Department of Mechanical & Aerospace Engineering

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Degrees Offered

- Bachelor of Science in Aerospace Engineering (B.S.A.E.)
- Bachelor of Science in Mechanical Engineering (B.S.M.E.)
- Dual Degree in Aerospace and Mechanical Engineering

FACULTY

CHAIR

- Jacky C. 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, Fluids Engineering
- Ever J. Barbero - Ph.D. (Virginia Polytechnic Institute & 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
- 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)
- Mario Perhinschi - Ph. D. (University of Bucharest, Romania)
  Flight Modeling and Simulation
- Songgang Qui - Ph. D.(University of Minnesota)
  Thermodynamics, Heat Transfer
- 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 Universtiy, 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 Mecanics and Materials
- Edward M. Sabolsky - Ph.D. (The 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
- John A. Christian - Ph.D. (University of Texas)
  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
- David S. Mebane - Ph.D. (Georgia Institute of Technology)
  Fuel Cells, Multi-Scale Simulation of Chemical and Electrochemical Systems
- Terence D. Musho - Ph.D. (Vanderbilt University)
  Nanoscale Thermal and Electrical Transport, Direct Energy Conversion
- Andrew C. Nix - Ph.D. (Virginia Polytechnic Institute & 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 Egines

TEACHING ASSISTANT PROFESSORS

- Peter D. Gall - Ph. D. (West Virginia University)
  Aerodynamics, Aircraft Design

RESEARCH ASSOCIATE PROFESSOR

- Thomas Evans - Ph. D. (West Virginia University)
  Solid Mechanics, Structures
- David C. Lewellen - Ph.D. (Cornell University)
  Fluid Dynamics, Turbulence
- Eduardo Sosa - Ph. D. (University of Puerto Rico)
  Thin Wall Structures

RESEARCH ASSISTANT PROFESSORS

- Marc Besch - Ph. D. (West Virginia University)
  Alternative Fuels, Engines and Emissions
- Yun Chen - Ph.D. (Universidade Tecnica de Lisboa)
  Material Science, Metal Hydrides, Cathode Material Development

- Derek Johnson - Ph.D. (West Virginia University)
  Alternative Fuels, Engines and Emissions
- Ross Ryskamp - Ph. D. (West Virginia University)
  Alternative Fuels, Engines and Emissions

VISITING PROFESSORS AND ADJUNCT PROFESSORS

- Alberto Ayala - Ph.D. (University of California, Davis)
  Engine Emissions
- Dureid Azzouz - Ph.D. (University of Southampton, U.K.)
  Fluid Mechanics
- David Booker - Ph. D. (Univeristy of Exeter)
  Exhaust Flow
- Albert Boretti - Ph.D. (University of Florence, Italy)
  Innovative Combustion Engines
- Darran R. Cairns - Ph.D. (University of Birmingham, U.K.)
  Materials Science
- Weigiang Ding - Ph.D. (Northwestern University)
  Nanostructures
- 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
- Yiqun Huang - Ph.D. (University of Texas, Austin)
  Engine and Emissions Control
- 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.)
  Structural Analysis, Power and Control Systems (CICATA-IPN)
- 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. (Universtiy of Rome Tor Vergata)
  Internal Combustion Engines, Emissions
- 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
- Matthew Robinson - Ph. D. (West Virginia University)
  Analysis and Optimization of Engines
- Alber Alphonse Sadek - Ph.D. (Osaka University)
  Alloys
- Brad Seanor - Ph.D. (West Virginia University)
  Controls 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 Systems, Wind Turbine Modeling and Design
- Gergis William - Ph.D. (West Virginia University)
  Structural Engineering
- 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)

Dual Degree in Aerospace Engineering and Mechanical Engineering

In the modern technical marketplace, college graduates must attain every competitive edge possible to enhance their career opportunities. One way to do this is with a master's degree following the bachelor's degree; however, this often results in more specialization than may be desired and may take an additional two years. Another option is to broaden the undergraduate experience, thus opening more opportunities for the graduate. The dual B.S.A.E./B.S.M.E. program awards both the aerospace engineering and mechanical engineering degrees at the completion of a planned curriculum.

