Department of Mechanical and Aerospace Engineering

Degrees Offered

• Master of science in mechanical engineering
• Master of science in engineering with a major in mechanical engineering
• Master of science in aerospace engineering
• Master of science in engineering with a major in aerospace engineering
• Doctor of philosophy in engineering with a major in mechanical engineering
• Doctor of philosophy in engineering with a major in aerospace engineering

The outcomes of the graduate programs in Mechanical Engineering are as follows:

• Holders of graduate degrees will have an expert-level understanding of the advanced principles of mechanical engineering, which include mechanical systems design, system dynamics, solid mechanics, energy systems, engineering materials, automatic controls, mechatronics, 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 mechanical 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.

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.

Faculty

Faculty members in the department have extensive research, industrial, and teaching experience and have published widely. Their combined experience helps them assist students in selecting relevant courses and research topics to meet their educational goals. The department has excellent laboratory facilities in the Engineering Sciences Building, the Engineering Research Building, and the new Engineering Sciences Building Annex to provide support for both instructional and research activities. The department has several special purpose laboratories located nearby, which include the Engine Research Center, the wind tunnel laboratory, and the aircraft test hangar at the Morgantown Municipal Airport (Hart Field). Funded research allows the department to maintain up-to-date facilities that include modern instrumentation and computing and lab equipment, including simulation and computer-controlled data acquisition systems.

Graduate Programs

The objectives of the departmental graduate-level programs are as follows:

1. To provide masters-level education for students in or entering the engineering profession
2. To provide an advanced graduate educational experience for students pursuing the doctoral degree

Three master’s degrees are offered in the department: master’s of science in aerospace engineering (M.S.A.E.), master’s of science in mechanical engineering (M.S.M.E.), and master’s of science in engineering (M.S.E.) with a major in mechanical engineering or aerospace engineering. The department also offers the doctor of philosophy (Ph.D.) degree with majors in mechanical engineering or aerospace engineering.

Courses

Only courses with grades of C or higher are acceptable for graduate credit, although all coursework taken will be counted in establishing the student’s grade point average. No more than nine hours of 400-level credit can be counted toward meeting the coursework requirements for the M.S. degree. Only 400-level courses that are approved for math credit (see the following section) and only 400-level courses approved as technical electives for the
B.S. degree in an engineering discipline are acceptable for course credit towards the M.S. degree. The technical elective(s) must not have been used to satisfy the B.S. degree. The absolute minimum requirement set by the department for coursework credit towards a Ph.D. degree is eighteen hours beyond the master’s degree at the 500-level or higher taken at WVU. However, the actual minimum number of coursework credits is set by the student’s advisory and examining committee and is based on the student’s background and the area of his/her Ph.D. dissertation. No more than twenty percent of the coursework beyond the minimum of eighteen credit hours required by the college for a doctoral degree can be at the 400-level. A minimum of twenty-four semester hours of research credit at the Ph.D.-level is required to meet dissertation requirements. Two consecutive semesters of full-time attendance at the WVU campus in Morgantown are necessary to meet the residency requirements of the Ph.D. program.

Math Requirements

The Department of Mechanical and Aerospace Engineering requires that the graduate coursework include six hours of advanced mathematics for the M.S. programs of study and a minimum of six additional hours of mathematics for the Ph.D. programs. A list of mathematics courses approved for graduate credit can be obtained from the graduate program director of the department.

Time Limitations

All requirements for a master’s degree must be completed within eight years preceding the student’s graduation. All students pursuing an M.S. degree in the MAE department are required to engage in research, and complete and defend successfully an M.S. thesis. They should identify a subject for their M.S. thesis research, form a three-member advisory and examining committee, 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 and six credit hours of M.S. thesis research is required for the M.S. degree. Students must pass a final examination administered by their advisory and examining committee before being certified for the degree.

Academic Areas

Graduate courses in the MAE department are organized under six academic areas: fluids and aerodynamics, solid mechanics and structures, design and controls, thermal sciences, bioengineering, and materials science. Students who are pursuing an advanced degree in either mechanical or aerospace engineering may perform their thesis or dissertation research and specialize in any one of these areas.

