DEPARTMENT OF AEROSPACE ENGINEERING

http://engineering.tamu.edu/aerospace

Head: R.D. Bowersox

Graduate Program Director: J.L. Valasek

Graduate Advisor: V.K. Kinra

The Department of Aerospace Engineering offers graduate work and research programs in aeronautical/aerospace engineering. Programs leading to the degrees of MEng, MS and PhD are available. The department also offers courses and faculty supervision for students pursuing the Doctor of Engineering degree. Major areas of interest are aero/fluid dynamics, hypersonics, computational fluid dynamics, fluid-structure interaction (aeroelasticity), flight mechanics, astrodynamics, spacecraft/aircraft dynamics and control, rotorcraft, computational mechanics, solid mechanics, micromechanics, nanomechanics, composite materials, bio-nano materials, aging aircraft and structures.

The aerodynamics and propulsion-related research within the department includes airfoil and wing analyses, boundary layer stability, turbulence, combustion, propulsion and flow-control for aircraft, land vehicles, wind turbines and other applications. A major focus within the department is viscous flows across the speed regimes ranging from incompressible subsonic to hypersonic. Fundamental transition research is performed using world-class quiet-flow facilities that include the Klebanoff/Saric Low Disturbance Tunnel and the NASA Langley/TAMU Mach 6 Quiet Tunnel. The Texas A&M University National Aerothermochemistry (TAMU-NAL) Laboratory is a graduate research facility for conducting leading research in support of national interests in high-speed gasdynamics, unsteady flows and flows with thermal and chemical non-equilibrium effects.

Research involving dynamics and control of autonomous intelligent vehicles, formation flying of spacecraft and other problems in astrodynamics is performed in the Center for Mechanics and Control. The Land, Air and Space Robotics (LASR) laboratory enables sensing and control research with emphasis on high fidelity emulation of close proximity motions of two or more vehicles. LASR is being utilized to research spacecraft on-orbit proximity operations, autonomous aerial refueling of UAVs and astronaut supervision of robots for surface operations on the Moon or Mars. Research related to satellite design, responsive space systems and autonomous rendezvous and docking is conducted by the AggieSat Lab Student Satellite Program. The department has a two-observatory facility on the grounds of the Physics Department’s Astronomy Teaching Observatory, which is used for research on fine resolution interferometric imaging of space objects via photonic quantum correlations. Recently founded Advanced Vertical Flight Lab (AVFL) conducts rotorcraft-related research focusing on design, development and flight testing of revolutionary vertical take-off and landing (VTOL) capable UAVs mainly at meso scales (commonly called Micro Air Vehicles or MAVs).

Investigations of materials and structural mechanics problems are undertaken in the Center for Mechanics of Composites. Research on nanomaterials, multifunctional material systems, multiscale modeling and integrated adaptive structures is coordinated by the Texas Institute for Intelligent Materials and Structures for Aerospace Vehicles (TiiMS). Research in the Electroactive Materials Characterization Laboratory focuses on processing-microstructure-property relationships in smart materials with the goal of developing new materials with unique combinations of mechanical, electrical and coupled properties for uses that range from advanced electronic devices and autonomous system concepts to the aerospace, automotive, medical and consumer industries.

Numerical simulations of complex fluid and solid mechanics problems are efficiently obtained with university and supporting departmental computational facilities.

Courses relating to structural mechanics and materials listed at the end of this section are contained within the College of Engineering listing. The mechanics and materials courses are administered by the Department of Aerospace Engineering and are taught by faculty from the Departments of Aerospace, Civil and Mechanical Engineering. A foreign language is not required for any of the aerospace degree programs.

Mechanics and Materials (MEMA)

The mechanics and materials course offerings perform three major functions. First, and most importantly, they are interdisciplinary vehicles for staff and students who study and conduct research in those increasingly important areas requiring a blending of mechanics and materials. Second, they provide the support base for graduate students to pursue studies in the traditional areas of either applied mechanics or materials science. Third, they provide a coordinated set of service courses for the engineering departments. Interested students should contact their department’s graduate advisor.