Students under this option pursue the B.S.A.E. and B.S.M.E. degrees simultaneously. This can be accomplished by declaring intentions as a freshman requesting admission to the programs or by informing an MAE advisor of the dual-degree preference. Maximum scheduling flexibility will result when this decision is made as early as possible in the student's academic career. Dual-degree students must take all courses listed in the 155-hour dual curriculum under the Major tab and satisfy the other requirements of the two individual programs.

The state of West Virginia is a member of a group of Academic Common Market (ACM) states. WVU allows residents of states within the ACM to enroll in the dual B.S.A.E. /B.S.M.E. program on an in-state tuition basis. Application must be made through the higher education authority of the state of residence.

Curriculum for the Dual Degree in Aerospace Engineering and Mechanical Engineering

A requirement for graduation in aerospace and mechanical engineering is a departmental grade point average of 2.0 or better for all required mechanical and aerospace engineering (MAE) courses. If a required MAE course is repeated, only the hours credited and the grade received for the last completion of the course is used in computing the student's departmental grade point average. Also a grade of C or better is required in each of the four required mathematics courses and physics 111.

It is important for students to take courses in the order specified as close as possible; all prerequisites and concurrent requirements must be observed. A typical B.S.A.E./B.S.M.E. degree program that completes degree requirements in four and a half years is listed below.

Students must complete a minimum of 155 credit hours to graduate - the total at the bottom reflects all possible course combinations		
Mechanical and Aerospace Engineering Core Requirements		
CHEM 115	Fundamentals of Chemistry	4
ECON 201	Principles of Microeconomics	3
ECON 202	Principles of Macroeconomics	3
ENGR 101	Engineering Problem Solving 1	2
ENGR 102	Engineering Problem-Solving 2	3
ENGR 199	Orientation to Engineering	1
Select one of the following: *		4
MATH 155	Calculus 1	

or MATH 153 & MATH 154	Calculus 1a with Precalculus and Calculus 1b with Precalculus	
MATH 156	Calculus 2 *	4
MATH 251	Multivariable Calculus *	4
MATH 261	Elementary Differential Equations *	4
PHYS 111	General Physics *	4
PHYS 112	General Physics	4
A minimum cumulative GPA of 2.0 is required in all MAE courses		
Dual Core		
MAE 215	Intro to Aerospace Engineering	3
MAE 241	Statics	3
MAE 211	Mechatronics	3
MAE 242	Dynamics	3
MAE 243	Mechanics of Materials	3
MAE 331	Fluid Mechanics	3
EE 221	Introduction to Electrical Engineering	3
EE 222	Introduction to Electrical Engineering Laboratory	1
MAE 316	Analysis-Engineering Systems	3
MAE 320	Thermodynamics	3
MAE 335	Incompressible Aerodynamics	3
MAE 343	Intermediate Mechanics of Materials	3
MAE 244	Dynamics and Strength Laboratory	1
MAE 322	Thermal and Fluids Laboratory	1
MAE 336	Compressible Aerodynamics	3
MAE 342	Dynamics of Machines	3
MAE 345	Aerospace Structures	3
MAE 365	Flight Dynamics	3
MAE 426	Flight Vehicle Propulsion	3
MAE 434	Experimental Aerodynamics	2
MAE 456	Computer-Aided Design and Finite Element Analysis	3
MAE 476	Space Flight and Systems	3
IENG 302	Manufacturing Processes	2
IENG 303	Manufacturing Processes Laboratory	1
MAE 411	Advanced Mechatronics	3
MAE 423	Heat Transfer	3
MAE 460	Automatic Controls	3
MAE 475	Flight Vehicle Design-Capstone	3
MAE 454	Machine Design and Manufacturing	3
MAE 471	Principles of Engineering Design	3
Aerospace Engineering Technical Electives		9
Mechanical Engineering Technical Electives		9
Aerospace Engineering or Mechanical Engineering Technical Electives		2
GEF Courses (Students who take ENGL 103 must take another technical Elective Course or department approved course) **		15
Total Hours		155

