 31-96.
Crighton, D.G., Dowling, A.P.,Ffowcs Williams, J.E., Heckl, M. and Leppington, F.G., Modern methods in analytical acoustics, Springer, 1992.

Lecture notes.

Aerospace Propulsion
(Course numbers in the range AE 241 - AE 249; AE 341 - AE 349)

AE 241 (JAN) 3:0
Combustion
Thermodynamics of reacting systems. Chemical kinetics: equilibrium, analysis of simple reactions, steady-state and partial equilibrium approximations. Explosion theories; transport phenomena: molecular and convective transports. Conservation equations of multi-component, reacting systems. Premixed flames: Rankine-Hugoniot relations, theories of laminar premixed flame propagation, quenching and flammability limits. Diffusion flames: Burke-Schumann theory, laminar jet diffusion flame. Droplet combustion, turbulent combustion. Closure problem, premixed and nonpremixed turbulent combustion. Introduction to DNS and LES
Instructor **K N Lakshmisha**
References
Turns, S.R., An Introduction to Combustion, McGraw-Hill, 2000.
Strehlow, R.A., Combustion Fundamentals, McGraw-Hill, 1985.
Kuo, K.K., Principles of Combustion, Wiley, 1986.
Law, C.K., Combustion Physics, Cambridge University Press, 2006.
Williams, F.A., Combustion Theory, 1985.

AE 242 (JAN) 3:0
Aircraft Engines
Description of air breathing engines, propeller theory, engine propeller matching, piston engines, turbofan, turbo-prop, turbojet, component analysis, ramjets, velocity and altitude performance, thrust augmentation starting, principles of component design/selection and matching.
Instructor **T S Sheshadri or D Sivakumar**
References
Zucrow, M.J., Aircraft and Missile Propulsion, Vols. I and II John Wiley, 1958.
Hill, P.G., and Peterson, C.R., Mechanics and Thermodynamics of Propulsion, Addison Wesley, 1965.
Shepherd, D.G., Aerospace Propulsion, American Elsevier Pub., 1972.

AE 243 (JAN) 3:0
Rocket Propulsion
Introduction to rocket engines, features of chemical rocket propulsion, rocket equation, thrust equation, quasi-one-dimensional nozzle flow, types of nozzles, thrust control and vectoring, aerothermochemistry, propellant chemistry, performance parameters, solid propellant rocket internal ballistics, components and motor design of solid propellant rockets, ignition transients, elements of liquid propellant rocket engines, and spacecraft propulsion.
Instructor **Charlie Oommen or NKS Rajan**

References

Sutton, G.P., Rocket Propulsion Elements, John Wiley and Sons, 2001.

Barrare, M., et al., Rocket Propulsion, Elsevier Co., 1960.

Huzel, D.K., and Huang, D.K., Modern engineering for design of liquid-propellant rocket engines, AIAA, 1992.

AE 244 (AUG) 3:0

Introduction to Acoustics - I

Conservation equations, wave equation, acoustic energy, intensity and source power, spherical waves, frequency content of rounds, levels and the decibel Fourier series and long duration rounds. Reflection, transmission and excitation of plane waves, specific acoustic impedance, multilayer transmission and reflection, radiation from vibrating bodies. Monopoles and Green's functions. Reciprocity in acoustics.

Instructor **T S Sheshadri**

Reference

Allan d'Pierce, Acoustics McGraw Hill Book Company, 1981.

AE 245 (AUG) 3:0

Advanced Combustion

Prerequisites **AE 203 or AE 241 or AE 242 or AE 243, or equivalent. These can however be waived after discussion with the course instructors.**

Introduction: review of chemical equilibrium, heat of combustion, adiabatic flame temperature, kinetics. Review of Reynolds transport theorem and conservation equations. Non-premixed flames: mixture fraction, coupling functions. Burke Schumann flame and droplet combustion. Premixed flames: Thermodynamic considerations – Rankine Hugoniot relations: deflagration and detonation, flame speed and thickness phenomenology. Adiabatic flame speed and flame speed with heat loss. Flame stretch, flame speed with stretch, experimental techniques to determine laminar flame speed.Chemical structure of a premixed flame. Introduction to Turbulent Combustion: RANS equations, Favre averaging, length scales, energy spectra, mixing, intermittency. Turbulent Premixed Flames: Regime Diagrams, Turbulent flame speed. Turbulent Non-Premixed Flames: Mixing, scalar dissipation rates, extinction. Introduction to Combustion Instabilities

Instructors **Santosh Hemchandra or Swetaprovo Chaudhuri**

References

Combustion Physics by C. K. Law, Cambridge 2006.