Faculty

Alfriend, Kyle T, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1967

Benzerga, Amine A, Professor
Aerospace Engineering

Bhattacharya, Raktim, Associate Professor
Aerospace Engineering
PHD, University of Minnesota, Twin Cities, 2003

Bowersox, Rodney D, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1992

Boyd, James G, Associate Professor
Aerospace Engineering
PHD, Texas A&M University, 1994

Chakravorty, Suman, Associate Professor
Aerospace Engineering
PHD, University of Michigan, 2004

Chamitoff, Gregory E, Professor of the Practice
Aerospace Engineering
PHD, Massachusetts Institute of Technology, 1992

Cizmas, Paul G, Professor
Aerospace Engineering
PHD, Duke University, 1995
Donzis, Diego A, Associate Professor
Aerospace Engineering
PHD, Georgia Institute of Technology, 2007

Dunbar, Bonnie J, Professor
Aerospace Engineering
PHD, University of Houston, 1983

Girimaji, Sharath, Professor
Aerospace Engineering
PHD, Cornell University, 1990

Hara, Kentaro, Assistant Professor
Aerospace Engineering
PHD, University of Michigan, 2015

Hartl, Darren J, Assistant Professor
Aerospace Engineering
PHD, Texas A&M University, 2009

Hurtado, John, Professor
Aerospace Engineering
PHD, Texas A&M University, 1995

Junkins, John L, Distinguished Professor
Aerospace Engineering
PHD, University of California, Los Angeles, 1969

Karpetis, Adonios N, Associate Professor
Aerospace Engineering
PHD, Yale University, 1998

Kinra, Vikram K, Professor
Aerospace Engineering
PHD, Brown University, 1975

Lagoudas, Dimitris, Professor
Aerospace Engineering
PHD, Lehigh University, 1986

Langari, Gholamreza, Professor
Aerospace Engineering
PHD, University of California, Berkeley, 1991

Le Graverend, Jean-Briac B, Assistant Professor
Aerospace Engineering
PHD, Ecole Nationale de Mécanique et d'Aérotechnique, France, 2013

Limbach, Christopher M, Research Assistant Professor
Aerospace Engineering
PHD, Princeton University, 2015

Majji, Manoranjan, Assistant Professor
Aerospace Engineering
PHD, Texas A&M University, 2009

Miles, Richard, Professor
Aerospace Engineering
PHD, Stanford University, 1972

Moble, Benedict, Assistant Professor
Aerospace Engineering
PHD, University of Maryland, 2010

Mortari, Daniele, Professor
Aerospace Engineering
PHD, University La Sapienza of Rome, 1980

Naraghi, Mohammad, Assistant Professor
Aerospace Engineering
PHD, University of Illinois at Urbana-Champaign, 2009

Pollock, Thomas C, Associate Professor
Aerospace Engineering
PHD, University of Virginia, 1977

Poludnenko, Oleksiy Y, Associate Professor
Aerospace Engineering
PHD, University of Rochester, 2004

Reed, Helen L, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1981

Saric, William S, Distinguished Professor
Aerospace Engineering
PHD, Illinois Institute of Technology, 1968

Shryock, Kristi J, Instructional Associate Professor
Aerospace Engineering
PHD, Texas A&M University, 2011

Skelton, Robert E, Professor
Aerospace Engineering
PHD, University of California, Los Angeles, 1976

Strganac, Thomas W, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1987

Tichonr, Nathan, Research Assistant Professor
Aerospace Engineering
PHD, The University of Texas at Austin, 1986

Talreja, Ramesh R, Professor
Aerospace Engineering
PHD, The Technical University of Denmark, 1974

Valasek, John L, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1983

Whitcomb, John D, Professor
Aerospace Engineering
PHD, Kyiv Aviation University, 2011

Vadali, Srinivas R, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1983

Whitcomb, John D, Professor
Aerospace Engineering
PHD, Virginia Polytechnic Institute and State University, 1988
Masters

- Master of Engineering in Aerospace Engineering (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/engineering/aerospace/meng)
- Master of Science in Aerospace Engineering (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/engineering/aerospace/ms)

Courses

AERO 601 Advanced Aerodynamics
Credits 3. 3 Lecture Hours.
Theoretical and approximate numerical solutions for incompressible and transonic flows and applications to airfoil, wing and whole-vehicle aerodynamics; approximate methods for boundary layers; introduction to aerodynamic design concepts; design of swept wings and delta wings, control surfaces, winglets, vortex generators and flow control. 
Prerequisite: Approval of instructor.