* Minimum Grade of C required

DUAL SUGGESTED PLAN OF STUDY

First Year			
Fall	**Hours**	**Spring**	**Hours**
CHEM 115 (GEF 2)	4	MATH 156 (GEF 8)	4
ENGL 101 (GEF1)	3	PHYS 111 (GEF 8)	4
ENGR 101	2	ENGR 102	3

ENGR 199	1	GEF 6	3
MATH 155 (GEF 3)	4	GEF 7	3
GEF 5	3		
	17		17

Second Year

Fall	Hours	Spring	Hours
MAE 215	3	MAE 211	3
MAE 241	3	MAE 242	3
MATH 251	4	MAE 243	3
PHYS 112 (GEF 8)	4	MAE 331	3
ENGL 102 (GEF1)	3	MATH 261	4
		ECON 201 (GEF 4)	3
	17		19

Third Year

Fall	Hours	Spring	Hours
MAE 316	3	MAE 244	1
MAE 320	3	MAE 322	1
MAE 335	3	MAE 336	3
MAE 343	3	MAE 342	3
EE 221	3	MAE 345	3
EE 222	1	MAE 365	3
ECON 202	3	Technical Elective	3
	19		17

Fourth Year

Fall	Hours	Spring	Hours
MAE 426	3	MAE 411	3
MAE 434	2	MAE 423	3
MAE 456	3	MAE 460	3
MAE 476	3	MAE 475	3
Two Technical Electives	6	IENG 302	2
		IENG 303	1
		Technical Elective	3
	17		18

Fifth Year

Fall	Hours
MAE 454	3
MAE 471	3
Three Technical Electives	8
	14

Total credit hours: 155

Note: The dual degree requires twenty hours of technical electives. The twenty hours consists of: nine hours of approved aerospace engineering technical electives, nine hours of approved mechanical engineering technical electives, and the final two hours can be either aerospace engineering or mechanical engineering approved technical electives. Students should consult with their academic advisor to select courses that form a clear and consistent pattern according to the career objectives of the student.

MAE 102. Introduction to Mechanical and Aerospace Engineering Design. 3 Hours.
PR: ENGR 101 with a minimum grade of C and (MATH 154 or MATH 155 with a minimum grade of C) and PR or CONC: PHYS 111. Engineering problem solving techniques related to mechanical and aerospace engineering topics through teamwork, written and oral communications, and using the computer, for algorithm development and computer aided design. Discussion of engineering professional and ethical behavior.

MAE 211. Mechatronics. 3 Hours.
PR: ENGR 102 or CHE 102 or MAE 102. Selection of mechanical and electronic components and integration of these components into complex systems. Hands-on laboratory and design experiments with components and measurement equipment used in the design of mechatronic products. (2 hr. lec., 3 hr. lab.).

MAE 215. Intro to Aerospace Engineering. 3 Hours.
PR: (ENGR 102 or CHE 102 or MAE 102) and (MATH 154 or MATH 155 with grade of C- or higher). Fundamental physical quantities of a flowing gas, standard atmosphere, basic aerodynamic equations, airfoil nomenclature, lift, drag and aircraft performance. Digital computer usage applied to aerodynamic and performance problems and aircraft design. (3 hr. lec.).

MAE 241. Statics. 3 Hours.
PR: WVU sections require PHYS 111 and (MATH 154 or MATH 155) all with a grade of C- or better, WVUIT sections require MATH 155 as a prerequisite. Engineering applications of force equilibrium. Vector operations, couples and moments, resultants, centers of gravity and pressure, static friction, free-body diagrams, trusses and frames.

MAE 242. Dynamics. 3 Hours.
PR: WVU sections require MATH 156 with a grade of C- or better and MAE 241, WVUIT sections require MATH 156 and MAE 241 as prerequisites. Newtonian dynamics of particles and rigid bodies. Engineering applications of equations of motion, work and energy, conservative forces, acceleration in several coordinate systems, relative motion, instantaneous centers, and plane motion.

MAE 243. Mechanics of Materials. 3 Hours.
PR: WVU sections require MATH 156 with a grade of C- or better and MAE 241, WVUIT sections require MATH 156 and MAE 241 as prerequisites. Stress deformation, and failure of solid bodies under the action of forces. Internal force resultants, stress, strain, Mohr's circle, and mechanical properties of materials, generalized Hooke's law. Axial bending and buckling loads, and combinations.

