

# Department of Mechanical and Aerospace Engineering

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## Degrees Offered

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

## 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.

## Educational Objectives of Graduate Programs

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

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 engineering discipline.
2. To develop the capacity of graduates to conduct independent research and/or technology development and innovation, through original contributions to the 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.

Four 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.), master's of science in materials science and engineering (M.S.M.S.&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, in aerospace engineering and in materials science and 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 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 for M.S. students and a list for Ph.D. students can be obtained from the graduate program director of the Department.

## Time Limitations

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, and complete and defend successfully 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.

A course-only master's degree option is available 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 WVU. All the requirements for this degree option must also be completed within eight years preceding the student's graduation.

All requirements for the Ph.D. program must be completed within eight years preceding the student's graduation. All students pursuing the Ph.D. program must take and pass the Ph.D. Qualifier Examination within the first two semesters in the program. A second and final attempt to pass the Ph.D. qualifier can be offered no later than the third semester. Students should identify a subject for their Ph.D. dissertation research, form a five-member advisory and examining committee, and file a plan of study by the end of their third semester of enrollment in the program. A minimum of eighteen credit hours of coursework with a minimum GPA of 3.3/4.0 and twenty-four credit hours of dissertation research is required for the Ph.D. degree. All Ph.D. students beginning their Ph.D. program on May 2016 or after, must document that they have submitted a journal paper manuscript to an archival journal or submitted a patent disclosure, prior to scheduling their dissertation defense. After the Ph.D. qualifying examination requirement and publication requirement are satisfied, students are required to produce and successfully defend a Research Proposal before the advisory and examining committee to attain Ph.D. candidacy. After at least one full semester of the Ph.D. proposal defense, candidates must produce and successfully defend a Ph.D. dissertation.

## 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 and engineering. Students who are pursuing an advanced degree in either mechanical or aerospace engineering and in materials science and engineering may perform their thesis or dissertation research and specialize in any one of these areas.

## FLUIDS MECHANICS 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, 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, and a particle image velocimeter (PIV) system. 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.

## SOLID MECHANICS AND DESIGN

The solid mechanics and design 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.

## DYNAMICS AND CONTROLS

The dynamics and controls area offers instructional and research opportunities for students who seek to attain the expertise required to 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; elastodynamic analysis, computer-aided design (CAD); and modeling, design, and analysis of energy management systems.

## THERMAL SCIENCES AND SYSTEMS

The thermal sciences and systems 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.

## MATERIAL SCIENCE AND ENGINEERING

The material 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 A. Bajura - Ph.D. (University of Notre Dame)  
Director NRCCE, Energy Sciences
- Ever J. 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 N. Clark - Ph.D. (University of Natal, South Africa)  
Provost WVU-IT, Multiphase Flows, I.C. Engines and Emissions
- Russel K. Dean - Ph.D. (West Virginia University)  
Vice Provost, Engineering Mechanics, Eng. Education
- Bruce S. Kang - Ph.D. (University of Washington)  
Experimental Mechanics, Advanced Materials
- John M. Kuhlman - Ph.D. (Case Western Reserve University)  
Fluid Mechanics
- Xingbo Liu - Ph.D. (University of Science and Technology of China, Beijing)  
Materials Science
- Kenneth H. Means - Ph.D., P.E. (West Virginia University)  
Kinematics, Dynamics and Stability, Friction and Wear
- Gary J. Morris - Ph.D. (West Virginia University)  
Fluid Mechanics, Combustion, Aerodynamics
- Victor H. Mucino - Dr.Eng., P.E. (University of Wisconsin-Milwaukee)  
Mechanical Engineering Design, CAD, Finite Element Analysis
- Marcello R. Napolitano - Ph.D. (Oklahoma State University)

Aircraft Stability and Control, Feedback Control, Unmanned Airborne Vehicles (UAVs)

- Samir N. Shoukry - Ph.D. (Aston University, Birmingham, U.K.)  
Pavement Modeling, Non-destructive Evaluation, Structural Dynamics, Neural nets, Instrumentation
- Nithi T. Sivaneri - Ph.D. (Stanford University)  
Structural Mechanics, Composite Materials, FEM, Numerical Methods
- James E. Smith - Ph.D. (West Virginia University)  
Mechanical and Aeronautical Design
- Nianqiang Wu - Ph.D. (Zhejiang University, China)  
Materials Science and Engineering