FLUIDS AND AERODYNAMICS

A variety of courses and facilities support graduate research in aerodynamics and fluid mechanics. Laboratories are located in college buildings and remote sites. Flow facilities include instrumented subsonic and supersonic wind tunnels, shock tubes, and several flow loops mainly used for research in gas-solid and density stratified flows. Available instrumentation includes eight channels of hot wire/film anemometry, two single-component and one three-component, laser Doppler velocimeter (LDV) systems. The department owns two flight simulation facilities, one that simulates translational and rotational motion in six degrees of freedom, and the other that relies on D-six software to provide “joystick only” flight simulation. Furthermore, the department built and operates different types of Unmanned Airborne Vehicles (UAV’s), as well as experimental aircraft and airborne systems that are housed in a hangar owned by the department at the Hart Field municipal airport in Morgantown. A significant portion of the current activity involves numerical solutions to flow problems and is supported by a computing facility dedicated to graduate research.

Although the faculty background and interests in the areas of aerodynamics and fluid mechanics are broad, recent research has been concentrated on applications of computational fluid dynamics (CFD) to investigate a wide variety of problems in fuel cell technology, fixed wing and rotorcraft aerodynamics, bioengineering, and combustion. The department’s faculty have accumulated extensive research experience in multiphase and density-stratified flows, low-speed aerodynamics, shock phenomena in two-phase systems, flow in microgravity, boundary layer control, and high-speed aerodynamics. Previous and current research areas include topics such as fluidized bed combustion, aerosol sampling, flow metering, flow distribution systems, numerical solutions to gas-solid flows, and fluid-particle turbulence interactions, including deposition on solid surfaces. The low-speed aerodynamics work is related to the design of vertical axis wind turbines and STOL airfoils. The research in high-speed aerodynamics deals with viscous-inviscid interactions in transonic, supersonic, and hypersonic flow.

SOLID MECHANICS AND STRUCTURES

The solid mechanics and structures area encompasses the theoretical, numerical, and experimental study of solid bodies, from concentration on local behavior of deformable bodies to the global response of structural elements. Hence, students may explore the mechanical behavior of materials in the neighborhood of micro-scale defects such as cracks, or investigate the behavior of large-scale bodies such as aerospace structures.

The faculty members specialized in this area carry out basic and applied research using state-of-the-art computational and experimental techniques. The areas of research include advanced metal alloys and composite materials, lightweight structures, safety and durability enhancements, real time monitoring and diagnosis of structural systems, aero elasticity, fracture mechanics, nonlinear dynamics and vibrations, biomechanics; and computational methods and experimental techniques, including optical and ultrasound methods. Furthermore, in cooperation with the Department of Civil and Environmental Engineering, MAE graduate students may pursue studies related to civil engineering. A large array of research facilities includes laboratories (materials, structures, vibrations, photo mechanics, biomechanics, fracture mechanics), computers (work stations, personal computers, computer-aided engineering), and mechanical and electronic shops.
DESIGN AND CONTROLS
The system control and design area offers instructional and research opportunities for students who seek to attain the expertise required to design or control the behavior of an engineering system in a dynamic environment. Instructional offerings equip the students with a foundation for developing prototype systems and for improving the performance of existing systems. Selected examples of research areas include flight simulation and controls, automatic controls, advanced instrumentation, microprocessor applications and non-destructive testing; parametric, stochastic, and integrated design methods; elastodynamic analysis, computer-aided design (CAD); and modeling, design, and analysis of energy management systems. The research endeavors of the faculty reflect a close association with current industrial-type, real-life situations.

THERMAL SCIENCES
The thermal sciences and engineering area encompasses the fields of thermodynamics, combustion, heat transfer, and power and energy systems. Graduate course offerings cover a wide range of topics in this area with applications to both aerospace and mechanical engineering problems. Recent research efforts include topics such as alternative fuels testing, internal combustion engine performance and emissions, fuel cell technology, heat transfer, numerical analysis of thermal systems, the analysis of fluidized bed combustion, energy analysis of buildings, oscillating jet combustion, deposition on turbine blades, and reactor design.

