Aerospace Engineering

The Aerospace Engineering program in the Mechanical and Aerospace Engineering and Engineering Mechanics Department offers comprehensive graduate education in a number of areas. Aerodynamics, gas dynamics, hypersonics, aerospace system design, aerospace propulsion, aerospace structures and flight dynamics and control are the major areas of emphasis. A great variety of interdisciplinary programs, meeting specific objectives are available. The Aerospace Engineering Program offers the master of science degree in aerospace engineering and the doctor of philosophy in aerospace engineering.

The master of science thesis program, which is required by the department for on-campus students, consists of a minimum of 30 semester hours, normally including 24 hours of course work with nine hours from the aerospace engineering core curriculum and at least six hours in mathematics and/or computer science. At least six credit hours of 400-level course work must be from aerospace engineering courses. In addition, a thesis from research equivalent to at least six credit hours in a major area must be prepared.

The master of science nonthesis program consists of a minimum of 33 semester hours, normally including 15 hours of course work in a major area and six hours in mathematics and/or computer science, of which 12 hours must be from the aerospace engineering core curriculum. At least nine hours of course work must be taken at the 400-level, with a minimum of six hours from aerospace engineering or mechanical engineering or engineering mechanics. A comprehensive examination from three out of the four areas must be passed. Examination in at least one of the four areas must be from the 400-level course. This program is restricted to part-time students who are enrolled in the UMR Engineering Education Center in St. Louis.

A student pursuing the doctor of philosophy degree normally follows a program of 90 credit hours of course work beyond the B.S. degree or 60 credit hours beyond the M.S. degree. For those with the M.S. degree, the 60 hours will consist of 36 credit hours of course work and 24 credit hours of thesis research. The Ph.D. course work must satisfy the departmental core course requirements for the M.S. degree. For the 36 credit hours of course work, fifteen credit hours must be taken outside the department including at least 12 hours of mathematics and/or computer science. A minimum of 15 credit hours of approved course work must be completed within the department. At least 9 credit hours of course work must be at the 400-level in the major field of study. In addition to these course requirements, a candidate must prepare a dissertation based on analytical and/or experimental research in a major area. This research must be equivalent to a minimum of 24 credit hours beyond the M.S. degree.

There are no foreign language requirements for the doctor of philosophy degree in aerospace engineering. However, a reading knowledge of one foreign language, either German, French or Russian, may be required for the doctor of philosophy degree if the candidate's advisory committee feels that it is necessary.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The qualifying exam consists of taking a minimum of nine credit hours of approved graduate course work at the 300- and 400-level, including six hours in the major field, of which three must be at the 400-level, and three hours of mathematics or computer science. To pass the qualifying exam, a student must have obtained a grade of B or better for all courses with a GPA of at least 3.25.

The comprehensive examination and the final examination, consisting of the dissertation defense, are conducted according to the rules of the Graduate Faculty, the School of Engineering, and the department. The Graduate Faculty has a residency requirement which must be satisfied by all doctoral students.

Typical examples of research activities are: analysis and design of composite structures, structural acoustics, aeroacoustics, smart structure, active and passive vibration control, optimization of systems based on structural dynamics or structural performance, astrodynamics, guidance and control of aircraft and missiles, robust multivariable control, neutral network architecture for control, estimation theory, real time flight simulation, non equilibrium shock wave structure, propulsion research with emphasis on how fuel variables influence combustion, atomization of liquid fuels in supersonic flow, flame stability in combustion systems, ramjet and supersonic combustion ramjet studies, computational fluid dynamics, laser interaction problems, free turbulent mixing, unsteady high angle of attack flow configurations, computer simulation of separated flows, low-speed and high-speed aerodynamics, aerodynamics of highlift devices, aerospace system design, and viscous effects in transonic flows.

The Mechanical and Aerospace Engineering and Engineering Mechanics complex has many well equipped laboratories located in the Mechanical Engineering Building on the main campus, a subsonic-flow laboratory in an off-campus facility, and an experimental area in the Engineering Research Laboratory Building. Some of the specially equipped laboratories in the main campus facility include a supersonic-flow laboratory with a Mach 4 blow-down wind tunnel, a hot-wire anemometer system, a Schlieren system, an airflow test facility, an acoustics and vibration laboratory, and extensive computer facilities including a personal computer laboratory, advanced computer graphics laboratory, computer learning center with engineering work stations. A laser diagnostics laboratory equipped with state-of-the-art lasers to conduct experiments related to aerodynamics and combustion. A composite materials testing laboratory with state-of-the-art material testing system, low velocity impact facility and high speed photography equipment. The flight simulator program at UMR incorporates a fixed-base real-time flight simulator with out-the-window display. The simulator system utilizes parallel processing on a dedicated Apollo DN10000 workstation with output used to drive cockpit instrumentation and to create graphic imagery.

Biological Sciences

The department of Biological Sciences offers an interdisciplinary approach to addressing problems in applied and environmental biology. The program will emphasize research that focuses on understanding environmental responses and adaptations in biological systems at the cellular and molecular levels. Departmental research efforts are distinguished by their association with other science and engineering disciplines on the UMR campus through collaborations with the Ceramic Engineering, Chemical Engineering, Chemistry, Civil Engineering, Computer Science, Computer and Electrical Engineering, Geology and Geophysics, Mechanical Engineering and Metallurgical Engineering departments.

The Department of Biological Sciences currently occupies space in Shrenk Hall together with the Departments of Chemistry and Chemical Engineering. Juxtaposition to these departments offers a strong academic environment with ample opportunity for interaction of faculty and students that is appropriate to an interdisciplinary graduate program.

Students who participate in the Applied and Environmental Biology Master of Science Degree program in the Department of Biological Sciences would have exceptional opportunities for performing the interdisciplinary research critical for understanding and solving environmental problems. An understanding of the environment and associated problems requires background knowledge and applications of modern technology derived from many traditional fields of science, mathematics and engineering. The unique focus on engineering and the sciences at UMR offers opportunity for integrated course work and collaborative research dealing with the complexities of environmental biology. In addition, faculty in the Department of Biological Sciences are actively involved in research centers on the UMR campus such as the Environmental Research Center, the Center for Environmental Science and Technology (CEST), and the Graduate Center for Materials Research.