MAE 244. Dynamics and Strength Laboratory. 1 Hour.
PR or Conc: MAE 242 and MAE 243. Experiments in dynamic and strength of materials. Mechanical properties and stress- strain curves of materials for tension, compression, shear, and torsion. Hardness, fatigue, and fracture of metals. Vibration.

MAE 271. Mechanical and Aerospace Engineering Design 1. 1 Hour.
PR: Consent. Hands-on applications of concepts learned in other courses to meet specified performance or competition criteria of capstone design courses. Introductory concepts of an integrated sophomore-junior-senior design team.

MAE 293. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

MAE 312. Introduction to Mechanical Design. 3 Hours.
Introduction to the process of designing mechanical objects and machines composed of multiple objects. Basics of engineering graphics, and creation of computer-based models of machine components and assemblies.

MAE 316. Analysis-Engineering Systems. 3 Hours.
PR: MATH 261 with a grade of C- or better, (ENGR 102 or CHE 102 or MAE 102), and MAE 242. Analytical, numerical, and computational techniques to analyze and solve engineering problems. Mathematical modeling, solution strategies, and analysis of results. Statistical techniques including probability distribution functions, regression analysis, and curve fitting.

MAE 320. Thermodynamics. 3 Hours.
PR: WVU sections require PHYS 111 and MATH 156, WVUIT sections require MATH 156 as a prerequisite. Principles of thermodynamics; properties of ideal gases and vapors; first and second laws of thermodynamics; basic gas and vapor cycles; basic refridgeration.

MAE 321. Applied Thermodynamics. 3 Hours.
PR: MAE 320. Applications to mechanical systems of fundamentals from thermodynamics; availability analysis; applied gas and vapor power cycles; applied refrigeration and psychrometry; mixtures of real gases and vapors; combustion; choked flow nozzles. (3 hr. lec.).

MAE 322. Thermal and Fluids Laboratory. 1 Hour.
PR: MAE 320. Experiments demonstrating fundamental concepts of thermal-fluid systems; hydrostatics, dynamic pressure forces, dimensional analysis, pipe pressure losses, drag on external bodies, flow measurements devices, engine performance, fan and turbine performance, saturated vapor curve determination. (3 hr. lab.).

MAE 331. Fluid Mechanics. 3 Hours.
PR: WVU sections require MATH 251 with a grade of C- or better and MAE 241, WVUIT sections require MATH 156 and MAE 242 as prerequisites. Properties of fluids, fluid statics, inviscid fluid dynamics, fluid kinematics, thermodynamic principles, mass momentum and energy principles, similitude and dimensional analysis, laminar and turbulent flow, vicous effects, flow in pressure conduits and external flows.

MAE 335. Incompressible Aerodynamics. 3 Hours.
PR: MATH 251 and (MAE 215 or MAE 331). Dynamics of vector fluid flow fields. Ideal fluid flow. Introduction to viscous boundary layers. Airfoil Theory. Finite-wing theory.

MAE 336. Compressible Aerodynamics. 3 Hours.
PR: MAE 320 and (MAE 215 or MAE 331). Analysis and design of compressible, inviscid flows; isentropic flow, shock waves, Prandtl-Meyer expansions, supersonic nozzles and diffusers. Airfoils in compressible flow and small perturbation theory, introduction to hypersonic-flow theory.

MAE 342. Dynamics of Machines. 3 Hours.
PR: WVU sections require MAE 242 and PR or CONC: MATH 261, WVUIT sections require MAE 242 as a corequisite. Analysis of motion and forces in linkages and mechanisms. Synthesis of plane mechanisms, analysis of cams, gears and gear trains. Fundamentals of vibrations in machines. Analysis techniques include graphical, analytical and computational methods.

MAE 343. Intermediate Mechanics of Materials. 3 Hours.
PR: MATH 251 with a grade of C or better and MAE 243. Introduction to elasticity. Strength under combined stresses.Energy methods. Column theory. Unsysmmetric bending. Fundamentals of fatigue and fracture.