Research facilities include a state-of-the-art engine research laboratory, three transportable emissions research laboratories, thermal analyzers, recording thermocouple data-acquisition systems, high-altitude simulation chamber for ablation and wear studies, a fluidized bed combustion laboratory, an electrically-heated, natural convection water facility, Schlieren systems for flows with varying density, and a water reservoir for thermal stratification studies.

BIOENGINEERING
Areas of research specialization related to bioengineering include ultrasound technology for imaging of body tissues and organs, respiratory and diseased tissue mechanics, orthopedic mechanics, bone growth and fracture, and the application to rehabilitation of computer-aided design and microprocessor-based instrumentation. Research facilities include a state-of-the-art ultrasound imaging laboratory, an aerosol inhalation exposure system, laser-based holographic and moire interferometric equipment, a lung acoustic impedance measurement system; and modern orthopedic, rehabilitation, and computer research laboratories.

MATERIALS SCIENCE AND ENGINEERING
The materials science and engineering area allows for the study of processing, structure, and properties of materials for structural, functional, and device applications. Areas of research emphasized within this area include advanced microscopy, composite materials, materials for fuel cells, smart materials, super alloys, facilities incorporating electron microscopy, scanning probe microscopy, electro-chemical characterization, thermal analysis, and mechanical testing facilities.

FACULTY

CHAIR
- Jacky Prucz - Ph.D. (Georgia Institute of Technology)
  Structural Design, Composite Materials, Solid Mechanics

PROFESSORS
- Richard Bajura - Ph.D. (University of Notre Dame)
  Director NRCCE, Energy Sciences
- Larry Banta - Ph.D. (Georgia Institute of Technology)
  Automation, Controls, Energy Management
- Ever Barbero - Ph.D. (Virginia Polytechnic Institute and State University)
  Materials, Experimental and Computational Mechanics
- Ismail Celik - Ph.D. (University of Iowa)
  Fluids Engineering, Fuel Cell Technology
- Nigel Clark - Ph.D. (University of Natal, South Africa)
  Associate VP for Academic Strategic Planning, Multiphase Flows, I.C. Engines and Emissions
- Russel Dean - Ph.D. (West Virginia University)
  Senior Associate Provost, Engineering Education
- Bruce Kang - Ph.D. (University of Washington)
  Experimental Mechanics, Advanced Materials
- John Kuhlman - Ph.D. (Case Western Reserve University)
  Fluid Mechanics
- Kenneth Means - Ph.D., P.E. (West Virginia University)
  Kinematics, Dynamics and Stability, Friction and Wear
• Gary Morris - Ph.D. (West Virginia University)
  Fluid Mechanics, Combustion, Aerodynamics
• Victor Mucino - Ph.D., P.E. (University of Wisconsin, Milwaukee)
  Mechanical Engineering Design, CAD, Finite Element Applications
• Marcello Napolitano - Ph.D. (Oklahoma State University)
  Aircraft Stability and Control, Feedback Control, Dynamics, Unmanned Airborne Vehicles (UAVs)
• Samir Shoukry - Ph.D. (Aston University, Birmingham UK)
  Pavement Modeling, Non-destructive Evaluation, Structural Dynamics, Neural Nets, Instrumentation
• Nithi Sivaneri - Ph.D. (Stanford University)
  Structural Mechanics, Composite Materials, FEM, Numerical Methods
• James E. Smith - Ph.D. (West Virginia University)
  Mechanical and Aeronautical Design

ASSOCIATE PROFESSORS
• Darran Cairns - Ph.D. (University of Birmingham, UK)
  Materials Science
• Wade Huebsch - Ph.D. (Iowa State University)
  Fluid Mechanics, CFD, Numerical Methods
• Haihui Li - Ph.D. (University of Calgary)
  Combustion, Emissions, Fuel efficiency of vehicles and internal combustion engines
• Xingbo Liu - Ph.D. (University of Science and Technology, Beijing)
  Materials Science
• Osama Mukdadi - Ph.D. (University of Colorado)
  Bioengineering, Acoustics, Solid mechanics and materials
• Mario Perhinschi - Ph.D. (Polytechnic Institute Bucharest, Romania)
  Aircraft Stability and Control, Flight Simulation
• Gregory Thompson - Ph.D. (West Virginia University)
  Thermodynamics, Machine Design.
• W. Scott Wayne - Ph.D. (West Virginia University)
  Machine design, Alternative fuels
• Nianqiang Wu - Ph.D. (Zhejiang University, China)
  Materials Science and Engineering