Combustion Theory by F. A. Williams, Westview Press 1994.

Turbulent Combustion by N. Peters, Cambridge 2000.

Unsteady Combustor Physics by T. Lieuwen, Cambridge 2012.

Turbulent Flows by S. B. Pope, Cambridge, 2000.

Recent literature.

Aerospace Structures

(Course numbers in the range AE 251 - AE 269; AE 351 - AE 369)

AE 251 (JAN) 3:0

Energy and Finite Element Methods

Prerequisite **AE 204 or ME 242 or CE 214 and knowledge of MATLAB**

Introduction to Energy Methods; Principle of Virtual Work, Principle of Minimum Potential Energy, Raleigh Ritz Method, Hamilton's Principle. Introduction to Variational Methods, Weak form of Governing Equation, Weighted residual method, Introduction to Finite elements, and Galerkin Finite elements. Finite Element Method - Various element formulations for metallic and composite structures, isoparametric element formulation, Numerical Integration, concept of consistency, completeness and mesh locking problems. Finite element methods for structural dynamics and wave propagation, Mass and damping matrix formulation, Response estimation through modal methods, direct time integration, Implicit and Explicit Methods. Introduction to super convergent finite element formulation and spectral finite elements.

Instructor **S Gopalakrishnan**

References

Cook, R.D., Malkus, D.S., and Plesha, M.E., Finite Element Analysis, John Wiley & Sons, New York, 1995.

Bathe, K.J., Finite Element Procedures, Prentice Hall, New York, 1996.

Varadan, V.K., Vinoy, K.J., and Gopalakrishnan, S., Smart Material Systems and MEMS, John Wiley & Sons, UK, 2006.

Gopalakrishnan, S., Chakraborty, A., and Roy Mahapatra, D., Spectral Finite Elements, Springer Verlag, UK, 2008.

AE 252 (JAN) 3:0

Analysis and Design of Composite Structures

Introduction to composite materials, concepts of isotropy vs. anisotropy, composite micromechanics (effective stiffness/strength predictions, load-transfer mechanisms), Classical Lamination Plate theory (CLPT), failure criteria, hygrothermal stresses, bending of composite plates, analysis of sandwich plates, buckling analysis of laminated composite plates, inter-laminar stresses, First Order Shear Deformation Theory (FSDT), delamination models, composite tailoring and design issues, statics and elastic stability of initially curved and twisted composite beams, design of laminates using carpet and AML plots, preliminary design of composite structures for aerospace and automotive applications. Overview of current research in composites.

Instructor **Dineshkumar Harursampath, G Narayana Naik**

References

Gibson, R.F., Principles of Composite Material Mechanics, CRC Press, 2nd Edition, 2007.

Jones, R.M., Mechanics of Composite Materials, 2nd Edition, Taylor & Francis, 2010 (Indian Print).

Daniel, I.M., and Ishai O., Engineering Mechanics of Composite Materials, Oxford University Press, 2nd Edition, 2005.

Reddy, J.N., Mechanics of Laminated Composite Plates and Shells – Theory and Analysis, CRC Press, 2nd Edition, 2004.

AE 253 (AUG) 3:0

Multi-Body Dynamics using Symbolic Manipulators

Computer-aided modeling and simulation of 3D motions of multi-body systems. Coupled, multibody kinematics and dynamics, reference frames, vector differentiation, configuration and motion constraints, holonomicity, generalized speeds, partial velocities and partial angular velocities, Rodrigues parameter, inertia dyadics, parallel axes theorems, angular momentum, generalized forces, energy integrals, momentum integrals, generalized impulses and momentum, exact closed – form and approximate numerical solutions. Comparing Newton/Euler's, Lagrange's and Kane's methods. Generation and solution of equations of motion using computer algorithms and software packages from amongst MotionGenesis™ Kane, AUTOLEVTM, MATHAMATICA® and MATLAB®. Overview of flexible multi-body dynamics and applications in aerospace vehicular dynamics.

Instructor **Dineshkumar Harursampath**

References

Kane, T., and Levinson, D., Dynamics Online: Theory and implementation with AUTOLEVTM. Online Dynamics Inc., Sunnyvale, CA, USA, 2000. Mitiguy, P. Advanced Dynamics and Motion Simulation, MotionGenesis, San Mateo, CA, USA, 2008.