## ASSOCIATE PROFESSORS

- Wade W. Huebsch - Ph.D. (Iowa State University)  
Fluid Mechanics, CFD, Numerical Methods
- Hailin Li - Ph.D. (University of Calgary, Canada)  
Combustion, Emissions, Fuel Efficiency of Vehicles and IC Engines
- Osama Mukdadi - Ph.D. (University of Colorado)  
Bioengineering, Acoustics, Solid Mechanics and Materials
- Mario G. Perhinschi - Ph.D. (Politehnica University of Bucharest, Romania)  
Aircraft Stability and Control, Flight Simulation
- Edward M. Sabolsky - Ph.D. (Pennsylvania State University)  
Materials, Ceramic Science
- Xueyan Song - Ph.D. (Zhejiang University, China)  
Materials Science, Electron Microscopy
- Gregory J. Thompson - Ph.D. (West Virginia University)  
Thermodynamics, Machine Design
- W. Scott Wayne - Ph.D. (West Virginia University)  
Machine Design, Alternative Fuels

## ASSISTANT PROFESSORS

- V'yacheslav Akkerman - Ph.D. (Umea University, Sweden)  
Turbulent Combustion, Flame Turbulization, Propulsion Instabilities in Rocket Engines
- Patrick H. Browning - Ph.D. (West Virginia University)  
Aerodynamics, Aircraft Design
- Marvin H. Cheng - Ph.D. (Purdue University)  
Instrumentation, Mechatronics, Dynamic Systems and Control
- John A. Christian - Ph.D. (University of Texas, Austin)  
Spacecraft Design, Navigation, Estimation Theory
- Cosmin E. Dumitrescu - Ph.D. (University of Alabama)  
Combustion, Alternate Fuels, IC Engines
- Jason N. Gross - Ph.D. (West Virginia University)  
Unmanned Aerial Vehicles, Avionic Systems, Flight Testing
- Yu Gu - Ph.D. (West Virginia University)  
Robotic Systems, Sensor Fusion
- Alfred E. Lynam - Ph.D. (Purdue University)  
Space Mission Design, Orbital Perturbations
- David S. Mebane - Ph.D. (Georgia Institute of Technology)  
Fuel Cells, Multi-Scale Simulation of Chemical and Electrochemical Systems
- Terrance D. Musho - Ph.D. (Vanderbilt University)  
Nanoscale Thermal and Electrical Transport, Direct Energy Conversion
- Andrew C. Nix - Ph.D. (Virginia Polytechnic Institute and State University)  
Turbines, Engines and Emissions
- Konstantinos Sierros - Ph.D. (University of Birmingham, U. K.)  
Flexible Optoelectronic Devices, Tribology, Materials for Renewable Energy
- Arvind Thiruvengadam - Ph.D. (West Virginia University)  
Emissions of Heavy-Duty Internal Combustion Engines

## TEACHING ASSISTANT PROFESSORS

- Pete Gall - Ph.D. (West Virginia University)  
Aerospace Systems Design

## RESEARCH ASSOCIATE PROFESSORS

- David C. Lewellen - Ph.D. (Cornell University)  
Fluid Dynamics, Turbulence

## RESEARCH ASSISTANT PROFESSORS

- Yun Chen - Ph.D. (Uniuersidade Tecnica de Lisboa)  
Material Science, Metal Hydrides, Cathode Material Development
- Thomas Evans - Ph.D. (West Virginia University)  
Solid Mechanics, Structures
- Derek Johnson - Ph.D. (West Virginia University)  
Alternative Fuels Engines and Emissions
- Eduardo Sosa - Ph.D. (University of Puerto Rico)  
Thin Wall Structures

## VISITING AND ADJUNCT PROFESSORS

- Alberto Ayala - Ph.D. (University of California, Davis)  
Energy, Engine Emissions
- Dureid Azzouz - Ph.D. (University of Southampton, U.K.)  
Fluid Mechanics
- Albert Boretti - Ph.D. (University of Florence, Italy)  
Innovative Combustion Engines
- Mark Bright - Ph.D. (West Virginia University)  
Materials Engineering, Pyrotech Inc.
- Darran Cairns - Ph.D. (University of Birmingham, U.K.)  
Materials Science
- Weigiang Ding - Ph.D. (Northwestern University)  
Nanostructures
- Renguang Dong - Ph.D. (Concordia University)  
Biomechanics, Human Vibrations, NIOSH
- Renguang Dong - Ph.D. (Concordia University)  
Biomechanics, Human Vibrations, NIOSH
- Mridul Gautam - Ph.D. (West Virginia University)  
Alternate Fuels, Engine and Emissions, VP for Research UNR
- Luis A. Godoy - Ph.D. (University of London, U.K.)  
Structural Stability
- Frank E. Goodwin - Sc.D. (Massachusetts Institute of Technology)  
Materials Engineering, ILZRO
- Valeriya Gritsenko - Ph.D. (University of Alberta, Canada)  
Neuroscience
- Huang Guo - Ph.D. (West Virginia University)  
Electro-Chemistry, Materials Science, Mechanical Engineering
- Srinkath Gururajan - Ph.D. (West Virginia University)  
Small Unmanned Aerial Vehicle Systems
- Nabil S. Hakim - Ph.D. (Wayne State University)  
Alternative Fuels Engines and Emissions
- Yiqun Huang - Ph.D. (University of Texas, Austin)  
Engine Emissions Control
- Paul E. King - Ph.D. (Oregon State University)  
Materials Engineering, NETL
- George Kiriakidis - Ph.D. (Salford University, U.K.)  
Physics, Mechanics
- Stephen Kukureka - Ph.D. (University of Birmingham, U.K.)  
Materials Science