Equipment items requisite to quality graduate laboratory experiences in the biological sciences are currently available within the department or in the laboratories of collaborators in the other disciplines. Faculty and students requiring vertebrate animals for research have access to the UMR Animal Research Facility, a resource facility for the UMR campus which is located in newly renovated space in Building #3 of the Bureau of Mines complex. The 1780 square foot renovated space includes colony rooms, a room for sterile surgery, a cage-washing room, and other support rooms. The renovated facility complies with all applicable PHS and USDA guidelines pertaining to facilities for maintenance of vertebrate animals for research. Faculty and students requiring analytical instruments have access to such equipment through the research centers at UMR such as the Environmental Research Center, the Center for Environmental Science and Technology (CEST), and the Graduate Center for Materials Research. The Department of Biological Sciences is also well equipped with state-of-the-art equipment for cell and molecular biology. This equipment includes various high speed and ultracentrifuges with fixed angle and swinging bucket rotors, laminar flow hoods, micro centrifuges, gel dryer, evaporative centrifuge, PCR machines, electroporator, protein and DNA gel-electrophoresis units and power supplies, UV cross-linker, semi-dry and submarine nucleic acid/protein transfer units, French pressure cell and press, numerous general use incubators, growth chambers, shaking incubators, sequencing gel apparatus and power supply, UV-Trans-illuminator, Polaroid photographic equipment, assorted teaching and research microscopes, nanopure water purification system, UV-Vis spectrophotometers, dark room, Beckman scintillation counter, micortiter plate reader, semi-automatic cell-harvester, media prep room with autoclaves,-70 C freezer, and automated media dispenser. Faculty and students also have access to a DNA core facility at the University of Missouri-Columbia which will synthesize oligonucleotides and determine DNA sequences for a reagnet-cost price. The department also has access to the University of Wisconsin Genetics Computer Group (GCG) programs that are available through the DNA core facility and are accessible from campus wide Computer Learning Centers (CLC's) which also provides access to software necessary for molecular biology applications. Equipment for environmental microbiology include a sterile microdrill/micropipet system and a Coy anaerobic chamber.

Ceramic Engineering

A baccalaureate degree in ceramic engineering , ceramic science, glass science or technology, or materials science is preferred for your admission to the departmental graduate program. However, a background in chemistry, physics, mathematics, or geology is acceptable.

The department staff has specialized interests in the product areas of glass, refractories, and electronic ceramics. Fundamental interests are in the structure of crystalline and amorphous materials, optical properties, electrical and electronic behavior, mechanical properties, thermodynamics and thermochemistry of solids, waste disposal, biomaterials, and ceramic processing.

The department specializes in research concerning the structure of vitreous materials, biological uses of glass, chemical corrosion of glass, materials processing, and thermal, electronic and mechanical behavior of ceramics. Crystalline structure; orientation effects; constitution of glass, color, radiation effects, infrared materials, electrical resistivity, ultrasonics, ferroelectric behavior; thermal shock, composites, defect chemistry and phase equilibria of perovskite oxides all represent ongoing areas of research endeavor.

A number of laboratories are equipped for your graduate research in ceramic materials. The equipment includes X-ray diffraction for elemental analysis, qualitative and quantitative; petrographic and reflected light microscopic equipment for characterization of microstructure of materials; a differential thermal analysis and thermal gravimetric unit for following chemical

changes at temperature; a precise automatic recording dilatometer; and many general and specific items of research equipment. Recent acquisitions include computerized X-ray diffraction equipment, particle size and surface area analyzers and image analysis systems.

The department has a strong affiliation with the Graduate Center for Materials Research at UMR. Three of the faculty are senior investigators and three are associates of this nationally recognized center. Much of the ceramic materials study pursued in this center focuses on biomaterials.

The department initiated the Electronic Materials Applied Research Center (EMARC) in 1996 under the direction of Dr. Harlan Anderson. Internationally known for research into fuel cell electrodes, the interdisciplinary team also addresses many other materials challenges which can be met by ferroelectrics and other electronic ceramics.

Refractories and structural ceramics are the focus of a large group of interdisciplinary faculty and students with the research emphases placed on corrosion mechanisms, strength and toughness, thermochemistry, effects of temperature and chemical gradients, and on shaped and monolithic components. Most of this research is supported by industrial sponsors.

Chemical Engineering

A baccalaureate degree in chemical engineering from an ABET-approved program with a minimum undergraduate grade point average 3.0/4.0 is generally required for admission to the departmental graduate program.

A special M.S. program is available for science majors which includes most undergraduate course requirements for the B.S. in chemical engineering that have not already been completed. A GPA of 3.5/4.0 or better or a ranking in the upper 10 percent of the class is required for admission to this program.

All graduate students are required to take CHE 433, 441, and 461. Either CHE 343 or 443 is recommended. A research thesis is required for the M.S. in all but special circumstances. Research for M.S. and Ph.D. may be coordinated. Graduate students may not participate in a cooperative work program without the written permission of the department chair.

The department specializes in research in the areas of theology, fluid mechanics, mixing, freeze drying, reaction engineering, biochemical engineering, adsorption/desorption, mass transfer and heat transfer in porous media, chromatography, perfusion chromatography, separations, transport phenomena, physical property measurements turbulence theory, instrumentation and control, thermodynamics, kinetics, polymers, computer-aided design, surface phenomena, and electrochemistry. Many research projects are performed in collaboration with the Materials Research Center, the Intelligent Systems Center and the Center for Environmental Science and Technology.

The Department of Chemical Engineering shares Schrenk Hall, a building of four floors, with the chemistry and biological sciences departments. The department's instructional and research laboratories and faculty offices are located here.

The department has excellent computer facilities equipped to handle all chemical engineering computational, modeling, and simulation requirements.

Special areas for instruction and research are maintained and include excellent and modern facilities for studying (1) simulation, control and optimization; (2) biconversion; (3) reaction mechanisms and kinetics; (4) experimental and theoretical studies of vapor-liquid equilibrium; (5) fluid mechanics and mixing; (6) rheology of complex fluids and polymers; (7) thermodynamics; (8) polymers and polymeric materials;

(9) adsorption/desorption processes; (10) freeze drying; (11) computer-aided design; (12) interfacial phenomena; (13) reaction rates at electrode surfaces; (14) transport phenomena; and (15) chromatography.

Facilities are available to assist with the construction of special research equipment.

Chemistry

The Department of Chemistry provides instructional programs in analytical, inorganic, organic, physical, polymer and biochemistry, as well as in more specialized areas. Besides the basic fields, there are programs in bioanalytical chemistry, cancer biology, colloids, corrosion, cosmochemistry, electrochemistry, environmental chemistry, molecular modeling, kinetics, organometallic chemistry, reaction mechanisms, solid state chemistry, surface, surface coatings, and theoretical chemistry. Interdisciplinary programs in materials science and atmospheric sciences are also available.

The Department of Chemistry requires that all of its graduates teach as part of their training for an advanced degree. The objective is to supplement your education and strengthen your professional preparation in academic practices. Financial support is often available from research grants for advanced students.

The Department of Chemistry shares facilities with the Departments of Chemical Engineering and Life Sciences. Two connected air conditioned buildings with research, teaching and computer laboratories are available.