AERO 602 The Theory of Fluid Mechanics
Credits 4. 3 Lecture Hours. 3 Lab Hours.
Entry-level graduate course on the theory of fluid mechanics, with emphasis on viscous subsonic flows; concepts of boundary layer theory, flow stability, transition and turbulence; laboratory includes elements of measurement techniques, numerical methods and physical modeling. 
Prerequisite: MATH 601 or registration therein.

AERO 603/MEMA 602 Continuum Mechanics
Credits 3. 3 Lecture Hours.
Development of field equations for analysis of continua (solids as well as fluids); conservation laws; kinematics, constitutive behavior of solids and fluids; applications to aerospace engineering problems involving solids and fluids. 
Prerequisite: Graduate classification. 
Cross Listing: MEMA 602/AERO 603.

AERO 605/MEE 603 Theory of Elasticity
Credits 3. 3 Lecture Hours.
Analysis of stress and strain in two- and three-dimensions, equilibrium and compatibility equations, strain energy methods; torsion of noncircular sections; flexure, axially symmetric problems. 
Prerequisite: graduate or senior undergraduate standing. 
Cross Listing: MEEN 603/AERO 605.

AERO 606 Multifunctional Materials
Credits 3. 3 Lecture Hours.
In-depth analysis of multifunctional materials and composites, and their novel applications. 
Prerequisites: MEMA 602/AERO 603/MEMA 602, MSEN 601. 
Cross Listing: MEMA 606 and MSEN 606.

AERO 608 Nanomechanics
Credits 3. 3 Lecture Hours.
Application of mechanics concepts to nano-scale behavior of materials. Review of continuum mechanics; Extensions to generalized continua; Nonlocal elasticity; Nano-scale plasticity. Focus on multi-scale modeling: Dislocation Dynamics; Quasi-Continuum method; Molecular dynamics with introductions to quantum mechanics and statistical mechanics. 
Prerequisite: AERO 603/MEMA 602. 
Cross Listing: MEMA 608 and MSEN 608.

AERO 609 Sustainability Metrics and Life Cycle Assessment in Engineering
Credits 3. 3 Lecture Hours.
Concepts of sustainability with associated metrics; application of systems engineering tools to facilitate assessment of viable options on products and processes; assessment of impact on the entire biosphere; product life cycle analysis. 
Prerequisite: Graduate classification.

AERO 615 Computational Fluid Dynamics for Aerospace Applications
Credits 3. 3 Lecture Hours.
Methods for solving internal and external flow problems; viscous and inviscid compressible flow, Euler, Navier-Stokes and Large Eddy Simulation solvers, boundary conditions. 
Prerequisite: MATH 601 or approval of instructor.

AERO 616 Damage and Failure in Composite Materials
Credits 3. 3 Lecture Hours.
Mechanisms and models related to damage and failure in composite materials subjected to mechanical loads. 
Prerequisite: Courses in composite materials, elasticity. 
Cross Listing: MEMA 616 and MSEN 636.

AERO 617/MEMA 625 Micromechanics
Credits 3. 3 Lecture Hours.
Eigenstrains; inclusions, and inhomogeneities; Eshelby's solution for an ellipsoidal inclusion; Eshelby's equivalent inclusion method. Effective elastic properties of composites; composite spheres and cylinders models; bounds on effective moduli; Hashin-Shtrikman bounds; applications to fiber, whisker and particulate reinforced composites; introduction to micromechanics of inelastic composites and solids with damage. 
Prerequisites: MEMA 602/AERO 603, or AERO 603/MEMA 602, AERO 605/MEEN 603. 
Cross Listing: MEMA 625/AERO 617.