Wolfram, S., The Mathematica® book, Cambridge University Press, 5th Edition, 2003.

AE 254 (AUG) 3:0

Fatigue and Failure of Materials

Fatigue and damage tolerance in aerospace structures. Fatigue mechanism (macro and micro aspects), fatigue properties and strength, concept of stress concentration factor, effect of residual stresses, total-life approaches (stress-life, strain-life, fracture mechanics), effect of notches, constant and variable amplitude loading (cycle counting, damage summation, etc), multi-axial fatigue theories. Special topics on fatigue in composites will also be covered.

Instructor **Suhasini Gururaja**

References

S Suresh, Fatigue of Materials, Cambridge University Press, 1991.

J Schijve, Fatigue of Structures and Materials, Kluwer Academic Publ 2001.

TL Anderson, Fracture Mechanics: Fundamentals and Applications, 3rd Edition, CRC Press 2005.

AE 255 (JAN) 3:0

Aeroelasticity

Pre-requiste **A course in solid or fluid mechanics.**

Effect of wing flexibility on lift distribution; Torsional wing divergence; Vibration of single, two, and multi-degree of freedom models of wing with control surfaces; Unsteady aerodynamics of oscillating airfoil; Bending-torsion flutter of wing; Gust response of an aeroelastic airplane; Aeroservoelasticity of wing with control surfaces.

Instructor **Kartik Venkatraman**

References

Wright, J.R., and Cooper, J.E., Introduction to Aircraft Aeroelasticity and Loads, John Wiley, 2008.
Hodges, D.H., and Alvin Pierce, G., Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002.
Fung, Y.C., An Introduction to the Theory of Aeroelasticity, Dover edition, 2002.
Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Dover edition, 1996.

AE 256 (JAN) 3:0

Wave Propagation in Structures

Structural dynamics and wave propagation, continuous and discrete Fourier transform, FFT, sampled wave forms, spectral analysis of wave motion, propagating and reconstructing waves, dispersion relations, signal processing and spectral estimation, longitudinal wave propagation in rods, higher order rod theory, flexural wave propagation in beams, higher order beam theories, wave propagation in complex structures, spectral element formulation, wave propagation in two dimensions, wave propagation in plates.

Instructor **S Gopalakrishnan**

References

Doyle, J.F., Wave propagation in Structures, Springer Verlag, New York, 1989.
Grof, K.F., Wave motion in Elastic Solids, Dover, New York, 1975.

AE 257 (JAN) 3:0

Engineering Optimization

Constrained and unconstrained minimization of linear and nonlinear functions of one or more variables, necessary and sufficient conditions in optimization, KKT conditions, numerical methods in unconstrained optimization, one dimensional search, steepest descent and conjugate gradient methods, Newton and quasi-Newton methods. Finite difference, analytical and automatic differentiation, linear programming, numerical methods for constrained optimization, response surface methods in optimization, orthogonal arrays, stochastic optimization methods.

Instructor **Ranjan Ganguli**

Reference

Ranjan Ganguli, Engineering Optimization: A Modern Approach, Universities Press, 2010.

AE 258 (JAN) 3:0

Non-Destructive Testing and Evaluation

Prerequisite **AE 204 or equivalent**

Fundamentals and basic concepts of NDT & E, Principles and applications of different NDE tools used for testing and evaluation of aerospace structures viz., ultrasonics, radiography, electromagnetic methods,
acoustic emission, thermography. Detection and characterization of defects and damage in metallic and composite structural components.

Instructor **M R Bhat**

Reference

Sharpe, R.A., Research Techniques in NDT, Metals Handbook -Vol.17.

AE 259 (JAN) 3:0

Rotary Wing Aeroelasticity

Review of structural dynamics. Dynamics of rotating beams: hinged rigid blades, elastic blades, rotor speed characteristics and fan plots, blades in flap, lag and torsion. Aerodynamic loads, forced response and vibration, harmonic balance method, finite element in time. Vehicle trim. Stability analysis methods: constant coefficients, Floquet theory. Blade aeroelastic instabilities. Ground resonance and air resonance.

Instructor **Ranjan Ganguli**

References

Bielawa, R.L., Rotary Wing Structural Dynamics and Aeroelasticity, AIAA Education Series, 1992. Johnson, W., Helicopter Theory, Dover, 1994.