The Department is well-equipped with state-of-the-art instrumentation for chemical research. The department has a number of support personnel to provide technical assistance with laboratory instrumentation, computers, laboratory hardware, and glassware. Instrumentation includes a Nicolet Magna 750 FT/IR spectrometer, a Bechman P/ACE System 2100 capillary electrophoresis instrument, a Kratos MS80 high resolution Mass Spectrometer, Varian 200 and 400 MHZ FT NMR Spectrometers with multinuclear, wide-angle solids, diffusion, and variable temperature capabilities, a 400 MHZ solids NMR, a spex 1403 Laser Raman Spectrometer with a Coherent Argon Ion Source, an Applied Color Systems 1800 Color Matching/Formulating Computing Spechtrophotometer, Centrifugal Partition Chromatographs, a Jasco J-600 Circular Dichroism Spectrometer, a Perkin-Elmer DSC/Thermal Mechanism Analyzer, Par 273 Potentiostats, a Johnson-Matthes

Magnetic Susceptibility Balance, a Faraday Low Temperature Magnetic Susceptibility Balance, and Harwell and Ranger Low Temperature Mossbauer Spectrometers. The department houses the most extensive collection of mass spectrometers in the state, comprising one of the best Mass Spectrometry laboratories in the nation. Backing up these instruments are a wide variety of chromatographs (GC, LC, IC), infrared spectrometers (FT and dispersive), NMR spectrometers, refrigerated ultra centrifuges, dispersive optical spectrometers (UV, VIS, Near IR, ICP, AA), calorimeters, radiation counters, oscilloscopes, and other modern instruments. Many of these instruments are computer driven. In addition, numerous PC/compatible, Macintosh and UNIX computers are available in laboratories, computer learning centers, and a computerized classroom, as well as, access to the university centralized computing facility. X-ray diffraction is performed in the Graduate Center for Materials Research on a Scintag 2000 Difractometer and other supporting equipment while neutron diffraction is on hand at the High Flux Reactor of the University of Missouri. This also supports nuclear chemistry. Facilities for studying very fast combustions and explosions, as well as a variety of new and innovative techniques for characterizing high energy materials, are provided in the Rock Mechanics and Explosives Research Center.

Civil Engineering

The department offers several areas of specialization. These are construction materials, environmental engineering, geotechnical engineering, hydraulic engineering and engineering hydrology, structural engineering, transportation, and infrastructure engineering. Samples of recent and ongoing funded research are drainage of highway subgrades, low-level nitrification with biofilm systems, determination of gas permeability of fine grained soils, determining stream stability and storm water detention in urban watersheds, evaluation of storm water drainage structures on bridges, urban watershed modeling, constitutive modeling of reinforced concrete structures, collapse studies of building structures and bridges subjected to interacting ground motion, theoretical and shake-table tests of hybrid-controlled structures, structural optimization with multi objective functions, a computerized tutoring system for structural analysis, and behavior of concrete structures reinforced with composites. While this list is representative, it is not all-inclusive.

Faculty expertise include analysis, design and control of seismic-resistant structures, design of cold-formed steel structures, design of reinforced concrete structures, FRP composite material for civil infrastructure, treatment processes for liquid industrial waste, behavior of granular base materials, asphalt and concrete as they relate to pavement analysis and design, river engineering and urban watershed dynamics and geotechnical engineering problems such as determination of the dynamic properties of silt soils, and seismic effects on retaining structures, piles and dynamic soil-structure-interaction, and evaluation of resistance of helical anchors. The breadth of faculty expertise and experience is wide, and the nature of ongoing research in any particular emphasis area varies considerably over time.

The basic prerequisite for admission to graduate study in the department is a bachelor of science degree in civil engineering from an ABET accredited school or equivalent. Students who have a degree from a nonaccredited school, or hold a bachelor of science degree in a field other than civil engineering, may be required to take civil engineering prerequisites to prepare for graduate courses. Specific prerequisites will depend on their academic background and intended area of specialization. Degree programs offered are the master of science in civil engineering (MSCE), master of science in environmental engineering (MSEnvE), the doctor of engineering, and doctor of philosophy (Ph.D.).

As part of a campus interdisciplinary program, this department also offers a course of study in hazardous waste engineering and science that leads to the MSCE or Ph.D. The core curriculum involves chemistry, civil engineering, and geological engineering. Students in other departments are likely to enter this program for advanced degrees in their respective fields. The civil engineering component is uniquely designed to apply the academic background of graduate civil engineers while showing them the interdisciplinary nature of hazardous waste engineering.

The Department of Civil Engineering is housed in the Butler-Carlton Civil Engineering Hall. The building provides office space for civil engineering faculty, staff, and graduate students, and contains class rooms and laboratories in which most civil engineering courses are taught. On the premises are a 175-seat auditorium and a smaller 120-seat auditorium with large-screen video projection capability. The building contains geotechnical laboratories, a hydraulics laboratory, abituminous materials testing laboratory, environmental engineering laboratories structures and materials testing laboratories and a shop. Laboratories are used for undergraduate instruction and shop facilities are used for construction and maintenance of specialized mechanical and electronic testing equipment needed to support teaching and research.

In addition, the building houses several computer learning centers (CLC) and research computing labs. The CLCs have printers, plotters and digitizers. Computers in the CLCs are networked within the department, across campus, and with World Wide Web. Departmental and campus network servers offer word processing, spreadsheet, graphing, CADD, and various specialized data analysis and processing software. All faculty, graduate students, and staff have access to network to facilitate communications, teaching and research.

The Department of Civil Engineering is home to the environmental research center, a structural engineering laboratory, and "shake table" in the nearby Engineering Research Laboratory. The Environmental Research Center is used for graduate and undergraduate research pertaining to groundwater and soil remediation, industrial and hazardous waste treatment, biological and chemical wastewater and water treatment, and

air pollution control. The structural engineering laboratory is used for graduate research in structural dynamics as well as testing of reinforced concrete structures and cold-formed steel structures. A "shake table" simulates earthquake conditions for the evaluation of earthen structures. The UMR Department of Civil Engineering has the faculty, staff, and physical facilities to support a wide range of research within the traditional emphasis areas of civil engineering. Although there are nationally recognized theorists among the faculty, the emphasis is on applied research with increasing attention given to interdisciplinary and interdepartmental work.

Computer Engineering

The mission of the Computer Engineering Program, consistent with the School of Engineering and the UMR campus mission statements, is the education of students to fully prepare them to provide leadership in the recognition and solution of society's problems in the area of Computer Engineering.

The Computer Engineering Program in the Department of Electrical Engineering and the Computer Engineering offers graduate programs of study which lead to the M.S. degree (thesis and nonthesis options) and Ph.D. degree. Both the Rolla campus and the Engineering Education Center in St. Louis offer M.S. programs. A great variety of multidisciplinary programs and research areas are available. While your graduate program will be designed to meet your needs all graduate programs normally include some specialization in one or more of the following four emphasis areas of computer engineering.

Emphasis Areas

Digital Systems Design topics include computer architecture, digital circuits, high performance systems, parallel processors, testing and VLSI design.

Electrical Engineering can be an emphasis area in Computer Engineering or a separate degree. See the section on Electrical Engineering for emphasis areas in electrical engineering.

Embedded Computer Systems topics include hardware/software co-design, microprocessor systems, real-time systems, and smart sensors.

Systems, Intelligence, and Software Engineering topics include computational intelligence, computer networks, dependability, fault tolerance, image processing, neural networks and a system security/survivability.