AERO 618/MEMA 626 Mechanics of Active Materials
Credits 3. 3 Lecture Hours.
Introduction to coupled field theories: constitutive response of materials with thermal and electromagnetic coupling; microstructural changes due to phase transformations; shape memory alloys; piezoelectric and magnetostrictive materials; active polymers and solutions. Micromechanics of active composites. 
Prerequisites: MEMA 602/AERO 603. 
Cross Listing: MEMA 626/AERO 618.

AERO 620 Unsteady Aerodynamics
Credits 3. 3 Lecture Hours.
Theoretical formulation of unsteady airfoil theory and techniques used for determining airloads on oscillating lift surfaces; exact solutions and various approximations presented and evaluated; application to problems of unsteady incompressible, subsonic and transonic flows about airfoils and wings. 
Prerequisite: Approval of instructor.
**AERO 621 Aeromechanics of Wind Turbines**  
Credits 3.3 Lecture Hours.  
Solid and fluid mechanics concepts applied to aerodynamics and aeroelasticity of wind turbine blades; failure analysis and structural design; composites and hybrid materials.  
**Prerequisite:** Graduate Classification.

**AERO 622 Spacecraft Dynamics and Control**  
Credits 3.3 Lecture Hours.  
Elements of analytical dynamics; modeling different types of spacecraft and control systems, sensors, and actuators; stability; control system design; effects of flexibility; attitude and orbital coupling; environmental effects.  
**Prerequisites:** AERO 422 or ECEN 420.

**AERO 623 Optimal Spacecraft Attitude and Orbital Maneuvers**  
Credits 3.3 Lecture Hours.  
Application of optimization and optimal control techniques to spacecraft maneuver problems; computation of open loop and feedback controls for linear and nonlinear spacecraft dynamical systems; low-thrust and impulsive control, discretization methods, case studies.  
**Prerequisite:** AERO 423 or equivalent.

**AERO 624 Celestial Mechanics**  
Credits 3.3 Lecture Hours.  
Analytical and numerical methods for computing spacecraft orbits under the influence of gravitational, aerodynamic, thrust and other forces; Keplerian two-body problem, perturbation methods, orbit determination, navigation and guidance for aerospace vehicles.  
**Prerequisite:** AERO 423 or equivalent.

**AERO 625 Modern Control of Aerospace Systems**  
Credits 3.3 Lecture Hours.  
Linear and nonlinear controllers for aircraft and spacecraft; state and output feedback of sampled-data control systems; feedback linearization and dynamic inversion; direct sampled-data design using optimal MIMO techniques; sensing considerations, sources and modeling of uncertainties unique to aircraft and spacecraft, robustness analysis.  
**Prerequisite:** AERO 422 or equivalent.

**AERO 626 Estimation of Dynamic Systems**  
Credits 3.3 Lecture Hours.  
Traditional concepts and recent advances in estimation related to modern dynamic systems found in aerospace disciplines; least squares estimation, state estimation, nonlinear filtering, aircraft position and velocity tracking, attitude determination of spacecraft vehicles, gyro bias estimation and calibration.  
**Prerequisites:** AERO 310 or equivalent; STAT 211 or equivalent.

**AERO 627 Principles of Structural Dynamics**  
Credits 3.3 Lecture Hours.  
Examination of flexible structures through a review of single degree-of-freedom dynamical systems followed by an in-depth study of continuous and multiple degree-of-freedom systems; emphasis on discrete modeling of structures for vibration analysis and dynamic analysis, with minimal development of methods such as finite elements.  
**Prerequisite:** Graduate classification.

**AERO 628 Advanced Spacecraft Dynamics and Control**  
Credits 3.3 Lecture Hours.  
Review of fundamental principles; introduction to alternate and advanced methods of dynamics and control for aerospace systems; alternate methods for generating and analyzing equations of motion; techniques for complex multibody systems; variable speed control moment gyros; method of quadratic modes; focus on modeling techniques for aerospace systems.  
**Prerequisite:** AERO 622.