ASSISTANT PROFESSORS
• Vyacheslav Akkerman - Ph.D. (Umea University, Sweden)
  Turbulent combustion and flame turbulization, Propulsion and combustion instabilities in rocket engines
• Patrick Browning - Ph.D. (West Virginia University)
  Aerodynamics, Aircraft Design
• Marvin Cheng - Ph.D. (Purdue University)
  Mechatronics, Dynamic Systems and Control
• John Christian - Ph.D. (University of Texas, Austin)
  Spacecraft Design, Spacecraft Navigation, Estimation theory
• Jason Gross - Ph.D. (West Virginia University)
  Unmanned aerial vehicle avionic systems and flight testing
• Yu Gu - Ph.D. (West Virginia University)
  Robotic Systems, Sensor Fusion
• Alfred Lynam - Ph.D. (Purdue University)
  Space mission design, Orbital perturbations
• David Mebane - Ph.D. (Georgia Institute of Technology)
  Fuel cells, Multi-scale Simulation of chemical and electrochemical systems
• Terrance Musho - Ph.D. (Vanderbilt University)
  Nanoscale thermal and electrical transport, Direct energy conversion
• Andrew Nix - Ph.D. (Virginia Polytechnic Institute and State University)
  Turbines, Engines and Emissions
• Edward Sabolsky - Ph.D. (Pennsylvania State University)
  Materials, Ceramic Science
• Konstantinos Sierrros - Ph.D. (University of Birmingham, United Kingdom)
Flexible optoelectronic devices, Tribology, Materials for renewable energy
• Xueyan Song - Ph.D. (Zhejiang University, China)
  Materials Science, Electron Microscopy

RESEARCH PROFESSORS
• Eric Johnson - Ph.D. (University of Wisconsin-Madison)
  Multiphase Flow, Combustion-Gasification, Coal Cleaning
• Donald Lyons - Ph.D., P.E. (Georgia Institute of Technology)
  Manufacturing Systems Engineering, Instrumentation, Engines and Emissions
• John Sneckenberger - Ph.D. (West Virginia University)
  System Design and Controls, Distributed Power Generation and Smart Electric Grids

RESEARCH ASSOCIATE PROFESSORS
• David Lewellen - Ph.D. (Cornell University)
  Fluid Dynamics, Turbulence

RESEARCH ASSISTANT PROFESSORS
• Arvind Thiruvengadam - Ph.D. (West Virginia University)
  Exhaust of heavy-duty internal combustion engines
• Jay Wilhelm - Ph.D. (West Virginia University)
  Unmanned aerial systems, Wind turbine modeling
• Hui Zhang - Ph.D. (Beihang University)
  Materials, Physics, Chemistry
• Yu Chen - Ph.D. (Universidade Tecnica de Lisboa)
  Material science, Metal hydrides, Cathode material development
• Thomas Evans - Ph.D. (West Virginia University)
  Solid Mechanics, Structures
• Pete Gall - Ph.D. (West Virginia University)
  Aerospace systems design.
• Derek Johnson - Ph.D. (West Virginia University)
  Alternative fuels engines and emissions
• Nathan Weiland - Ph.D. (Georgia Institute of Technology)
  Fuel-flexible Combustion, Coal/Biomass Co-gasification, Biomass Pyrolysis