Departmental Facilities

In addition to computer engineering laboratories, there are machine shops and electronic shops, as well as digital computer facilities. More information can be found on our home page: http://www.ece.umr.edu

Departmental Requirements

Admission requirements: Additional minimum departmental requirements beyond those stated in the section on Admission and Program Procedures of this catalog follows. For M.S. applicants, a B.S. degree in computer engineering from an ABET accredited university or a closely related field like Computer Science, an undergraduate cumulative GPA (or last 2 years) of 3.2/4.0 or equivalent, a GRE Quantitative score of 730 and a GRE Analytical score of 640. Applicants close to satisfying these requirements may be eligible for Special Graduate Student status or be required to take some undergraduate courses for no graduate credit. For students from international universities, equivalent degree and GPA as stated above GRE scores as stated above, TOEFL score of 580 for students from countries where English is not the primary language. For Ph.D. applicants, the same as M.S. plus a M.S. degree in computer engineering or a closely related field, GPA of 3.5/4.0, and three letters of recommendation. Exceptional B.S. applicants may apply directly for the Ph.D. program.

Program Requirements: Additional minimum departmental requirements beyond those stated in the section on Admission and Program Procedures of this catalog follows. M.S. with thesis programs require a minimum of 21 hours of course work. For M.S. with thesis and M.S. without thesis programs, 200 level out of department courses should be prerequisite for 300 level courses. For Ph.D. programs approximately 90 hours beyond the B.S. or 60 hours beyond the M.S. are required.

Ph.D. Language Requirement: As a Computer Engineering Ph.D. student, you are not required to satisfy a language requirement. However, you may have language requirements included in your plan of study if your advisory committee feels that this inclusion would be useful or necessary for your research.

Research: Significant research is expected for the M.S. thesis and Ph.D. dissertation as well as publication of the results. The student should work closely with the Major Advisor and Committee to determine when these expectations are met. Length of research time and/or research credit hours will not automatically satisfy this requirement.

Computer Science

The Computer Science Department offers comprehensive M.S. and Ph.D. degree programs that focus on the design and implementation of software systems and algorithms (problem solving techniques). While instruction and research are on the leading edge of computing, the Department endeavors to keep class size small to facilitate student and faculty interactions.

The CS faculty has a broad range of scholarly interests. These interests include computational science, graphics and robotics, information systems (traditional and multimedia), intelligent systems (artificial intelligence and machine learning), parallel and distributed computing, as well as software engineering. The faculty is not only actively doing research in these areas, they integrate their research experiences with the classroom experiences. A number of the faculty have external support for their research.

The Department maintains several of its own laboratories. Some of these laboratories are specially equipped research laboratories while others are general purpose computing laboratories that are assessable to all students. Numerous other general purpose comput-

ing laboratories are provided on campus and are assessable to students from all departments. Access to many computers is available through Ethernet from all university owned facilities. Dial-ups support a large number of off-campus users. A large number of computing languages (including C++, C, Java, Fortran, Lisp, and Prolog) and special-purpose software tools (including CASE tools, Oracle database systems, Matlab and CLIPS) are available on various Unix and Windows platforms.

Admission Requirements: In addition to those requirements stated in the section of this catalog devoted to Admission and Program Procedures, the Computer Science Department has additional requirements for each of its degree areas.

M.S. in Computer Science (thesis or nonthesis):

A minimum GRE verbal score of 370 and for those not speaking English as their native language, a TOEFL score of 570.

A minimum combined GRE quantitative and analytical score of 1200.

An undergraduate GPA of 3.0/4.0 or better over the last 2 years or successful completion of 12 graduate hours in Computer Science as a Special Graduate Student at UMR, with at least a 3.0 GPA, as per graduate requirements.

Content of the following courses:

- Calculus I, II, and III
- Linear Algebra
- Statistics
- Pascal, C or C++
- Computer Organization
- Data Structures
- File Structures or Database
- Numerical Methods
- Discrete Mathematics
- Operating Systems

Ph.D. in Computer Science:

Application is made to the UMR admissions office along with the required transcripts, etc. Applicants who do not have a graduate degree will normally request admission to the M.S. program first. Applicants must submit a letter outlining tentative research interests and career goals along with GRE verbal, quantitative, and analytical test scores. The advanced subject area test in Computer Science is recommended. Admission to the Ph.D. program in computer science is granted by majority vote of the Computer Science Graduate Faculty and approval of the College Dean.

Program Requirements:

M.S. with Thesis: The M.S. degree with thesis requires the completion of 24 hours of graduate course work (a minimum of 6 at the 400 level), 6 hours of research, and the successful completion and defense of a research thesis.

M.S. without Thesis: The M.S. degree without thesis requires the completion of 30 hours of graduate course work (a minimum of 9 hours at the 400 level).

Ph.D. Program

Requirements for the Ph.D. in Computer Science include:

Qualifier exam over graduate-level courses in core areas.Research Readiness presentation based on survey of current Computer Science Literature. Comprehensive exam. Dissertation and Defense reporting the results of original research which meets the standards of current disciplinary journal-quality research publications

The Ph.D. program is under the guidance of an advisory committee which is appointed no later than the semester following passage of the qualifying exam.

Financial Assistance

Financial assistance is available to graduate students in the form of assistantships and fellowships.

Research opportunities for advanced students exist in the Department's Experimental Computation Laboratory and in the UMR Intelligent Systems Center as well as other research labs on campus.

Applicants for graduate assistantships must submit their score from a GRE advanced subject test. For applications forms, contact the graduate coordinator.

Additional Information: can be found by visiting the Department's web page at: http://www.cs.umr.edu or contact us at 573-341-4491 or at our email address: compsci@cs.umr.edu

Electrical Engineering

The mission of the Electrical Engineering Program, consistent with the School of Engineering and the UMR campus mission statements, is the education of students to fully prepare them to provide leadership in the recognition and solution of society's problems in the area of Electrical Engineering.

The Electrical Engineering program in the Department of Electrical and Computer Engineering offers graduate programs of study which lead to the M.S. degree (thesis and nonthesis options), the Ph.D. degree and the doctor of engineering degree. Both the Rolla campus and the Engineering Education Center in St. Louis offer M.S. programs. While your graduate program will be designed to meet your needs, all graduate programs normally include some specialization in one or more of the following six emphasis areas of electrical engineering.

Emphasis Areas

Circuits and electronics topics include network analysis and synthesis, computer-aided circuit design, distributed circuits, communications circuits and linear and nonlinear electronic circuits.

Communications and signal processing topics include signal design, coding, modulation, detection, and filtering for both analog and digital systems.

Computer Engineering can be an emphasis area in electrical engineering or a separate degree. See the section on Computer Engineering for emphasis areas in computer engineering.

Controls and Systems Engineering: Our technological demands today impose extremely challenging and widely varying control problems. These problems include control of aircraft, space and underwater vehicles,

automobiles, chemical processes, manufacturing, robotics, environmental systems, and smart structural systems. Control Systems Engineering studies will emphasize linear and nonlinears system, digital control, process control system simulation, optimal control and estimation, robust control, neural networks and fuzzy logic based control systems, and control of smart structures.