Bramwell, Done, Balmford, Bramwell's Helicopter Dynamics, Butterworth-Heineman, 2001.

AE 260 (JAN) 3:0

Modal analysis: Theory and Applications

Introduction to modal testing and applications, Frequency Response Function (FRF) measurement, properties of FRF data for SDOF and MDOF systems, signal and system analysis, modal analysis of rotating structures; exciters, sensors application in modal parameter (natural frequency, damping and mode shape) estimation. Vibration standards for human and machines, calibration and sensitivity analysis in modal testing, modal parameter estimation methods, global modal analysis methods in time and frequency domain, derivation of mathematical models – modal model, response model and spatial models. Coupled and modified structure analysis. Application of modal analysis to practical structures and condition health monitoring.

Instructor **S B Kandagal**

References

Ewins, D.J., Modal analysis: Theory and Practice, Research Studies Press Ltd., England, 2000.

Clarence W. de Silva, Vibration: Fundamentals and Practice, CRC press New York, 1999

G. McConnel, Vibration testing: Theory and Practice, John Wiley & Sons, Inc., New York, 1995.

AE 261 (AUG) 3:0

Structural Vibration Control

Introduction to vibration control, passive and active vibration control. Concept of vibration isolation, dynamic vibration absorber, visco-elastic polymers as constrained and unconstrained configuration in passive vibration control. Constitutive modeling of structures with PZTs/PVDF materials, electro restrictive, magneto restrictive and shape memory alloys. Application of PZT patches, PVDF films, electro restrictive, magneto restrictive materials and shape memory alloys (SMA) in structural vibration control.

Instructor **S B Kandagal**

References

Nashif, D.N., Jones, D.I.G., and Henderson, J.P., Vibration damping, John Wiley, New York, 1985. Srinivasan, A.V., and McFarland, D.M., Smart Structures: Analysis and Design, Cambridge University Press, Cambridge, 2001.
Inman, D.J., Vibration with Control, John Wiley, New York, 2006.

AE 262 (JAN) 3:0
Introduction to Helicopters
Hover, axial flight and autorotation, rigid blade flapping in forward flight, multi-blade coordinates, different reference planes. Helicopter quasi-steady and unsteady aerodynamics, rotor wake modeling and dynamic stall. Floquet theory, introduction to rotor control performance and vibration. Helicopter design process.
Instructors **Ranjan Ganguli and S N Omkar**
References
Gessow, A., and Myers, G.C. Jr., Aerodynamics of the Helicopter. Frederick, Unger Publishing Co., New York, 1967.
Leishman, G.J., Principles of Helicopter Aerodynamics, Cambridge University Press, 2000.

AE 263 (JAN) 3:0
Atmospheric Flight Dynamics
Prerequisite **AE 201 or equivalent**
Review of equations of motion, stability derivative estimation, static stability and control, longitudinal and lateral modes, transfer function and response characteristics, feedback and automatic control, response to atmospheric gust and turbulence. Handing qualities, human pilot modelling case studies of typical airplanes, roll and spin characteristics, flight simulators, stability and control derivative estimation from wind tunnel and flight tests.
Instructors **Dinesh K Harursampath and Radhakant Padhi**
References
Babistor, A.H., Aircraft Stability and Control, Pergamon Press.
Elkin, B., Dynamics of Atmospheric Flight, John Wiley and Sons.
Mcroer D Ashikenbars I and Graham D., Aircraft Dynamics and Automatic Control, Princeton University Press.
ESDU Data Sheets

AE 351 (AUG) 3:0
Research Techniques in Non-Destructive Evaluation
Prerequisite **Ae 258 or equivalent and consent of instructor**
Quantitative non destructive evaluation involved probabilistic methods of quality control and life assessment. Signal analysis and image processing in NDE, ultrasonic, thermographic and tomographic methods for evaluation of composites.
Instructor **M R Bhat**
References
American Society of Metal (ASM) Hand Book, Volume 17.

Thompson, D.O., and Chimenti, D.E. Eds, Review of progress in quantitative Non Destructive Evaluation. Annual Conference proceedings.