VISITING AND ADJUNCT PROFESSORS
• Alberto Ayala - Ph.D. (University of California, Davis)
  Energy, Engine Emissions
• Mark Bright - Ph.D. (West Virginia University)
  Materials Engineering, Pyrotech Inc.
• Renguang Dong - Ph.D. (Concordia University)
  Biomechanics, Human Vibrations, NIOSH
• Mridul Gautam - Ph.D. (West Virginia University)
  Alternative fuels, engines and emissions
• Luis Godoy - Ph.D. (University of London)
  Structural Stability
• Frank Goodwin - Sc.D. (Massachusetts Institute of Technology)
  Materials Engineering, ILZRO
• Nabil Hakim - Ph.D. (Wayne State University)
  Alternative Fuels Engines and Emissions
• Paul E. King - Ph.D.
  Materials engineering, NETL
• Stephen Kukureka - Ph.D. (University of Birmingham)
• Alejandro Lozano-Guzman - Ph.D. (Newcastle University)
  Dynamic Systems (CICATA-IPN Mexico)
• Eugene McKenzie - Ph.D. (West Virginia University)
  Mechanical Engineering Design, NIOSH
• Chris Menchini - Ph.D. (West Virginia University)
Computational fluid dynamics, Fire modeling
• Koorosh Mirfakraie - Ph.D.
• Vincenzo Mulone - Ph.D. (University of Rome, Tor Vergata)
  Engine Emissions
• John Nuzkowski - Ph.D. (West Virginia University)
  Alternative fuels and engine emissions, UNF
• Ming Pei - Ph.D.
  Tissue Engineering
• Steven Raque - B.S. (Virginia Polytechnic Institute and State University)
  Space vehicle design
• Alberto Traverso - Ph.D.
  DIMSET - Italy
• Steven Woodruff - Ph.D. (University of Michigan)
  Combustion optical phenomena
• Kirk Yerkes - Ph.D.

Admission
The applicant must first submit a completed application, application fee, and transcripts of all college work (directly from the institution) to the WVU Office of Admissions. Each applicant is required to complete an applicant information form and have three recent reference letters (using standard forms available from the department) sent directly to the department; at least two of the three references should be from the institution last attended.

Regular Admission Requirements
Minimum requirements for admission as a regular student into the graduate programs of the department are summarized as follows:

• An applicant for admission into the M.S. or 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 college work if he/she holds a B.S. or M.S. degree, respectively, from an accredited or internationally recognized program, as stated above.
• Applicants for admission into the B.S.M.S. degree track must have a grade point average of 3.5 or higher at the end of the first semester in the junior year of the curriculum. Applicants for admission into the direct-track from B.S. to Ph.D. degree option must have a grade point average of 3.5 or higher if they commence their graduate studies in the department as Ph.D. students or must have a cumulative grade point average of 4.0 if they transfer from the M.S. degree program by the end of their first year of graduate studies in the department.
• International students must demonstrate proficiency in communicating in English (a minimum TOFEL Score of 550, or IBT Score of 79, or IELTS Score of 6.5). (This requirement will be waived for applicants who have completed a recent four-year bachelor’s degree in the USA.)
• All international applicants who have not received their undergraduate degree in the USA are required to submit GRE general test scores with the engineering subject test score being optional. The GRE scores required for admission as a regular graduate student in the department need to be seventy-fourth percentile 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.

Provisional Admission
An applicant not qualifying for the admission status of regular graduate student, either due to marginally insufficient grade point average or GRE performance, incomplete credentials, or inadequate academic background, may be admitted as a provisional student at the discretion of the Admissions Committee of the department. Requirements for attaining regular student status must be stated in a letter of admission. Provisional students must sign a contract, which lists in detail all requirements that have to be met for attaining regular student status, typically no later than the end of the first semester at WVU.

All of the graduate degree programs offered by the department require the student to attain an overall grade point average of 3.0 or higher both in all the courses required for the degree program and in all the courses taken at WVU in order to meet graduation requirements. The cumulative grade point average (GPA) is calculated on the basis of courses only, and excludes credit for research, for which the received grade can be either S (satisfactory), or U (unsatisfactory) . Note: A grade of U in research is equivalent to a grade of F in a regular course and it can decrease drastically the GPA of a graduate student.

Doctoral Admission
ADMISSION TO DOCTOR OF PHILOSOPHY PROGRAM
To be eligible for admission into the doctor of philosophy degree program with a major in aerospace or mechanical engineering, a candidate 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.