**AERO 629 Experimental Aerodynamics**  
Credits 3.3 Lecture Hours.  
Review of fundamental principles in aerodynamics; basics of instrumentation, electronics, data-acquisition; experimental techniques in aerodynamics/fluid mechanics; pressure, skin friction, force and velocity measurement techniques in wind and water-tunnel testing; conventional and novel techniques in data-processing and systems modeling; smart systems in experimental aerodynamics.  
**Prerequisite:** AERO 601.

**AERO 630 Introduction to Random Dynamical Systems**  
Credits 3.3 Lecture Hours.  
Building on basic probability theory, course covers theory and applications of discrete and continuous random processes. Particular attention shall be paid to the response of dynamical systems (discrete, linear and non-linear), to random input processes and their application to Engineering Systems.  
**Prerequisite:** Graduate classification.

**AERO 631 Model Predictive Control for Aerospace Systems**  
Credits 3.3 Lecture Hours.  
Nonlinear optimal control and optimization, optimal control theory, dynamical systems stability and control, approximation theory, convex optimization; control of engineering systems with state and control constraints with parametric uncertainty; formulate optimal control problems, solve as nonlinear programming problems using available solvers; requires background in control theory.  
**Prerequisites:** Graduate classification and AERO 623 or comparable course.

**AERO 632 Design of Advanced Flight Control Systems - Theory and Application**  
Credits 3.3 Lecture Hours.  
Modeling, analysis, design and implementation of advanced flight control problems, specifically aerospace engineering applications; includes choice of controlled variables, reduction of controlled variables, design methodology, computational framework, implementation issues, and software environments using various toolboxes.  
**Prerequisites:** Graduate classification and approval of instructor.

**AERO 633 Advanced Aerospace Multibody Dynamics**  
Credits 3.3 Lecture Hours.  
Techniques for modeling, simulation, and analyzing multibody dynamical systems; includes development of kinematic expressions for articulating bodies, adding and constraining degrees of freedom through mappings; familiarization with industry codes, such as DISCOS; appreciation of learned techniques on various systems, including omni-directional vehicles, Stewart platforms, and gyroscopically-stabilized walking robots.  
**Prerequisites:** AERO 622 or graduate classification and approval of instructor.
AERO 640 Turbulence Processes
Credits 3. 3 Lecture Hours.
Fundamentals of conservation, Lagrangian, transformation, variance properties; flow features: laminar, transition, turbulence regimes, characteristics, spectrum; statistical (filter/average) description: scales, Reynolds, arbitrary averaging, realizability; elementary turbulence processes: viscous, advective/inertial, role of pressure; elementary process models, viscous RDT, RDT for velocity gradients, equipartition of energy, restricted Euler equations; isotropic, homogeneous turbulence. May be taken 2 times for credit.

AERO 641 High-Speed Combustion for Propulsion
Credits 3. 3 Lecture Hours.
Study topics in combustion relevant to high-speed subsonic/supersonic air-breathing propulsion; emphasis on the structure of detonations and the operation of combustors under supersonic conditions; structure of shock-waves and the mixing/chemical kinetics that take place in high speeds.
Prerequisite: Graduate classification.

AERO 642 Laser Diagnostics for Combustion and Propulsion
Credits 3. 3 Lecture Hours.
Laser diagnostics topics as applied to combustion and propulsion; brief exposition of fundamental electromagnetic theory; practice of basic experimental laser techniques used to measure thermochemistry; basic implementation of Raman and Rayleigh scatterings; Laser-Induced Fluorescence (LIF); detection methods, optical systems, noise contributions, and signal enhancement techniques will be discussed.
Prerequisite: Graduate classification.

AERO 643 High-Performance Computational Fluid Dynamics
Credits 3. 3 Lecture Hours.
Numerical simulations of fluid dynamics problems on massively parallel computers; focus on Direct Numerical Simulations (DNS) where all dynamically relevant scales are resolved; elements of both high-performance computing (HPC) and numerical methods to solve incompressive and compressible flows.
Prerequisite: AERO 615 or approval of instructor.

AERO 645/MSEN 645 Failure Mechanics of Engineering Materials
Credits 3. 3 Lecture Hours.
Introduction and integration of key experimental, theoretical and computational aspects of failure in engineering materials, including metals, alloys and polymers; brittle fracture, ductile fracture and brittle-to-ductile transitions.
Prerequisites: Graduate classification; MSEN 601.
Cross Listing: MSEN 645/AERO 645.

