Aerospace Engineering, M.S.A.E., Ph.D.

Degrees Offered
- Masters of Science, Aerospace Engineering (M.S.A.E.)
- Doctor of Philosophy, Aerospace Engineering (Ph.D.)

Educational Objectives of the Departmental Graduate-Level Programs:
1. To provide high quality advanced master-level and Ph.D. level education to graduate engineering students to enable successful careers in technology development, innovation and research, with depth and breadth in one or several areas of the aerospace engineering discipline.
2. To develop the capacity of graduates to conduct independent research and/or technology development and innovation, through original contributions to the aerospace engineering discipline and to disseminate the results of their scholarly work.
3. To instill in graduates the drive for leadership in technology development, innovation and research and to contribute to the advancement of the profession in a societal and economic context.

The outcomes of the graduate programs in Aerospace Engineering are as follows:
- Holders of graduate degrees will have an expert-level understanding of the advanced principles of aerospace engineering, which include aerospace systems design, aircraft or spacecraft dynamics, stability and control, flight mechanics and simulation, advanced materials, vehicle propulsion, aerodynamics, aeroelasticity, and computational mechanics.
- Holders of graduate degrees will hold paramount the highest standards of ethical and professional responsibility in the practice of their profession to contribute to the well-being of society and to the advancement of the aerospace engineering profession.
- Holders of Ph.D. degrees will have furthered original research contributions to the state of the art in their specific areas of expertise and will be able to develop innovative research in order to advance the frontiers of knowledge, secure sponsored research, and disseminate its findings through scholarly publications.

Masters Admissions
The minimum requirements for admission as a regular student into the M.S. degree in Aerospace Engineering program are summarized as follows:
- Applicants for admission into the M.S. in Aerospace Engineering degree program must have earned a grade point average (GPA) of 3.0 or better (out of a possible 4.0) in any previous engineering degree, from an accredited or internationally recognized program.
- International applicants must meet the WVU requirement of English language proficiency (https://graduateadmissions.wvu.edu/how-to-apply/apply-for-2022-2023/international-graduate-applicant/).
- International applicants (who have not received their undergraduate degree from an accredited USA institution) are required to submit GRE general test scores. The GRE scores required for admission as a regular graduate student is seventy-fourth percentile (74%) or higher in the Quantitative section (strictly enforced). The GRE scores for the verbal and analytical sections will be taken into consideration in the admission process.
- Three recent reference letters, at least two of which, should be from professors the institution last attended.

Doctoral Admissions
The minimum requirements for admission into the Ph.D. degree in Aerospace Engineering Program are summarized as follows:
- Applicants must hold or expect to receive (by the enrollment date) a M.S. degree in an engineering discipline from an institution which has an ABET accredited undergraduate program in engineering or an internationally recognized program in engineering (except for students qualified for the direct track to Ph.D. degree option, described below). Qualified candidates holding a M.S. degree in applied sciences can also be considered for admission into the Ph.D. program.
- Applicants for admission into the Ph.D. degree program must have earned a grade point average (GPA) of 3.0 or better (out of a possible 4.0) in all previous engineering degrees (B.S. and M.S.), from an accredited or internationally recognized program.
- Three recent reference letters, at least two of which should be from professors of the institution last attended.
- International applicants must meet the WVU requirement of English language proficiency (https://graduateadmissions.wvu.edu/how-to-apply/apply-for-2022-2023/international-graduate-applicant/).
- International applicants (who have not received their undergraduate degree from an accredited USA institution) are required to submit GRE general test scores. The GRE scores required for admission as a regular graduate student is seventy-fourth percentile (74%) or higher in the Quantitative section (strictly enforced). The GRE scores for the verbal and analytical sections will be taken into consideration in the admission process.

Direct-Track PhD Admissions
The Department of Mechanical and Aerospace Engineering (MAE) offers a direct track option from the bachelor of science (B.S.) to the doctor of philosophy (Ph.D.) degree for prospective qualified students holding a B.S. degree in an engineering discipline, materials science, mathematics, or
applied sciences from an accredited undergraduate program or an internationally recognized program. This is an accelerated track that provides outstanding candidates the option of earning a Ph.D. degree in less than five years after graduating from an undergraduate program by engaging early in their Ph.D. dissertation research without having to complete a research thesis for a master of science (M.S.) degree. To qualify for the direct track degree option, all applicants must have:

- A cumulative grade point average (GPA) of 3.5/4.0 or higher in his/her undergraduate studies
- A minimum of seventy-fourth percentile (74%) in the quantitative section of the standardized Graduate Record Examination (GRE).
- Three recent reference letters, at least two of which, should be from professors of the institution last attended.
- International applicants must meet the WVU requirement of English language proficiency (https://graduateadmissions.wvu.edu/how-to-apply/apply-for-2022-2023/international-graduate-applicant/).