ADMISSION TO THE DIRECT-TRACK TO PH.D. DEGREE OPTION

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 first a thesis research for a master of science (M.S.) degree. To qualify for the direct track degree option, a candidate must have earned a cumulative grade point average (GPA) of 3.5 or higher in his/her undergraduate studies and attain seventy-fourth percentile in the quantitative section of the standardized Graduate Record Examination (GRE). Students who are pursuing an M.S. degree in the MAE department have also the possibility of transferring into the direct track option provided that they earn a GPA of 4.0 and attain seventy-fourth percentile in the quantitative section of the GRE by the end of their first two semesters of graduate studies at WVU. Students admitted into the direct track option are considered to be Ph.D. students in the MAE department.

Master of Science in Mechanical Engineering

Students wishing to pursue a program leading to a M.S.M.E. degree are required to have a B.S.M.E. or B.S.A.E. from an accredited ABET curriculum or its equivalent. Students with an engineering background other than mechanical or aerospace engineering normally will be required to strengthen their background.

The plan of study must include at least six hours of advanced mathematics beyond a first course in differential equations, and twelve total hours of courses from at least two areas of study in mechanical engineering. Students are normally required to write a thesis. On occasion, part-time off-campus students may be given permission to substitute a problem report for a thesis when they can present compelling evidence of equivalent experience. A maximum of six hours of research credit is counted toward meeting degree requirements for the thesis option; a maximum of three hours of research credit is counted for the problem report option. The student’s plan of study is formulated jointly with his/her advisory committee based upon the interests and educational goals of the student. Students not completing a thesis will be required to include six hours of methods courses in their programs of study.

Master of Science in Aerospace Engineering

Students wishing to pursue a program leading to a M.S.A.E. degree are required to have a B.S.A.E. or B.S.M.E. from an accredited ABET curriculum or the equivalent. Students with an engineering background other than aerospace or mechanical engineering normally will be required to strengthen their background. Programs of study must comply with the rules and regulations as outlined in the general requirements for graduate work in the College of Engineering and Mineral Resources. The student’s program of study is formulated jointly by the student and his/her committee. Normally, a thesis is required of all candidates for the degree of master of science in aerospace engineering.

The plans of study for the M.S.A.E. degree must include six semester hours of advanced mathematics beyond a first course in differential equations and at least twelve semester hours of courses taken from any two areas of the department. The remainder of the coursework may consist of other courses from mechanical and aerospace engineering, other departments in the College of Engineering and Mineral Resources, or advanced course work in mathematics, chemistry, and physics. A maximum of six hours of research credit is counted toward degree requirements for thesis work. Students not completing a thesis will be required to include six hours of methods courses in their plans of study.

Graduation Requirements

The M.S.M.E. and M.S.A.E. degrees require completion of twenty-four hours of coursework (with a minimum cumulative grade point average of 3.0/4.0) plus six hours of research leading to a thesis. The coursework must include six hours of mathematics from an approved list and twelve hours of courses from Mechanical and Aerospace Engineering, of which six hours must be selected in sets of two courses from any of the five following areas:

1. Solid mechanics and structures
2. Design dynamics and controls
3. Fluids and aerodynamic
4. Thermal sciences and systems
5. Material science and engineering

Doctor of Philosophy

The doctorate is a research degree which requires the accumulation of eighteen credit hours of coursework taken at WVU at the 500-level or higher and twenty-four credit hours of research, also taken at WVU. The remaining requirements for the degree are as follows: (1) passing successfully the
qualifying examination, (2) admission to candidacy, (3) one-year residency on campus, (4) completion of dissertation research, and (5) defense of a research dissertation. All students pursuing a Ph.D. degree in the MAE department are expected to engage in research and complete and successfully defend a Ph.D. dissertation. They should identify a subject for their Ph.D. dissertation, form a five-member advisory and examining committee, and file a plan of study by the end of their second semester of enrollment in the graduate program. At least one member of the graduate faculty from outside the department is required to serve on the advisory and examining committee.

The Ph.D. degree signifies that the holder has the competence to function independently at the highest level in the chosen field. Hence, the number of years involved in attaining or retaining competency cannot be readily specified, nor can an exact program of study be defined. However, one has a maximum of five years to complete all the requirements for Ph.D. from the date of admission to candidacy.