Electromagnetics, devices, and optics constitutes a single emphasis area in the electrical and computer engineering department. Electromagnetic topics include the generation, propagation, and detection of electromagnetic fields and waves. In addition to the intentional generation of electromagnetic waves, unintentional electromagnetic radiation can occur. This unintentional radiation often accompanies the operation of high-speed digital electronic circuits. Electromagnetic compatibility is concerned with the removal or reduction of these unintentional and undesirable effects. The devices portion of this area is concerned with modeling and development of new electronic components as well as the characterization and growth of semiconductor materials. Optical topics include applications of fiber optics, optical processing, optical computing, and smart sensing. Fiber optic telecommunications encompass waveguides, photonic sources and detectors, and modulation and control techniques. Smart sensing deals with physical measurements in structures using integral optical devices.

Power and machinery studies include application of computer methods to power system analysis and control, power system relaying and protection, power quality load management, finite inertia power systems (such as those on ships, hybrid electric vehicles, and spacecraft), and electromechanical energy conversion devices (such as rotating machinery, power electronic converters, and electric drive systems).

Departmental Facilities

In addition to the electrical engineering laboratories, there are machine shops and electronic shops, as well as digital computer facilities. More information can be found on our home page: http://www.ece.umr.edu

Departmental Requirements

Admission Requirements: Additional minimum departmental requirements beyond those stated in the section on Admission and Program Procedures of this catalog follows. For M.S. applicants, a B.S. degree in electrical engineering from an ABET accredited university or a closely related field like physics, an undergraduate cumulative GPA (or last two years) of 3.2/4.0 or equivalent, a GRE Quantitative score of 730, and a GRE Analytical score of 640. Applicants close to satisfying these requirements may be eligible for Special Graduate Student status or be required to take some undergraduate courses for no graduate credit. For students from international universities, equivalent degree and GPA as stated above, GRE scores as stated above, and a TOEFL score of 580 for students from countries where English is not the primary language. For Ph.D. applicants, the same as M.S. plus a M.S. degree in electrical engineering or a closely related field, GPA of 3.5/4.0, and three letters of recommendation. Exceptional B.S. applicants may apply directly for the Ph.D. program.

Program Requirements: Additional minimum departmental requirements beyond those stated in the section on Admission and Program Procedures of this catalog follows. M.S. with thesis programs require a minimum of 21 hours of course work. For M.S. with thesis and M.S. without thesis programs, 200 level out of departmental courses should be prerequisite for 300 level courses. For Ph.D. programs, approximately 90 hours beyond the B.S. or 60 hours beyond the M.S. are required.

Ph.D. Language Requirement: As an electrical engineering Ph.D. student, you are not required to satisfy a language requirement. However, you may have language requirements included in your plan of study if your advisory committee feels that this inclusion would be useful or necessary for your research.

Research: Significant research is expected for the M.S. thesis and Ph.D. dissertation as well as publication of the results. The student should work closely with the Major Advisor Committee to determine when these expectations are met. Length of research time and/or research credit hours will not automatically satisfy this requirement.

Engineering Management

Graduate programs leading to the M.S. and Ph.D. degrees are offered in Engineering Management.

The discipline involves designing, operating and continuously improving systems by integrating engineering and management knowledge. This integration starts with an awareness of customer needs and market conditions. It then seeks to optimize the use of people, equipment, money and information to achieve desired objectives. The discipline also seeks to develop students into individuals with leadership potential who can achieve high quality results in an ethical manner and with respect for the environment.

The major goal of entering students is to enhance the usefulness of their previously acquired technical background.This is accomplished through both classes and research designed to expand ones knowledge of the management and operation of organizations in today's competitive environment. This broader understanding is further enhanced with the opportunity to acquire specialized knowledge in many areas that exist in the interface between the classical engineering and management disciplines. These areas range from Management of Technology through Manufacturing and additional descriptive information is provided below.

Management of Technology focuses on the leadership and administrative aspects of modern techno-managerial enterprises and decision making in an organization. Manufacturing Engineering focuses on design, operation and improvement of Manufacturing and Packaging Systems. Industrial and Quality Engineering focuses on acquisition, analysis, and interpretation of data in support of decision making, optimization and continuous improvement of commercial and government systems.

Master of Science

The MS degree program is offered on the Rolla campus and as outreach programs at several locations including the UMR Engineering Education Center in St. Louis; at Fort Leonard Wood; and by video and/or internet throughout the United States and selected international locations.

The MS non-thesis program requires completion of at least 10 three-hour courses approved by the academic advisor. The M.S. with thesis option requires thirty credit hours including the thesis.

Most students begin their engineering management course work with management for engineers and conclude with a capstone course at the advanced level. A graduate student already holding or completing a masters degree may obtain a second MS in Engineering Management by completing at least an additional 24 credits of work.

Doctor of Philosophy

A candidate for the Ph.D. in engineering management, must complete the equivalent of at least three years of full-time work beyond the bachelor's degree. The content of all Ph.D. programs is individually structured by the student in consultation with and approved by the students advisory committee.

All requirements for the degree must normally be completed within an eight-year period. Each candidate must spend at least two sequential semesters in full-time residence at UM-Rolla.

At appropriate points in their program, Ph.D. students must pass a qualifying examination, a comprehensive examination, and a defense of dissertation.

Some recent Ph.D. dissertation titles are:

- Artificial Vision: Three Dimensional Object Recognition using Neural Networks,
- Cost Management for Building Design and Engineering in Japan,
- New product Development Process for the Microelectro Mechanical Systems Industry: an Exploratory Study,
- Robust Parameter Design of Precision Injection Molding,

Typical Courses or Specialization Areas

Management of Technology

- Advanced Personnel Management
- Management for Engineers
- Technical Entrepreneurship
- Legal Environment
- Engineering Cost Accounting
- Industrial Marketing System Analysis
- Project Management
- Case Studies in General Management
- Advanced Marketing Management
- Advanced Finance Management
- Management Information Systems
- Technological Innovation Management
- Managerial Decision Making

Industrial Engineering–E MGT 311-Human Factors

- Methods of Industrial Engineering
- Work Design
- Business Logistics Systems Analysis
- Advanced Facilities Planning and Design
- Advanced Engineering Economy
- Industrial System Simulation
- Mathematical Programming
- Industrial Queuing Theory
- Smart Engineering System Design
- Safety Engineering Management
- Systems Eng. Analysis I & II
- Systems Architecturing
- Smart Engineering Systems Design
- Human Factors

Manufacturing Engineering

- Computer Integrated Manufacturing Systems (CIM)
- Production Planning – Scheduling
- Interdisciplinary Problems in Manufacturing Automation
- Advanced Manufacturing through Neural Networks
- Expert Systems in Manufacturing and Engineering
- Introduction to Neural Networks and Applications
- Advanced Manufacturing Systems Integration
- Advanced Production Management
- Value Analysis
- Industrial Ecology
- Integrated Process Development

Other courses of study are available. Such as Systems Engineering, Quality Engineering, Packaging and Information System

Criteria for Admission

Admission is limited to applicants with a B.S. degree in engineering, certain physical sciences, mathematics, or computer science and a superior academic record. Applicants are required to submit the Graduate Record Examination (GRE) scores for admission evaluation. Applicants whose native language is not English are also required to take the Test of English as a Foreign Language (TOEFL). Evidence of skill in computer programming and engineering statistics is required; if lacking, these may be satisfied without graduate credit thru courses at UM-Rolla or elsewhere.