**Admission Requirements 2023-2024**

The above Admission Requirements above will be the same for the 2023-2024 Academic Year.

MSAE Major Code: 3005

PhD Major Code: 3006

For specific information on the following programs, please see the links to the right:

- Aerospace Engineering, M.S.A.E.
- Aerospace Engineering, Ph.D.

**Thesis Based Master's Degrees**

All the requirements for thesis based master's degrees (M.S.A.E., M.S.M.E. and M.S.M.S.&E.) in the MAE Department must be completed within eight years preceding the student's graduation. All students in these programs are required to engage in research, complete and successfully defend a master's thesis. They must identify a subject for their thesis research, form a three-member advisory and examining committee (AEC), and file a plan of study by the end of their second semester of enrollment in the graduate program. A minimum of twenty-four credit hours of coursework with a minimum overall GPA of 3.0/4.0 and six credit hours of M.S. thesis research are required for the thesis based master's degrees. Students must pass a final examination administered by their advisory and examining committee before being certified for the degree. All thesis based master's degree students have to comply with core requirements by selecting a "core area" and taking two of the courses listed in that area, and in addition they have to comply with the mathematics requirements by taking two courses from an approved list. Four additional courses can be selected from a list of technical electives, or from the core and mathematics lists to complete the coursework requirements, with no more than three courses at the 400 level.

**Course Based Master's Degree**

A course-only master's degree option is available (M.S.E.), in which students are required to complete thirty-three credit hours of coursework with a minimum overall GPA of 3.0/4.0 and pass a comprehensive examination administered by an advisory and examining committee. Students pursuing a course-only master's degree option are not eligible to receive financial support from the MAE Department. All the requirements for this degree option must also be completed within eight years preceding the student's graduation.

**Ph.D. Degrees**

The MAE Department offers Ph.D. Programs in Aerospace Engineering, in Mechanical Engineering and in Materials Science and Engineering. These programs require a minimum of eighteen credit hours of graduate level coursework plus a minimum of twenty-four credit hours of research. Students in the Ph.D. program must take and pass the Ph.D. Qualifier examination by the second semester of the program with a second attempt no later than the third semester in the program if necessary. After the qualifier examination, students are expected to produce a dissertation proposal and defend it before a five-member advising and examining committee (AEC). Subsequent the successful proposal defense, students must comply with the journal paper publication (or patent disclosure) requirement in order to attain Ph.D. Candidacy. Finally Ph.D. candidates must successfully defend a Ph.D. dissertation and submit it to WVU library through the ETD protocol to fulfill all the requirements for the degree.

**COURSES**

**MAE 515. Analytical Methods in Engineering. 3 Hours.**

PR: Consent. Index notation for determinants, matrices, and quadratic forms; linear vector spaces, linear operators including differential operators; calculus of variations, eigenvalue problems, and boundary value problems.
MAE 516. Computational Methods in Engineering. 3 Hours.
PR: Knowledge of undergraduate-level Statics, Dynamics, Fluid Dynamics, Numerical Analysis, as well as MATLAB or any other basic programming language such as C++ or Python. Students will be introduced to essential concepts in computational methods; functional approximations, system of nonlinear equations, curve fitting, numerical differentiation and integration. Explicit, implicit, and iterative techniques will be used in conjunction with finite difference, finite volume and finite element methods, with emphasis on applications in mechanical and aerospace engineering including aerodynamics, heat transfer, mechanics of materials, and so on.

MAE 521. Advanced Thermodynamics 1. 3 Hours.
PR: MAE 321 or MAE 426. First and second laws of thermodynamics with emphasis on entropy production and availability (exergy); Maxwell's relationships and criteria for stability; equations of state and general thermodynamic equations for systems of constant chemical composition.

MAE 525. Heavy Duty Vehicle Emissions. 3 Hours.
PR: Graduate student standing in engineering or instructor consent. Present research and development of advanced heavy-duty engines and their use in vehicle powertrains. Study emissions formation and control from existing and developing heavy-duty vehicle system designs using conventional and hybrid propulsion systems.

MAE 526. Advanced Internal Combustion Engine. 3 Hours.
PR: MAE 425 with a minimum grade of C- or consent. An intermediate to advanced examination of internal combustion engine thermochemical processes, instrumentation, diagnostics, data analysis and modeling, with focus on preparing the student for advanced engine research.

MAE 528. Introduction to Fuel Cell Technology. 3 Hours.
PR: Graduate student standing in engineering or consent. Fuel cells definition, types and application areas, thermodynamics of fuel cells, introduction of electrochemistry, Nernst Potential, Butler-Volmer and Tafel equations, experimental techniques, computational techniques, fuel cell materials, fuel processing and storage, stack, and system design.

MAE 531. Fluid Mechanics 1. 3 Hours.