AERO 649/MEMA 649 Generalized Finite Element Methods
Credits 3. 3 Lecture Hours.
Systemic introduction to the theory and practice of generalized finite element (FE) methods, including GFEM, the hp-cloud method, particle methods, and various meshless methods with similar character; precise formulation of the methods are presented; known theoretical results for convergence; important issues related to implementation, issues of numerical integration.
Prerequisite: Graduate classification.
Cross Listing: MEMA 649/AERO 649.

AERO 650 Spacecraft Attitude Determination
Credits 3. 3 Lecture Hours.
Spacecraft attitude determination systems; attitude and error parameterizations, attitude sensors, data processing and calibration; introduction to single- and three- axis attitude determination and to optimal attitude and error estimation: ECI motion and time definitions.
Prerequisite: AERO 423 or equivalent.

AERO 651 Human Spaceflight Operations
Credits 3. 3 Lecture Hours.
Essential aspects of human spaceflight operations as performed NASA; in-depth understanding of the state-of-the-art in spacecraft operations, including spacecraft systems, ground and launch operations, mission management and on-orbit activities such as science, robotics, spacewalking, and human health maintenance; applications to future space systems.
Prerequisite: Graduate classification.

AERO 660 Nonlinear Flight Dynamics
Credits 3. 3 Lecture Hours.
Nonlinear equations of motion for coupled aircraft motions; coupled aerodynamic phenomena; application of the direct method of Lyapunov to nonlinear aircraft motions; elastic airplane equations of motion.
Prerequisite: AERO 421 or approval of instructor.

AERO 661 Optical Methods in Aerospace Engineering
Credits 3. 3 Lecture Hours.
Analysis and design of imaging and interferometric instruments for flight in and above the atmosphere and ground-based observation of orbiting objects; assessment of optical component and system performance.
Prerequisite: Graduate classification.

AERO 670 Turbulence Modeling
Credits 3. 3 Lecture Hours.
Identification of physical features that render Navier-Stokes equation difficult to compute or model; includes Reynolds-averaged and filtered Navier-Stokes equations for unresolved stresses; development of closure models for pressure-strain correlation, dissipation and turbulent transport Reynolds; algebraic Reynolds stress modeling, Large Eddy Simulations (LES) and hybrid methods; validation and prediction studies.
Prerequisites: AERO 640 and graduate classification or approval of instructor.

AERO 672 Perturbation Methods in Mechanics
Credits 3. 3 Lecture Hours.
Develop approximate solutions to algebraic, differential, and integral equations; analysis of nonlinear oscillations, nonlinear waves, and boundary-layers; emphasis on combined numerical/perturbations techniques and reducing Partial Differential Equation (PDE) to Ordinary Differential Equation (ODE).
Prerequisites: Graduate classification in aerospace, mechanical or civil engineering.

AERO 673 Boundary Layer Stability and Transition
Credits 3. 3 Lecture Hours.
Analytical, numerical, and experimental methods for the stability of bounded shear flows; includes techniques for estimating transition to turbulence and the control of transition through laminar flow control.
Prerequisites: Graduate classification and AERO 601, 602, or 603 or approval of instructor.
AERO 674 Hypersonic Flow
Credits 3. 3 Lecture Hours.
Theoretical formulation of hypersonic flow theory; techniques for hypersonic flowfield analysis; high temperature effects, including both equilibrium and nonequilibrium flows; classical and modern computational methods.
Prerequisite: AERO 303 or equivalent.

AERO 676 Aerothermochemistry
Credits 3. 3 Lecture Hours.
Fundamentals of kinetic theory, chemical thermodynamics and statistical mechanics; applications to high temperature chemically reacting equilibrium and nonequilibrium aerodynamic flows.
Prerequisite: AERO 303 or equivalent.

AERO 681 Seminar
Credit 1. 1 Lecture Hour.
Selected research topics presented by the faculty, students and outside speakers.
Prerequisite: Graduate classification.