Departmental Laboratories

The department has sevaral "hands on" type laboratories. Additional information, including a live view of the Integrated Systems Facility, can be obtained from the department's web page at www.umr.edu/~emgt and clicking on the "EMGT Labs" link. Each of these labs is directed by faculty that works closely with students to enhance their learning experience. The description below gives a brief introduction that will help you understand the purpose of each lab.

Integrated Systems Facility (ISF)

The Integrated Systems Facility in the Engineering Management Department (http://www.umr.edu/~isf) is a state-of-the-art 5000 square foot facility housing seven workcells with over $1,000,000 worth of modern manufacturing equipment. The facility aims to provide an excellent foundation for undergraduate and graduate level courses, MS and PhD theses, and research. ISF provides a strong educational background in the areas of manufacturing processes, computer aided design and manufacturing (CAD/CAM), quality assurance and control, process planning, scheduling, packaging, shop floor control, automation in manufacturing, computer integrated manufacturing, and flexible manufacturing systems.

Automation and integration in manufacturing is the major focus of research at the Integrated Systems Facility. In that scope, ISF deals with a wide spectrum of research from process planning to shop floor control and deepens the understanding of processes and systems in today's complex manufacturing environment. The research carried out at the Integrated System Facility is anticipated to make both the local and state-manufacturing base more competitive by increasing the rate of innovation and responsiveness to changing needs.

ISF also provides technical service and technological support to industry at local and state levels. In addition, ISF plays an important role in the distance education programs of the university.

Smart Engineering Systems Lab (SESL)

Engineering Systems of the next century need to be autonomous to meet the challenge of flexibility and customized design requirements imposed on manufacturing and service systems by the global economy. The research focus of the Smart Engineering Systems Lab (SESL) (http://www.umr.edu/~sesl) is to build "smart" components for engineering systems currently available today. The term "smart" in this context indicates physical systems that can interact with their environment and adapt to changes both in space and time by their ability to manipulate the environment through self-awareness and perceived models of the world based on both quantitative and qualitative information. The emerging technologies of artificial neural networks, fuzzy logic, evolutionary programming, chaos, wavelets, fractals, complex systems, and virtual reality provide essential tools for designing such systems.

The focus of the SESL can be achieved by developing smart engineering architectures that integrate and/or enhance the current and future technologies necessary for developing smart engineering systems while illustrating the real life application of these architectures. The smart engineering system design and operations cut across a diversity of disciplines, namely: Manufacturing, Electrical, Computer, Mechanical, Bio-Medical, Civil and other related fields such as Applied Mathematics, Cognitive Sciences, Biology, and Medicine. Current research topics inlcude, adaptive global stock management, data mining, artificial life, internet-based pattern recognition, adaptive assessment of System Engineering practicies, autonomous continuous assessment of railway bridge safety. Capabilities of the computational intelligence models developed are often demonstrated physically in the lab through mini autonomous research robots.

Sustainable Design Lab (SDL)

The Sustainable Design lab (SDL) in the Engineering Management Department (http://www.umr.edu/~sdl) has been established under National Science Foundation and industry grants. The mission of the SDL is to establish a state-of-the-art research and teaching facility for advancing technologies enabling rapid and sustainable product realization. The research and teaching topics pursued at SDL include the following: Environmentally Conscious Design and manufacturing, Life Cycle Engineering, Integrated product/process design, CAD/CAM, Reverse Engineering, design automation, concurrent and collaborative engineering, Design for Assembly and Manufacture (DFMA), Supply chain management, and Value analysis.

Design Engineering Center

The center is the outreach arm of the Engineering Management Department. The focus is on research and service activities in support of the educational goals of the department through externally funded projects.

Current areas of research include Total Quality Management, concurrent Engineering, Taguchi Methods, the Design Process Modeling, Design Optimization.

Engineering Mechanics

The basic prerequisite for admission to graduate study in the Engineering Mechanics program in the Mechanical and Aerospace Engineering and Engineering Mechanics Department is the bachelor of science degree in an engineering discipline which provides an adequate background in engineering mechanics. Applicants lacking this background will be required to take such courses as are necessary to correct these deficiencies. It is recommended that prospective graduate students in engineering mechanics carry their mathematics preparation somewhat further than is required for most other master of science or doctoral programs in engineering.

The Engineering Mechanics program offers the master of science and the doctor of philosophy degrees. The master of science thesis program, which is required for all on-campus students, consists of a minimum of 30 semester hours, normally including 24 hours of course work with 12 hours from the engineering mechanics core curriculum and at least a total of six hours of mathematics/computer science. At least six credit hours of 400 level course work, exclusive of research, must be from the Engineering Mechanics courses.

The engineering mechanics core curriculum consists of four areas: Continuum Mechanics, Solid/Fluid Mechanics, Dynamics/Vibrations, and Mathematics/Computer Science. If you desire the master of science degree, you must take at least three hours in each of the four areas.

The master of science nonthesis program, available to off-campus students only, consists of a minimum of 33 semester hours, including 12 hours from the core curriculum, and at least six hours in mathematics and/or computer science, including the three hours taken to satisfy the core curriculum requirements. At least nine hours of course work with a minimum of six hours from engineering mechanics/mechanical engineering/aerospace engineering courses must be at the 400 level. After successful completion of the course work or during the final semester of studies, a written comprehensive examination from three out of the four areas of the core curriculum must be passed. Examination in at least one of the four areas must be from a 400-level course.

A student pursuing the doctor of philosophy degree normally follows a program of 90 credit hours of course work beyond the B.S. degree or 60 credit hours of course work beyond the M.S. degree. For those with the M.S. degree, the 60 hours will consist of 36 credit hours of course work and 24 credit hours of thesis research. A minimum of 24 semester hours of course work must be Engineering Mechanics with at least one three-hour course from each of the following areas: Dynamics and Vibrations, Fluid Mechanics, Solid Mechanics, Materials Engineering, Experimental Mechanics, and Computational Mechanics. A minimum of 12 credit hours of mathematics/Computer Science and a minimum of 12 credit hours in a minor field outside, but pertinent to, the major field of study must be taken. At least 9 credit hours of course work, exclusive of research, must be at the 400-level in the major field of study. In addition to these course requirements, you must prepare a dissertation based on analytical and/or experimental research in your major area. This research must be equivalent to a minimum of 24 semester credit hours.

There are no foreign language requirements for the master of science or for the doctor of philosophy degrees. However, a reading knowledge of one foreign language may be required for the Ph.D. degree if your advisory committee feels that it is necessary.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The qualifying exam consists of taking a minimum of nine credit hours of approved graduate course work at the 300- and 400-level, including six hours in the major field, of which three must be at the 400-level and three hours of mathematics or computer science. To pass the qualifying exam, a student must have obtained a grade of B or better for all the courses with a GPA of at least 3.25.