MAE 345. Aerospace Structures. 3 Hours.
PR: MAE 343. Torsion of thin-walled beams. Flexural shear flow. Thermal analysis of aerospace structures. Introduction to composite materials. Buckling of plates.

MAE 361. Introduction to Unmanned Aerial Systems. 3 Hours.
PR: MAE 215. Introduction to history, current domestic regulations, and policies on unmanned aerial systems. Vehicle aerodynamics, propulsion, structures, launch and recovery, mission planning, weapons and sensor payloads, and ground and airborne system data links. Use of numerical tools, computer-aided design tools, and common engineering planning tools.

MAE 365. Flight Dynamics. 3 Hours.
PR: MAE 242 and MAE 335. Aircraft equations of motion. Modeling of aerodynamic forces and moments. Aircraft static and dynamic stability. Solution of equations of motion via Laplace transformation. Transfer functions. Simulation of open-loop aircraft dynamics. Aircraft handling qualities.

MAE 370. Aviation Ground School. 3 Hours.
Nomenclature of aircraft, aerodynamics, civil air regulations, navigation, meteorology, aircraft, and aircraft engines. May serve as preparation for private pilot written examinations. (2 hr. lec., 2 hr. lab.) (Not approved as a technical elective.).

MAE 371. Mechanical and Aerospace Engineering Design 2. 2 Hours.
PR: MAE 271 with a grade of C or better or Consent. Continued applications of concepts learned in other courses to meet specified performance or competition criteria of capstone design courses. Intermediate concepts of an integrated sophomore-junior-senior design team.

MAE 411. Advanced Mechatronics. 3 Hours.
PR: MATH 261 with a grade of C or better and MAE 211 and EE 221 and EE 222. Instrumentation and measurements emphasizing systems that combine electronics and mechanical components with modern controls and microprocessors. First and second order behavior, transducers and intermediate devices, measurement of rapidly changing engineering parameters, microcontrollers and actuators. (2 hr. lec., 3 hr. lab.).

MAE 415. Balloon Satellite Project 1. 1 Hour.
Student teams propose, design, construct, and test experimental packages, launched as payloads via a weather balloon that is tracked and recovered. Data acquired by the experimental payloads is analyzed.

MAE 417. Balloon Satellite Project 2. 2 Hours.
PR: MAE 415. Student teams propose, design, construct, and test complex experimental packages, launched as payloads via a weather balloon that is tracked and recovered. Data acquired by the experimental payloads is analyzed.

MAE 421. Problems in Thermodynamics. 3 Hours.
PR: MAE 321 or consent. Thermodynamic systems with special emphasis on actual processes; problems designed to strengthen the background of the student in the application of the fundamental thermodynamic concepts. (3 hr. lec.).

MAE 423. Heat Transfer. 3 Hours.
PR: WVU sections require MATH 261 with a grade of C- or better and MAE 320 and (MAE 331 or MAE 335), WVUIT sections require MAE 320 and MAE 321 as prerequisites and MAE 419 as a corequisite. One-, two-, three-dimensional steady state conduction: transient conduction; free and forced convection; radiation; heat exchangers; heat and mass transfer by analytical, numerical analogical and experimental methods; design of thermal systems.

MAE 424. Applications in Heat Transfer. 3 Hours.
PR: MAE 423. Application of basic heat transfer theory and digital computation techniques to problems involving heat exchangers, power plants, electronic cooling, manufacturing processes, and environmental problems. (3 hr. lec.).

MAE 425. Internal Combustion Engines. 3 Hours.
PR: WVU sections require MAE 320, WVUIT sections require MAE 321 as a prerequisite. IC engine operating characteristics; engine cycles; thermochemistry and fuels; air and fuel induction; fluid motion within combustion chamber; combustion; exhaust flow; emissions and air pollution; heat transfer in engines; friction and lubrication; advanced engine concepts.

MAE 426. Flight Vehicle Propulsion. 3 Hours.
PR: MAE 336. Equilibrium combustion thermodynamics. Quasi one-dimensional flow with friction and total temperature change. Thermodynamics of aircraft engines. Aerodynamics of inlets, combustors, nozzles, compressors, and turbines. Performance of rockets. Ideal rocket analysis. (3 hr. lec.).