AERO 684 Professional Internship
Credits 1 to 4. 1 to 4 Other Hours.
Engineering research and design experience at government or industry facilities away from the Texas A&M campus; design projects supervised by faculty coordinators and personnel at these locations; projects selected to match student's area of specialization.
Prerequisites: Graduate classification and approval of committee chair and department head.

AERO 685 Directed Studies
Credits 1 to 12. 1 to 12 Other Hours.
Special topics not within scope of thesis research and not covered by other formal courses.
Prerequisite: Graduate classification in aerospace engineering.

AERO 689 Special Topics in...
Credits 1 to 4. 1 to 4 Lecture Hours.
Selected topics in an identified area of aerospace engineering. May be repeated for credit.
Prerequisite: Approval of instructor.

AERO 691 Research
Credits 1 to 23. 1 to 23 Other Hours.
Technical research projects approved by department head.

MEMA 602/AERO 603 Continuum Mechanics
Credits 3. 3 Lecture Hours.
Development of field equations for analysis of continua (solids as well as fluids); conservation laws; kinematics, constitutive behavior of solids and fluids; applications to aerospace engineering problems involving solids and fluids.
Prerequisite: Graduate classification.
Cross Listing: AERO 603/MEMA 602.

MEMA 606 Multifunctional Materials
Credits 3. 3 Lecture Hours.
In-depth analysis of multifunctional materials and composites, and their novel applications.
Prerequisites: MEMA 602/AERO 603/AERO 603/MEMA 602, MSEN 601.
Cross Listing: AERO 606 and MSEN 606.

MEMA 608 Nanomechanics
Credits 3. 3 Lecture Hours.
Application of mechanics concepts to nano-scale behavior of materials. Review of continuum mechanics; Extensions to generalized continua; Nonlocal elasticity; Nano-scale plasticity. Focus on multi-scale modeling: Dislocation Dynamics; Quasi-Continuum method; Molecular dynamics with introductions to quantum mechanics and statistical mechanics.
Prerequisite: AERO 603/MEMA 602.
Cross Listing: AERO 608 and MSEN 608.

MEMA 611 Fundamentals of Engineering Fracture Mechanics
Credits 3. 3 Lecture Hours.
Understanding of the failure of structures containing cracks with emphasis on mechanics; linear elastic fracture mechanics, complex potentials of Muskhelishvili and Westergaard, J-integral, energy release rate, R-curve analysis, crack opening displacement, plane strain fracture toughness testing, fatigue crack propagation, fracture criteria, fracture of composite materials.
Prerequisite: AERO 603/MEMA 602.

MEMA 613/MSEN 610 Principles of Composite Materials
Credits 3. 3 Lecture Hours.
Classification and characteristics of composite materials; micromechanical and macromechanical behavior of composite laminae; macromechanical behavior of laminates using classical laminate theory; interlaminar stresses and failure modes; structural design concepts, testing and manufacturing techniques.
Prerequisite: MEMA 602/AERO 603.
Cross Listing: MSEN 610/MEMA 613.

MEMA 616 Damage and Failure in Composite Materials
Credits 3. 3 Lecture Hours.
Mechanisms and models related to damage and failure in composite materials subjected to mechanical loads.
Prerequisite: Courses in composite materials, elasticity.
Cross Listing: AERO 616 and MSEN 636.

MEMA 625/AERO 617 Micromechanics
Credits 3. 3 Lecture Hours.
Eigenstrains; inclusions, and inhomogeneities; Eshelby's solution for an ellipsoidal inclusion; Eshelby's equivalent inclusion method. Effective elastic properties of composites; composite spheres and cylinders models; bounds on effective moduli; Hashin-Shtrikman bounds; applications to fiber, whisker and particulate reinforced composites; introduction to micromechanics of inelastic composites and solids with damage.
Prerequisite: MEMA 602/AERO 603.
Cross Listing: AERO 617/MEMA 625.