The comprehensive examination and the final examination, consisting of the dissertation defense, are conducted according to the rules of the Graduate Faculty, the School of Engineering, and the department. The Graduate Faculty has a residency requirement, which must be satisfied by all doctoral students.

The Engineering Mechanics program offers graduate studies in a number of widely pursued areas including elasticity, plasticity, experimental stress analysis, vibrations, shock wave propagation, structural dynamics, composite materials, and computational mechanics. Some staff members are associated with the Rock Mechanics and Explosive Research Center, and the Graduate Center for Materials Research. Some others work in the interdisciplinary areas bridging with the mechanical and aerospace engineering fields. You may participate in the solution of technical problems found in those areas.

Members of the faculty and their graduate students are currently conducting research in most of the areas listed above. Some examples of current research are: minimization problems for constrained media, viscoelastic deformations of rubber rollers, adiabatic shear banding, penetration mechanics, cyclic delamination growth in fibrous laminated composites, failure analysis of metal and ceramic matrix composites, analysis of laminated composite plates and shells, crack propagation in elastic/plastic plates, cavitation, strain measurements by Moire interferometry, combined experimental/analytical modeling of dynamic structures, neuromuscular control of robots, and human body kinematics.

Most of the offices, classrooms, and laboratories are housed in the Mechanical Engineering complex. Four main laboratories are for vibration analysis, materials testing, experimental stress analysis, and composite materials fabrication and testing. The laboratories are well equipped with state-of-the-art machines, and are used for both research and instruction. Also, facilities listed in the Mechanical and Aerospace Engineering program, and those housed in the Rock Mechanics and Explosive Research Center and the Graduate Center for Materials Research are available to Engineering Mechanics graduate students.

English

The Department of English has entered into a cooperative agreement with the Department of English of the University of Missouri – St. Louis to offer the Master of Arts in English. A maximum of 12 graduate semester hours may be taken at UMR (with no more than 9 credit hours at the 300 level).

The program provides an avenue for place-bound secondary teachers, traditional and non-traditional UMR students, and other qualified residents of South Central Missouri to pursue advanced work whether for career advancement or for personal and lifelong learning and enrichment. The program is also designed to help a select group of incoming freshman to complete their bachelor's and Master's degrees in five years; for more information, contact the Honor Academy (Master Student Fellowship Program).

Candidates for the M.A. in English must meet the admission requirements of both the Graduate Schools and of the Department of English at UMR and UMSL. Candidates must have a bachelor's degree, with at least 24 hours in English above the freshman level, 12 in literature courses. Normally only students with a grade point average of at least 3.0 in undergraduate English courses and an overall average of 2.75 will be considered. Applicants must submit scores for the Graduate Record Examination.

In general, students scoring below the 65th percentile on the verbal examination will not be accepted

into the program. Students may retake the examination to improve their scores. In addition, the Departments require letters of recommendation from two English professors with whom the student has worked. The letters, the undergraduate record, and the Graduate record Examination scores will be the basis for the admission decision. Students must submit fiction or poetry in application for the creative writing track. Three emphasis areas are available-literature, composition, and creative writing.

Applications are strongly encouraged by 1 May for fall semester and for the summer session, and 1 December for the winter semester. Late applicants will be considered but cannot be assured of admission. For more information, contact the Department of English.

Environmental Engineering

The Civil Engineering Department offers three environmental degree options: the M.S. in Environmental Engineering (MSEnvE), M.S. in Civil Engineering (MSCE) with an environmental emphasis, and the Ph.D. (Environmental emphasis). The Environmental Engineering Program' curriculum prepares graduates to provide leadership in their careers as environmental professionals by providing a strong foundation in the fundamental and applied chemical, biological, physical and engineering principles of environmental engineering. The Environmental Engineering Program faculty have backgrounds primarily in Civil, Environmental, and Chemical Engineering. To enter the graduate program, applicants should hold a B.S. degree in an engineering discipline from an ABET accredited school or equivalent. Those who hold a non-engineering degree, may be required to complete prerequisite courses in mathematics, chemistry, fluid mechanics, hydraulics, engineering mechanics, mechanics of materials, and/or engineering economics.

The program includes strong design and research components. The curriculum is tailored to the individual while providing all students with a strong foundation in environmental engineering principles. Current research emphasis areas of the environmental engineering faculty include fundamental and applied aspects of: 1) in situ and exsitu groundwater and soil remediation; 2) industrial and hazardous wastes treatment technology development; 3) biological wastewater treatment; 4) drinking water treatment; 5) phytoremediation; and 6) air pollution assessment and control.

Graduate and undergraduate research is conducted primarily in the Environmental Research Center (ERC) located in the Engineering Research Laboratory. The environmental engineering laboratories used for teaching and research total more than 6,500 square feet. The ERC provides state-of-the-art instruments (e.g., GC, HPLC, AA, TOC, spectrophotometers, respirometers, etc.) and facilities. Additionally, excellent computing facilities are available to students in the research labs and computing centers. The environmental instrumentation in the ERC is complemented by a broad range of specialized instruments available through the Environmental Trace Substances Laboratory, a Division of the Center for Environmental Science and Technology (CEST). Faculty in the Environmental Engineering Program in Civil Engineering collaborate extensively with faculty and researchers in other departments at UM-Rolla and elsewhere.

Geological and Petroleum Engineering

Geological Engineering

Geological engineering is the application of the knowledge and principles of geology to the solution of problems in engineering practice. These applications include the evaluation of geological conditions for environmental protection studies, for groundwater resource and pollution investigations, for mineral and energy development, for site selection of civil works facilities and for land use and environmental impact analysis.

The geological engineering laboratories are well equipped for research relating to physical and hydraulic properties of rock, groundwater hydrology, remote sensing, and geographic information systems. Computer applications are emphasized, and the department has a laboratory equipped with a variety of personal computer equipment for student use. A groundwater hydrology laboratory is equipped to conduct research in subsurface fluid flow and computer facilities are available for the modeling of flow through porous media.

The geotechnical laboratory houses equipment to conduct basic soil and rock testing, including shear and compressive strength, durability, consolidation, permeability, and basic physical properties. Field equipment is available to conduct strength and permeability testing, advance shallow exploratory boreholes, measure water levels and water quality parameters.

Recent research projects utilizing this laboratory have evaluated slope stability and novel slope stabilization methods, measured the long-terms effects of weathering on rock strength and durability, and assessed sliding shear strength of dam foundations.

The department maintains a computer learning center and Geographic Information Systems Laboratory with Pentium PCs, a Sun Workstation and a variety of peripheral devices such as scanners, digitizers, and printers. ERDAS, IDRIS, Autocad Map and World, Arc View, and other software packages are available for instruction and research. Applications of GIS and Remote Sensing Technology which are stressed include site characterization and selection, geologic hazards mapping and terrain analysis.

Petroleum Engineering

Petroleum engineering specializes in drilling analysis, formation evaluation, production optimization, reservoir mechanics, oil recovery methods, computer applications, and the mathematical modeling of petroleum reservoirs, and drilling systems.