AE 352 (JAN) 3:0

Nonlinear Mechanics of Composite Structures

Pre-requiste **AE 252 or equivalent and consent of instructor**

Introduction to classical geometrical and physical non-linearities and non-classical geometrophysical non-linearities in structural mechanics. Mechanics of composite lamina and laminates including response and failure as affected by nonlinearities. Variational asymptotic methods of constructing nonlinear composite beam, plate and shell theories. Non-classical effects resulting from non-linearities. Effects of nonlinearities on stability of thin-walled structures. Introduction to nonlinear finite element analysis including mixed formulations. Applications to engineering structures like pipes, springs and rotor blades.

Instructor **Dineshkumar Harursampath**

Hodges, D.H., Nonlinear Composites Beam Theory, Progress in Astronautics & Aeronautics Series, 2013.

Berdichevsky, V.L., Variational Principles of Continuum Mechanics, I. Fundamentals & II. Applications. Interaction of Mechanics & Mathematics Series, Springer, 2009.

Current literature in International Journal of Nonlinear Mechanics, International Journal of Solids and Structures etc.

AE 353 (JAN) 3:0

Micromechanics of composites

Prerequisites **Solid mechanics or equivalent and consent of instructor**

Introduction to tensors, properties of tensors, concepts of isotropy and anisotropy, micromechanical homogenization theory, Eshelby's approach, self-consistent schemes, Mori-Tanaka Mean field theory, bounds on effective properties, concentric cylinder models, introduction to computational homogenization, introduction to damage mechanics, statistical aspects of microstructure

Instructor **Suhasini Gururaja**

References

Micromechanics of defects in solids, T. Mura 1982

Micromechanics of composite materials, Brett Bendnarcyk et al, 2012

Open literature

Navigation, Guidance, and Control

(Course numbers in the range AE 271 - AE 279; AE 371 - AE 379)

AE 271 (JAN) 3:0

Guidance Theory and Applications

Prerequisite **AE 205 or equivalent**

Fundamentals of guidance; interception and avoidance; taxonomy of guidance laws, classical and empirical guidance laws; applied optimal control and optimal guidance laws; differential games and pursuit evasion problems. Recent advances in guidance theory. Collision detection and avoidance strategies. Applications to guided missiles. Unmanned aerial vehicles and mobile robots.

Instructors **A Ratnoo and Debasish Ghose**

References

Zarchan, P., Tactical and Strategic Missile Guidance, AIAA Publications, 4th Edition, 2002.

G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, 2004.

N.A.Sneyhdor, Missile Guidance and Pursuit, Ellis Horwood Publishers, 1998.

AE 272 (AUG) 3:0

Biologically Inspired Computing and its Applications

Prerequisite **Working knowledge of MATLAB or any other programming language**

Introduction, neural networks – different learning techniques, McCulloch-Pitts neuron, perceptrons, delta rule, multilayer perceptron networks, radial basis function network, self-organizing networks. Introduction to evolutionary computing and GA, GA terminology and operators (mutation, crossover, inversion). Selection, replacement and reproduction strategies. Fitness, proportional, random, and tournament and rank based selection. Swarm intelligence – basic ideas, swarm behavior, flocking, self-organization, adaptation, multi-agent systems, trail laying, self-assembling, task handling, combinatorial optimization. Applications of biologically inspired algorithms in engineering.

Instructor **S N Omkar**

References

Bonabeau, E., Dorigo, M., and Theraulaz, G., Swarm Intelligence: From Natural to Artificial Systems, Oxford University Press, 1999.

Simon Haykin, Neural Networks – A Comprehensive Foundation, 2nd Edition, Prentice-Hall, Inc., 1999.

Michalewicz, Z., Genetic Algorithms+Data Structures=Evolution Programs, 3rd Edn, Springer-Verlag, Berlin, 1996.

AE 273 (JAN) 3:0

Unmanned Aerial Vehicles

Prerequisites **AE 201 and AE 205**

History of Unmanned Air Vehicle (UAV) development. Unmanned aircraft systems: coordinate frames, kinematics and dynamics, forces and moments, lateral and longitudinal autopilots. UAV navigation: accelerometers, gyros, GPS. Path planning algorithms: Dubin’s curves, way-points, Voronoi partitions.

Path following and guidance: Straight line and curve following, vision based guidance; Future directions and the road ahead.

Instructor **Ashwini Ratnoo**

References

Randal W.Beard and Timothy W.McLain: Small Unmanned Aircraft: Theory and Practice, Princeton University Press, 2012.

Kimon P.Valavanis: Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy, Springer, 2007.