- Andrew D. Lowery - Ph.D. (West Virginia University)  
Control Systems
- Alejandro Lozano-Guzman - Ph.D. (University of New Castle Upon Tyne, U.K.)  
Dynamic Systems (CICATA-IPN Mexico)
- Ayyakkannu Manivannan - Ph.D. (The University of Tokyo, Japan)  
Materials Chemistry Characterization
- Eugene A. McKenzie - Ph.D. (West Virginia University)  
Mechanical Engineering Design, NIOSH
- Chris Menchini - Ph.D. (West Virginia University)  
Computational Fluid Dynamics, Fire Modeling
- Vincenzo Mulone - Ph.D. (University of Rome, Tor Vergata)  
Engine Emissions, Fluid Mechanics
- John Nuzkowski - Ph.D. (West Virginia University)  
Alternative Fuels and Engine Emissions, UNF
- Ming Pei - M.D., Ph.D. (Beijing Medical University, China)  
Tissue Engineering, HSC-WVU
- Alber Alfonse Sadek - Ph.D. (Osaka University, Japan)  
Alloys
- Brad Senior - Ph.D. (West Virginia University)  
Control Systems
- Benjamin Shade - Ph.D. (West Virginia University)  
Engine Emissions, IAV Automotive
- Alberto Traverso - Ph.D. (University of Genoa, Italy)  
Energy Systems and Control, DIMSET - Italy
- Nathan Weiland - Ph.D. (Georgia Institute of Technology)  
Energy Systems, Experimental, Computational, Theoretical Methods
- Jay Wilhelm - Ph.D. (West Virginia University)  
Unmanned Aerial Vehicles, Wind Turbine Modeling
- Gergis William - Ph.D. (West Virginia University)  
Structural Engineering
- Steven Woodruff - Ph.D. (University of Michigan)  
Combustion Optical Phenomena
- Sergiy Yakovenko - Ph.D. (University of Alberta, Canada)  
Neuroscience
- Kirk Yerkes - Ph.D. (University of Dayton)  
Energy Optimized Aircraft

## **PROFESSORS EMERITI**

- Larry Banta - Ph.D. (Georgia Institute of Technology)
- Eric Johnson - Ph.D. (University of Wisconsin-Madison)
- John Loth - Ph.D. (University of Toronto, Canada)
- Michael G. Palmer - Ph.D. (West Virginia University)
- John E. Sneckenberger - Ph.D. (West Virginia University)
- Wallace S. Venable - Ed.D. (West Virginia University)
- Richard E. Walters - Ph.D. (West Virginia University)

## **Admission**

The applicant must first submit a completed an on-line 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 a research thesis 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 3.5/4.0 or higher in his/her undergraduate studies and attain a minimum of 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 in their third semester in the program, provided that they earn a GPA of at least 3.75/4.0 and attain a minimum of 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.

## 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 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.**

PR: Consent. Advanced dynamics and thermodynamics of fluids. Basic laws of conservation of mass and momentum in differential, vector, and integral forms. Application to internal flows, fluid machinery, and structures.

**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 594A. Seminar. 1-6 Hours.**

Special seminars arranged for advanced graduate students.

**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.**

PR: MAE 336 or equivalent. Nonsteady gas dynamics and shock interactions; compressible flow theory in subsonic, transonic, and supersonic regimes, and their numerical treatment.

**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.**

PR: MAE 242. Newtonian and Lagrangian mechanics. Dynamics of discrete systems and rigid bodies analyzed utilizing Newtonian and Lagrangian formulations.

**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.

**MAE 645. Energy Methods in 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. 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.**

PR: CHE 366 or Consent. Optical and electron microscopic principles and techniques. Sample preparation methods. Microstructures of engineering materials. Laboratory demonstrations and experiments.

**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 of 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 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 (MSE) 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 693A-Z. 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. 1-6 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 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 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. Thesis or 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.