MEMA 626/AERO 618 Mechanics of Active Materials
Credits 3. 3 Lecture Hours.
Introduction to coupled field theories: constitutive response of materials with thermal and electromagnetic coupling; microstructural changes due to phase transformations; shape memory alloys; piezoelectric and magnetostrictive materials; active polymers and solutions. Micromechanics of active composites.
Prerequisite: MEMA 602/AERO 603.
Cross Listing: AERO 618/MEMA 626.
MEMA 634/CVEN 753 Damage Mechanics of Solids and Structures  
**Credits 3. 3 Lecture Hours.**  
Damage mechanics; constitutive modeling of damage behavior of materials; application of thermodynamic laws; computational techniques for predicting progressive damage and failure; plasticity; viscoplasticity; viscoelasticity; cohesive zone modeling; fatigue and creep damage; damage in various brittle and ductile materials (e.g., metal, concrete, polymer, ceramic, asphalt, biomaterial, composites).  
**Prerequisite:** CVEN 633 or approval of instructor.  
**Cross Listing:** CVEN 753/MEMA 634.

MEMA 635 Structural Analysis of Composites  
**Credits 3. 3 Lecture Hours.**  
Formulation and analysis structural response of laminated composite components; bending, vibration and stability of laminated composite plates; interlaminar stresses, effect of shear deformation on structural response; numerical modeling of laminated plates.  
**Prerequisite:** MEMA 613/MSEN 610.

MEMA 641 Plasticity Theory  
**Credits 3. 3 Lecture Hours.**  
Theory of plastic yield and flow of two and three-dimensional bodies; classical plasticity theories, unified viscoplastic theories, numerical considerations; applications and comparisons of theory to experiment.  
**Prerequisite:** MEMA 602/AERO 603.  
**Cross Listing:** MSEN 641 and MEEN 666.

MEMA 646 Introduction to the Finite Element Method  
**Credits 3. 3 Lecture Hours.**  
Weak or variational formulation of differential equations governing one- and two-dimensional problems of engineering; finite element model development and analysis of standard problems of solid mechanics (bars, beams and plane elasticity), heat transfer and fluid mechanics; time-dependent problems; computer implementation and use of simple finite element codes in solving engineering problems.  
**Prerequisite:** Senior or graduate classification.

MEMA 647 Theory of Finite Element Analysis  
**Credits 3. 3 Lecture Hours.**  
Finite elements models of a continuum; virtual work principle; plane stress and plane strain finite element models; bending of plates; axisymmetric problems; three-dimensional stress analysis; isoparametric formulations; finite element computer programs to solve typical structural problems.  
**Prerequisite:** Graduate classification or approval of instructor.

MEMA 648 Nonlinear Finite Element Methods in Structural Mechanics  
**Credits 3. 3 Lecture Hours.**  
Tensor definitions of stress and strain, finite strain, geometric and material nonlinearities; development of nonlinear finite element equations from virtual work; total and updated Lagrangian formulations; solution methods for nonlinear equations; computational considerations; applications using existing computer programs.  
**Prerequisite:** MEMA 647 or equivalent.

MEMA 649/AERO 649 Generalized Finite Element Methods  
**Credits 3. 3 Lecture Hours.**  
Systemic introduction to the theory and practice of generalized finite element (FE) methods, including GFEM, the hp-cloud method, particle methods and various meshless methods with similar character; precise formulation of the methods are presented; known theoretical results for convergence; important issues related to implementation, issues of numerical integration.  
**Prerequisite:** Graduate student status.  
**Cross Listing:** AERO 649/MEMA 649.

MEMA 670 Computational Materials Science and Engineering  
**Credits 3. 3 Lecture Hours.**  
Modern methods of computational modeling and simulation of materials properties and phenomena, including synthesis, characterization, and processing of materials, structures and devices; quantum, classical, and statistical mechanical methods, including semi-empirical atomic and molecular-scale simulations, and other modeling techniques using macroscopic input.  
**Prerequisites:** Approval of instructor; graduate classification.  
**Cross Listing:** MSEN 670 and CHEN 670.

MEMA 689 Special Topics in...  
**Credits 1 to 4. 1 to 4 Lecture Hours.**  
Selected topics in an identified area of mechanics and materials. May be repeated for credit.  
**Prerequisite:** Approval of instructor.