MAE 427. Heating, Ventilating, and Air Conditioning. 3 Hours.
PR: WVU sections require MAE 320 or consent, WVUIT sections require MAE 321 and MAE 423 as prerequisites or department consent. Air and humidity relations; comfort and indoor air quality; building heat transfer; design heating and cooling loads; air distribution; refrigeration; systems and equipment; system energy analysis; control systems.

MAE 430. Microgravity Research 1. 3 Hours.
Student team conceives and proposes a unique research experiment, to be flown on NASA microgravity research aircraft. Team also begins design, construction, and testing of apparatus.

MAE 431. Microgravity Research 2. 3 Hours.
PR: MAE 430. Student team completes design, construction, and testing of research experiment; that is then flown on NASA microgravity research aircraft. Data required from experiment is analyzed and reported.

MAE 432. Engineering Acoustics. 3 Hours.
PR: MATH 261 or consent. Theory of sound propagation and transmission. Important industrial noise sources and sound measurement equipment. Selection of appropriate noise criteria and control methods. Noise abatement technology. Laboratory studies and case histories. (3 hr. lec.).

MAE 433. Computational Fluid Dynamics. 3 Hours.
PR: MAE 316 and (MAE 331 or MAE 335) with a grade of C or better in each, or consent. Introduction to modern computational fluid dynamics. Development and implementation of finite- difference schemes for numerical flow solution. Grid Generation. Explicit, implicit, and iterative techniques. Emphasis on applications. Validation and verification of solution. (3 hr. lec.).

MAE 434. Experimental Aerodynamics. 2 Hours.
PR: MAE 336. Aerodynamic testing and instrumentation. Supersonic and low-speed wind tunnel testing including shock waves, aerodynamic forces, pressure distribution on an airfoil and boundary layers. Application of schlieren optics, thermal anemometry and laser doppler velocimetry. (1 hr. lec., 3 hr. lab.).

MAE 437. Vertical/Short Takeoff and Landing Aerodynamics. 3 Hours.
PR: MAE 336. Fundamental aerodynamics of V/STOL aircraft. Topics include propeller and rotor theory, helicopter performance, jet flaps, ducted fans, and propeller-wing combinations. (3 hr. lec.).

MAE 438. Introduction to Gas Dynamics. 3 Hours.
PR: MAE 331 or consent. Fundamentals of gas dynamics, one-dimensional gas dynamics and wave motion, measurement, effect of viscosity and conductivity, and concepts of gas kinetics. (3 hr. lec.).

MAE 439. Hypersonic Gas Dynamics. 3 Hours.
PR: MAE 336 or consent. Hypersonic shock and expansion wave relations; hypersonic inviscid flowfields: approximate and numerical methods, blast wave theory; hypersonic boundary layers and aerodynamic heating. (3 hr. lec.).

MAE 441. Gas Turbine Design and Durability. 3 Hours.
PR: MAE 320 and (MAE 335 or MAE 331). Design of gas turbine engines for aircraft propulsion and industrial power generation. Theory of operation and characteristics of gas turbines. Design considerations, component operation, and durability of the individual components.

MAE 443. Mechanical Behavior and Materials. 3 Hours.
PR: MAE 343 or consent. Reveal the mechanical behavior of materials, including elastic behavior, plastic deformation, high temperature deformation and deformation of non-crystalline materials like polymer and composites. It also covers the materials microstructures and their effects on mechanical properties.

MAE 446. Mechanics of Composite Materials. 3 Hours.
PR: MATH 251 and MAE 243. Fundamental methods for structural analysis of fiber reinforced composites. Particularities of composite applications in design and manufacturing of structural components: performance tailoring, failure criteria, environmental effects, joining and processing. (3 hr. lec.).

MAE 447. Aeroelasticity. 3 Hours.
PR: MAE 345. Vibrating systems of single degree and multiple degrees of freedom, flutter theory and modes of vibration, torsional divergence and control reversal. (3 hr. lec.).