Ph.D. Qualifying Exam

The Ph.D. qualifying examination is the method of assessing whether the student has attained sufficient knowledge of the discipline and supporting fields in order to undertake independent research or practice. Students are required to pass a qualifying examination administered by the department which tests for a minimum level of proficiency expected of all students in a given area. It is expected that students will take the qualifying exam during their first or second semester of enrollment in the Ph.D. program; however, it is required that full-time students pass the qualifying examination no later than the end of the third semester of enrollment in their Ph.D. program. Students admitted in the direct track from B.S. to Ph.D. degree option are expected to take the qualifying exam by the end of their fourth semester of enrollment in the MAE graduate program. As the student progresses, his or her advisory and examining committee is charged with evaluating the student’s competency in the specific area of study through the assessment of a dissertation proposal for the research to be completed and the evaluation of the student’s plan of study and associated coursework. After these requirements are completed, the student is formally admitted to candidacy for the Ph.D. degree. Only at this point can a student be called a doctoral candidate; admission to the graduate program for the purpose of pursuing the Ph.D. degree is not equivalent to becoming a Ph.D. candidate. Doctoral candidates are allowed no more than five years to complete the remaining degree requirements after admission to candidacy. An extension of time can be obtained only by repeating the qualifying and candidacy examinations and meeting any other requirements specified by the student’s advisory and examining committee.

Ph.D. Degree

Students intending to pursue a doctoral program in the College of Engineering and Mineral Resources with an emphasis in mechanical or aerospace engineering should have earned a M.S. degree in some engineering discipline. Qualified candidates holding a M.S. degree in applied sciences can also be considered for admission into the Ph.D. program. Eligible students holding a B.S. degree are permitted to enroll directly in the Ph.D. program through the direct track from B.S. to Ph.D. degree option. The doctoral courses of study are selected to fit the particular interests and objectives of the student, with proper attention given to broadening related areas of study. The research work for the doctoral dissertation may entail a fundamental investigation into a specialized area or a broad and comprehensive study in a related subject.

COURSES

MAE 515. Analytical Methods-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 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 528. Intro 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 Material. 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 565. Artif. Intellig. Techn. in MAE. 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/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/Kinetics-Material. 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 593A-Z. 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 637. Multiphase Flows. 3 Hours.
PR: MAE 331. Particle dynamics including particle-particle and particle-surface interactions; fluidized bed concepts; mathematical models and numerical methods as applied to multiphase flows; design and instrumentation pertaining to multiphase units.

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-Engr Matrls. 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.

MAE 645. Energy Methods-Applied Mechanics. 3 Hours.
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. Adv Mechanics: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 650. Mechanical Metallurgy. 3 Hours.
PR: MAE 244 or Consent. Elastic behavior and plastic theory. Dislocation theory. Strengthening mechanisms and fracture. Mechanical properties from materials testing including tension, torsion, fracture toughness, fatigue, and creep.

MAE 652. Advanced Kinematics: Mechanisms. 3 Hours.
PR: MAE 452 or Consent. Analytical synthesis of mechanisms with up to five accuracy points; Burmester curve theory and path curvature theory; force and moment balancing of mechanisms; computer-aided dynamic analysis of mechanisms and inverse dynamic analysis.

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 654. Advanced Machine Design. 3 Hours.
PR: Consent. Design for extreme environments, material selection, lubrication and wear, dynamic loads on cams, gears, and balancing of multiengines and rotors, electromechanical components.

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 Mech Engr. 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 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 680. 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 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 691A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

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

MAE 694A-Z. Seminar. 0-6 Hours.
Special seminars arranged for advanced graduate students.

MAE 695. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.
MAE 697. Research. 1-15 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 742. 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 743. 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: 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 791A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

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

MAE 797. Research. 1-15 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 798. Dissertation. 1-6 Hours.
PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698), or dissertations (798). Grading is normal.

MAE 799. Graduate Colloquium. 1-6 Hours.
PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University’s facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department’s 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.