MAE 532. Dynamics of Viscous Fluids. 3 Hours.
PR: Consent. Derivation of and exact solutions for the Navier-Stokes equations; laminar boundary-layer theory, similarity solutions, and integral methods.

MAE 534. Fluid Flow Measurements. 3 Hours.
PR: MAE 336 or Consent. Principles and measurements of static and dynamic pressures and temperatures, velocity, and Mach number and forces. Optical techniques and photography. Design of experiments. Review of selected papers from the literature. (2 hr. lec., 3 hr. lab.).

MAE 543. Advanced Mechanics of Materials. 3 Hours.
PR: Consent. Shear flow and shear center; curved beams; unsymmetrical bending, energy methods in structural analysis; theories of failure; instability of structures; beams on elastic foundation.

MAE 561. Satellite Navigation. 3 Hours.
PR: MAE 411 and MAE 460 or consent. Examination of various segments of the Global Positioning System. Applications, error sources, and advanced methods for mitigating these errors sources. Estimation procedures, algorithms, and GPS processing will be introduced and utilized.

MAE 565. Artificial Intelligence Techniques in Mechanical and Aerospace Engineering. 3 Hours.
Introduction to solving complex problems in mechanical and aerospace engineering using genetic (evolutionary) algorithms, fuzzy logic-based modeling and control, and artificial neural networks.

MAE 580. Crystallography and Crystals. 3 Hours.
Introduction to the principles of structure of materials, and theory and applications of diffraction and imaging techniques for materials characterization using X-ray diffraction and transmission electron microscopy (TEM).

MAE 583. Thermodynamics and Kinetics of Materials. 3 Hours.
Fundamental concepts of thermodynamics and kinetics of materials. Classical thermodynamics. Examples of the application of thermodynamic concepts to the analysis of material systems.

MAE 593. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

MAE 621. Advanced Thermodynamics 2. 3 Hours.
PR: MAE 521 or Consent. Thermodynamics of multi-component inert and reacting systems; equilibrium analysis; introduction to irreversible processes involving diffusion and chemical kinetics; application of concepts to heterogeneous systems.

MAE 623. Conduction Heat Transfer. 3 Hours.
PR: MAE 423 or Consent. Analytical and numerical solutions of steady and non-steady heat conduction problems in one-, two-, and three dimensional bodies; solution of linearized equations; applications include extended surfaces, moving surfaces, moving heat sources, and instrumentation techniques.

MAE 624. Convection Heat Transfer. 3 Hours.
PR: MAE 423 or Consent. Laminar and turbulent flows in forced and free convection systems; external and internal flows with application to heat exchanger design; introduction to aerodynamic heating.
MAE 625. Radiation Heat Transfer. 3 Hours.
PR: MAE 423 or consent. Classical derivation of black body radiation laws; gray body and non-gray analysis; radiant properties of materials, radiant transport analysis, specular-diffuse networks, gas radiation, thermal radiation measurements; analytical, numerical solutions, and study of selected publications. (3 hr. lec.).

MAE 631. Gas Dynamics. 3 Hours.

MAE 633. Computational Fluid Dynamics. 3 Hours.
PR: MAE 532 or equivalent. Finite difference methods; convergence and stability; Navier-Stokes equations; discretization methods; grid distribution; solution of difference equations; pressure coupling; application to conduction/convection, boundary layers, and recirculating flows; introduction to general purpose CFD codes.

MAE 635. Turbomachinery. 3 Hours.
PR: MAE 320 or Consent. Flow problems encountered in design of water, gas, and steam turbines, centrifugal and axial flow pumps and compressors, design parameters.

MAE 636. Fundamentals of Turbulent Flow. 3 Hours.
PR: MAE 532 or consent. Statistical theories of turbulence and recent applications. Basic experimental data and length and time scale analysis. Application of semi-empirical theories to pipe, jet, and boundary-layer flow.

MAE 640. Continuum Mechanics. 3 Hours.
PR: MAE 242 and MAE 243. Mathematical preliminaries including index notation; analysis of stress; analysis of deformation; fundamental laws, field equations, and constitutive equations; application to fluids and solids.

MAE 641. Theory of Elasticity 1. 3 Hours.
PR: Consent. Cartesian tensors; plane stress and plane strain; 2-D problems in Cartesian and polar coordinates; stress and strain in 3-D; general theorems; torsion of noncircular sections.

MAE 642. Intermediate Dynamics. 3 Hours.

MAE 643. Inelastic Behavior of Engineering Materials. 3 Hours.
PR: MAE 543 or Consent. Characterization and constitutive relations of engineering materials; nonlinear elasticity, plasticity, viscoelasticity and creep; numerical implementation.

MAE 644. Fracture Mechanics. 3 Hours.
PR: MAE 641. Linear-elastic and elastic-plastic fracture mechanics; fatigue, dynamic, and creep crack growth; fracture mechanics models for composite materials.