MAE 454. Machine Design and Manufacturing. 3 Hours.
PR: WVU sections require MATH 261 with a grade of C- or better and MAE 342 and MAE 343, WVUIT sections require MAE 243 as a prerequisite and MAE 342 as a corequisite. Working stresses, theories of failure, fatigue, welded joints, design of machine elements such as shafting, screws, springs, belts, clutches, brakes, gears, bearings, and miscellaneous machine elements. Design for manufacturability considerations.

MAE 456. Computer-Aided Design and Finite Element Analysis. 3 Hours.
PR: WVU sections require MATH 261 with a grade of C- or better and MAE 343 and (MAE 342 or MAE 345), WVUIT sections require MATH 251 and MAE 454 and MAE 455 as prerequisites and MAE 423 as a corequisite. Computer aided design fundamentals and formulation of the stiffness matrix and load vector 1D and 2D elements based on variational principles. Analytical and finite element solution of vibration and heat transfer problems. Explore applications of CAD/FEM packages in design case studies.

MAE 459. Hybrid Electric Vehicle Propulsion and Control. 3 Hours.
Hybrid electric vehicle propulsion system modeling and simulation. Hybrid electric vehicle powertrain architectures. Mathematical modeling of hybrid vehicle components including vehicle longitudinal dynamics, batteries, electric motors, engines, transmissions, inverters. Development of hybrid supervisory control algorithms for powertrain management and optimization.

MAE 460. Automatic Controls. 3 Hours.
PR: WVU sections require MATH 261 with a grade of C- or better, WVUIT sections require EE 221 and MATH 261. Modeling and simulation of mechanical systems using transfer functions. 1st and 2nd order systems with associated specification. Block algebra and concept of Equivalent Transfer Function. Steady state errors. Routh-Hurwitz criteria for stability. Root locus based design of proportional controllers and compensators. Introduction to state variables modeling.

MAE 461. Applied Feedback Control. 3 Hours.
PR: MAE 460 or Consent. Application of automatic control theory. Transfer functions and block diagrams for linear physical systems. Proportional, integral, and derivative controllers. Transient and frequency response using Laplace transformation. (3 hr. lec.).

MAE 462. Design of Robotic Systems. 3 Hours.
PR: Consent. Mechanical automation design associated with robotic systems, including economic justification and ethics. Geometric choices and controller specifications for programmable manipulators. Workstation strategies such as CNC and CIM for computer-based flexible manufacturing. (3 hr. lec.).

MAE 465. Flight Mechanics 2. 3 Hours.
PR: MAE 365. Fundamental concepts of feedback control system analysis and design. Automatic flight controls, and human pilot plus airframe considered as a closed loop system. Stability augmentation. (3 hr. lec.).

MAE 466. Spacecraft Dynamics. 3 Hours.
PR: MAE 476. Development of rigid-body equations of motion for aerospace vehicles. Introduction to spacecraft attitude representations, including direction cosine matrices, Euler angles, and quaternions. Brief discussion of airplane flight dynamics. Discussion of attitude dynamics, stabilization, and control in the presence of external torques. Brief discussion of attitude hardware.

MAE 467. Introduction to Flight Simulation. 3 Hours.
PR: MAE 365. Fundamental concepts of flight simulation are introduced through interaction with tools of different complexity from simplified linear and non-linear models to a six degrees-of-freedom motion based flight simulator.

MAE 470. Unmanned Aerial Vehicle Design/Build/Fly Competition 1. 1 Hour.
PR: Consent. Hands-on applications of concepts learned in other courses to meet specified flight performance and competition criteria. Advanced aerodynamic and material concepts are utilized by an integrated sophomore, junior, senior team.

MAE 471. Principles of Engineering Design. 3 Hours.
PR: MAE 320 and MAE 331 and MAE 342 and MAE 343. Topics include design problems in mechanical engineering, deal with analytical and experimental methodologies in fluid, thermal, and structural areas, decision-making techniques, optimization, computer aided design and economic consideration.

MAE 472. Engineering Systems Design. 3 Hours.
PR: MAE 320 and MAE 331 and MAE 342 and MAE 343. Identification and solution of challenging engineering problems through rational analysis and creative synthesis. Planning, designing, and reporting on complex systems on individual and group basis. (6 hr. lab.).