AE 274 (JAN) 3:0

Topics in Neural Computation

Prerequisite **Knowledge of algebra, numerical methods, calculus and familiarity with programming in Python and MATLAB.**

Foundation of neural networks: perceptron, multi-layer perceptron, radial basis function network, recurrent neural network; Evolving/online learning algorithms; Deep neural networks: Convolutional neural network, restricted Boltzmann machine; Unsupervised learning; Advanced topics: Reinforcement learning and deep-reinforcement learning; Spiking neural network---spiking neuron, STDP, rank-order learning, synapse model, SEFRON.

Instructors **Suresh Sundaram**

References

S. Haykin, Neural Networks, Pearson Education, 2ed, 2001.

AE 371 (JAN) 3:0

Applied Nonlinear Control

Introduction and motivation, phase plane analysis, mathematical preliminaries. Review of functional analysis, topology and matrix theory; Lyapunov stability theory: autonomous systems; back-stepping design; dynamic inversion (feedback linearization). Applications of neural networks in control system design, neuro-adaptive control, nonlinear observers, Lyapunov stability theory: non-autonomous systems, adaptive control, advanced nonlinear flight control.

Instructor **Radhakant Padhi**

Prerequisite **AE 205 and 272 or equivalent; familiarity with MATLAB**

Marquez, H.J., Nonlinear Control Systems Analysis and Design, Wiley, 2003.

Slotine, J.J.E., and Li, W., Applied Nonlinear Control, Prentice Hall, 1991.

Khalil, H. K., Nonlinear Systems, Prentice Hall, 1996.

Behera, L., and Kar, I., Intelligent Systems and Control, Oxford Univ. Press, 2009.

Lecture Notes.

AE 372 (JAN) 3:0

Applied Optimal Control and State Estimation

Prerequisites **AE 205 or equivalent and familiarity with MATLAB**

Introduction and motivation review of static optimization, calculus of variations and optimal control formulation; numerical solution of two-point boundary value problems: shooting method, gradient method and quasi-linearization; Linear Quadratic Regulator (LQR) design: Riccati solution, stability proof, extensions of LQR, State Transition Matrix (STM) solution; State Dependent Riccati Equation (SDRE) design; dynamic programming: HJB theory; approximate dynamic programming and adaptive critic design; MPSP Design; optimal state estimation: Kalman filter, extended Kalman filter; robust control design through optimal control and state estimation; constrained optimal control systems: Pontryagin minimum principle, control constrained problems, state constrained problems; neighbouring extremals and sufficiency conditions. Discrete time optimal control: Generic formulation, discrete LQR.

Instructor **Radhakant Padhi**

References

Naidu, D.S., Optimal Control Systems, CRC Press, 2002.

Sinha, A., Linear Systems: Optimal and Robust Control, CRC Press, 2007.

Bryson, A.E., and Ho, Y-C, Applied Optimal Control, Taylor and Francis, 1975.

Stengel, R.F., Optimal Control and Estimation, Dover Publications, 1994.

Sage, A.P., and White, C.C. III, Optimum Systems Control, 2nd Ed., Prentice Hall, 1977.

Kirk, D.E., Optimal Control Theory: An Introduction, Prentice Hall, 1970. Lewis, F.L., Optimal Control, Wiley, 1986.

Lecture Notes.

AE 373 (JAN) 3:0

Cooperative Control with Aerospace Applications

Introduction to cooperative control, mathematical preliminaries: algebraic graph theory, matrices for cooperative control, stability of formations. Consensus algorithms, consensus for single and double integrator dynamics, consensus in position, direction, and attitude dynamics. Distributed multi-vehicular cooperative control. Generalized cyclic pursuit; spacecraft formation flying. UAV applications in search, coverage, and surveillance of large areas, and in monitoring and controlling of hazards. Routing and path planning of UAVs. Role of communication. Operation in uncertain environments and uncertainty.

Instructor **D Ghose**

References

Shamma, J. (ed), Cooperative Control of Distributed Multi-Agent Systems, John Wiley, 2008.

Qu, Z., Cooperative Control of Dynamical Systems, Springer Verlag, 2009.

Ren, W., and Beard, R., Distributed Consensus in Multi-vehicle Cooperative Control: Theory and Applications, Springer, 2007.

Rasmussen, S., and Shima, T. (Eds.), UAV Cooperative Decision and Control: Challenges and Practical Approaches, SIAM Publications, 2008.