PR: Consent. Variational principles of mechanics and applications to engineering problems; principles of virtual displacements, minimum potential energy, and complementary energy, Castigliano's theorem, Hamilton's principle. Applications to theory of plates, shells, and stability.

MAE 646. Advanced Mechanics of Composite Materials. 3 Hours.
PR: MAE 446 or Consent. Manufacturing, testing, and diagnostics of composite materials. Anisotropic plates with cutouts. Inelastic behavior of polymer matrix composites. Analysis of advanced composites such as metal matrix, ceramic matrix, and textile.

MAE 648. Experimental Stress Analysis. 3 Hours.
PR: Consent. Strain gage techniques and instrumentation; stress analysis using optical methods such as photoelasticity and interferometric techniques; NDE and NDT or problems involving stress analysis. (2 hr. lec., 3 hr. lab.).

MAE 649. Microscopy of Materials. 3 Hours.

MAE 653. Advanced Vibrations. 3 Hours.
PR: Consent. Dynamic analysis of multiple degree-of-freedom discrete vibrating systems; Lagrangian formulation; matrix and numerical methods; impact; mechanical transients.

MAE 656. Advanced Computer Aided Design. 3 Hours.
Geometric modeling; finite element meshing; design approaches, case studies using CAD principles; projects utilizing state-of- the-art CAD packages. (2 hr. lec., 3 hr. lab.).

MAE 660. Feedback Control in Mechanical Engineering. 3 Hours.
PR: Consent. Emphasis on design of control systems using classical, frequency domain, and time domain methods; advanced mathematical modeling of physical systems, compensation, stabilization, pole placement, state estimation; extensive use of computerized design tools, especially Matlab.
MAE 662. Robot Mechanics and Control. 3 Hours.
Kinematic and dynamic behavior of industrial robot manipulators; formulation of equations of motion for link joint space and end effector Cartesian space; path planning and trajectory motion control schemes.

MAE 663. Instrumentation in Engineering. 3 Hours.
PR: Consent. Theory of instrumentation suitable for measuring rapidly changing force, pressure, strain, temperature, vibration, etc.; computerized acquisition, analysis, and transmission of data; methods of noise reduction. (2 hr. lec., 3 hr. lab.).

MAE 686. Materials Science and Engineering Seminar. 1 Hour.
Mandatory seminar series for all materials science and engineering (MS&E) majors. Recent developments in materials science and engineering.

MAE 687. Materials Engineering. 3 Hours.
A study of materials engineering fundamentals emphasizing semiconductor, polymer, metal, and ceramic/cementitious material systems. Mechanical and physical properties, theoretical aspects, testing, design criteria, manufacturing, and economics of material systems. Laboratory testing and evaluation. (Equivalent to CE 687, CHE 687, EE 687, MINE 687, and IMSE 687.).

MAE 691. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

MAE 693. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

MAE 694. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

MAE 695. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

MAE 697. Research. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.).

MAE 721. Fundamentals of Combustion. 3 Hours.
PR: MAE 321 or MAE 426. Thermodynamics, chemical kinetics, and diffusion of reacting gases; laminar and turbulent flames; flame stability and ignition.

MAE 733. Perfect Fluid Theory. 3 Hours.
PR: Consent. Conformal mapping including Schwarz-Christoffel and Joukowski transformations. Inviscid flows over airfoils, spheres, cones, wedges, and bodies of revolution. (3 hr. lec.).

MAE 741. Theory of Elasticity 2. 3 Hours.
PR: MAE 641. Complex variable methods, stress couples, nonlinear elasticity, numerical methods, potential methods, boundary value problems, and various special topics.

MAE 743. Theory of Elastic Stability. 3 Hours.
PR: Consent. Stability of discrete mechanical systems, energy theorems, buckling of beams, beam columns and frames, torsional buckling, buckling of plates and shells, and special topics.

MAE 744. Theory of Plates and Shells. 3 Hours.
PR: MAE 543 or Consent. Classical and modern theories of plates; dynamic response, nonlinear effects, and exact and approximate solutions of plates; application to rectangular and circular plates; membrane shells; shells with bending stiffness.

MAE 760. Advanced Topics in Control Theory. 3 Hours.
PR: MAE 660 or MAE 465. State feedback through eigenstructure assignment; Observers and Kalman filters; multiple-model adaptive estimation and control; parameter estimation; direct and indirect model-reference adaptive-control algorithms; introduction to neural networks.

MAE 790. Teaching Practicum. 1-3 Hours.
PR: Consent. Supervised practice in college teaching of Benjamin M. Statler College of Engineering and Mineral Resources courses. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

MAE 791. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

MAE 793. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

MAE 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

MAE 797. Research. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.).