MAE 473. Bioengineering. 3 Hours.
PR: MAE 243 or consent. Introduction to human anatomy and physiology using an engineering systems approach. Gives the engineering student a basic understanding of the human system so that the student may include it as an integral part of the design. (3 hr. lec.).

MAE 474. UAV Design/Build/Fly Comp. 1-3 Hours.
PR: Consent. Hands-on applications of concepts learned in other courses to meet specified flight performance and competition criteria. Advanced aerodynamic and materials concepts are utilized by an integrated sophomore-junior-senior team.

MAE 475. Flight Vehicle Design-Capstone. 3 Hours.
PR: ENGL 102 and MAE 215 and MAE 365 or consent. Preliminary design of flight vehicles; with regard for performance and stability requirements, considering aerodynamics, weight and balance, structural arrangement, configuration, cost safety, guidance, and propulsion effects. (1 hr. lec., 6 hr. lab.).

MAE 476. Space Flight and Systems. 3 Hours.
PR: MAE 316. Introduction to fundamental concepts of space flight and vehicles, emphasizing performance aspects and basic analytical expressions. Common analysis methods and design criteria for launch vehicles, orbital mechanics, atmospheric re-entry, stabilization, thermal, power, and attitude control.

MAE 477. Space Systems Design. 3 Hours.
PR: MAE 475 or MAE 471. Conceptual and/or preliminary design of space vehicles and/or systems including structures, CAD, orbital mechanics, propulsion, thermal control, life support, power systems, communications, system integration and cost analysis. (1 hr. lec., 6 hr. lab.).

MAE 478. Guided Missile Systems. 3 Hours.
PR: MAE 336 and PR or Conc: MAE 426. Design philosophy according to mission requirements. Preliminary configuration and design concepts. Aerodynamic effects on missiles during launch and flight. Ballistic missile trajectories. Stability determination by analog simulation. Performance determination by digital and analog simulation. Control, guidance, and propulsion systems. Operational reliability considerations. (3 hr. lec.).

MAE 479. Space Mechanics. 3 Hours.
PR: MATH 261 and MAE 242. Flight in and beyond earth's atmosphere by space vehicles. Laws of Kepler and Orbital theory. Energy requirements for satellite and interplanetary travel. Exit from and entry into an atmosphere. (3 hr. lec.).

MAE 482. Flight Simulation for Aircraft Safety. 3 Hours.
PR: MAE 365 or consent. Introduction to flight modeling and simulation tools for aircraft health management through analysis and accommodation of abnormal flight conditions.

MAE 484. Spacecraft Propulsion. 3 Hours.
PR: MAE 336. Brief introduction to aircraft propulsion including turbojets. Introduction to rocket and spacecraft propulsion. The rocket equation, staging, liquid rocket engines and solid rocket motors, thermochemistry, and combustion.

MAE 485. Flight Vehicle Design 2. 3 Hours.
PR: MAE 475. Detailed design of a major aircraft component and evaluation through experiments or simulation of performance and design requirements compliance.

MAE 486. Spacecraft Design 1. 3 Hours.
PR: MAE 215 and MAE 316 and MAE 476. Engages students into the process of designing spacecraft and space missions as it is executed in both government and industry. Addresses each of the major subsystems found in most modern spacecraft. Includes computer and hands-on laboratory assignments.

MAE 487. Spacecraft Design 2. 3 Hours.
PR: MAE 486. The course is focused on a team-based design exercise to develop an end-to-end spacecraft mission concept. Typical process issues are addressed such as science investigation, trajectory analysis, detailed design of each spacecraft subsystem, discussion of engineering trade studies, risk analysis, budget, and schedule.

MAE 490. Teaching Practicum. 1-3 Hours.
PR: Consent. Teaching practice as a tutor or assistant.

MAE 491. Professional Field Experience. 1-18 Hours.
PR: Consent. (May be repeated up to a maximum of 18 hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

MAE 493. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

MAE 494. Seminar. 1-3 Hours.
PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

MAE 495. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.

MAE 496. Senior Thesis. 1-3 Hours.
PR: Consent.

MAE 497. Research. 1-6 Hours.
Independent research projects.

MAE 498. Honors. 1-3 Hours.
PR: Students in Honors Program and consent by the honors director. Independent reading, study or research.