The petroleum engineering laboratories contain modern equipment designed to study the many problems encountered in oil and gas production. These problems include: determination and interrelation of chemical and physical properties of petroleum and petroleum

products, analysis of oil well cores and interpretation of core analysis, determination of physical properties of reservoir fluids, measurement of fluid flows, and formulation of specialized drilling fluids.

Laboratory facilities are available for research in oil recovery. A modern computer laboratory is used for both class work and research.

Geology and Geophysics

Graduate work in geology and geophysics is offered at both the master of science and doctoral levels. Programs are designed to provide you with an understanding of the fundamentals and principles of geology, geochemistry, and geophysics. Research investigations comprise a significant part of each program, and at the doctoral level an original contribution to the science is required.

The department offers a single program and degree in geology and geophysics. The department also offers five emphasis areas 1) geology, 2) geochemistry, 3) geophysics, and 4) groundwater environmental geology, and 5) petroleum geology.

In geology and geochemistry, opportunities for research at both the M.S. and Ph.D. levels are available in mining geology, petroleum geology, stratigraphy and sedimentation, geochemistry, clay mineralogy, ore microscopy, process mineralogy, structural geology, igneous and metamorphic petrology, and volcanology.

In geophysics, opportunities for research at both the M.S. and Ph.D. levels are available in the areas of reflection seismology, theoretical seismology, geophysical data analysis, gravity, magnetics, and the theory and practice of electrical methods of measuring the response of the earth to applied electrical and magnetic fields.

The study of the earth and other planets includes all areas of scientific inquiry. To work effectively in so broad a discipline requires considerable depth and breadth of understanding of physical principles and advanced proficiency in mathematics, particularly for those students contemplating advanced studies in geophysics. A thorough undergraduate training in an earth or physical science is ordinarily regarded as necessary prerequisite for advanced study in geology or geophysics.

Earth sciences have been an integral part of the university since its founding. The department has a long and proud history of faculty and students who have contributed to the advancement of the science and to mineral exploration. The university was formerly the University of Missouri School of Mines and Metallurgy. Because of the school's tradition and location near the Missouri Lead District the emphasis of the department has been in hard rock exploration. While still maintaining its traditional role in hard rock mining, the department has expanded to include geochemistry, geophysics, and soft rock geology. Our graduates find employment in both the mining and petroleum industries. It is our intention to provide the student with a sufficiently diverse and complete education that he or she may seek employment in any area of the earth sciences.

The department has a wide variety of equipment for research and exploration in geology, geochemistry, and geophysics. In addition to the facilities of the department, the Missouri State Geological Survey, and the U.S. Geological Survey's mid-continent mapping division are also located in Rolla. Cooperative research with other departments within the university or other campuses of the University of Missouri may be undertaken by our faculty and graduate students. For example, students interested in remote sensing may work with the departments of geological engineering or electrical engineering, both of which have image processing systems. Interaction with mining engineering, metallurgy, and various other departments is routine. Cooperative programs are also undertaken with local mining companies, petroleum companies, or other industries using the skills and techniques of the earth scientist. Thus, your research interests need not fall entirely within the interests of our faculty or within the bounds of the equipment directly available within the department.

Although degree level is not a requirement for professional practice in geology or geophysics, the B.S. should usually be considered a preparatory, the M.S. should be considered the professional degree, and the Ph.D. should be sought by candidates interested in a career in teaching or research. The M.S. degree is granted with the thesis option only. A qualifying examination is required of all Ph.D. students within the first semester of residency or, preferably, prior to registration. For students whose native language is not English, a minimum score of 550 on the standard Test of English as a Foreign Language is generally required for admission.

History

The department of History has entered into a cooperative agreement with the Department of History of the University of Missouri – St. Louis to offer a Master of Arts in History. A maximum of 12 graduate semester hours may be taken at UMR (with no more than 9 credit hours at the 300 level).

Manufacturing Engineering

The UMR Manufacturing Engineering Education Program offers the interdisciplinary Master of Science (MS) and Master of Engineering (MEng) degrees on campus. Both degree programs are intended for a student with a BS degree in engineering to learn about modern manufacturing technologies involving computers and automation.

The MS program is a research-oriented degree where the courses supplement the thesis research. The MEng program is designed such that the course selection is flexible and the student is allowed to take courses pertaining to his or her area of interest. A practice-orientated project is required by Meng program, which provides an opportunity for the student to participate in a practical project related to a manufacturing process. The MEng program is structured so that individuals,

such as working engineers, who wish to improve their knowledge and skills can complete their degree in one year.

The basic admission requirements include 1) B.S. degree in engineering; and 2) Ranked in upper third of undergraduate class OR a GPA greater than 3.0/4.0. GRE and TOEFL over 550 are required for international students. The MS program requires 30 credit hours and a thesis: 12 credit hours from the Manufacturing Core Areas; 6 credit hours of 400 level courses in manufacturing; 3 credit hours of approved Mathematics or Computer Science, 6 credit hours for thesis research, and 3 credit hours of graduate courses in manufacturing. The MEng Program requires 30 credit hours and a practice – oriented project. The course requirement include 12 credit hours from the Manufacturing Core Areas, 6 credit hours of 400 level courses in manufacturing; 3 credit hours of approved Mathematics or Computer Science, 3 credit hours for work related to the practice oriented project, and 6 credit hours of graduate courses in manufacturing. The practice orientated project is defined by the student and academic advisor. At the end of the project experience the student should demonstrate not only the proficiency of operating certain manufacturing processes, but also the capability to improve the process. At the end of the MEng program, a presentation and a report documenting the practice oriented projects are required. For both programs, at most 6 credit hours of two hundred level classes can be completed in the degree.

For both programs, each student must take at least one course from each of the core areas in manufacturing engineering during his or her first two semesters of graduate work. The core requirements may be deemed satisfied if a student has already taken a core course as a technical elective in his or her undergraduate program, thus allowing more freedom in the selection of other courses. The related courses in Manufacturing Core Areas are selected and offered from various departments. The Manufacturing Core Areas include:

- Materials and Manufacturing Processes
- Process, Assembly and Product Engineering
- Manufacturing Competitiveness
- Manufacturing System Design

The Graduate committee for each student in the interdisciplinary degree program will consist of three faculty of which at least two must be from the Manufacturing Education Committee (MEC). The major advisor should also be a member of the Manufacturing Education Committee. MEC is formed by over 40 faculty members from various departments, such as Basic Engineering, Ceramic Engineering, Chemical Engineering, Computer Science, Electrical and Computer Engineering, Engineering Management, Mechanical and Aerospace Engineering and Engineering Mechanics, Metallurgical Engineering, and Mining Engineering. For details regarding the application, curriculum, courses in Manufacturing Core Areas, and MEC faculty, you may also wish to explore the program's web page at:

http://www.umr.edu/~mgfe/

Some examples of research areas in which you can specialize include:

- Design for Manufacturing/Assembly
- CAD/CAM/CIM
- Product/Process Development
- Manufacturing Management
- Manufacturing Processes
- Manufacturing Materials
- Lean Manufacturing
- Rapid Product Realization
- Programmable Controllers
- Assembly & Automation
- Manufacturing Plant Layout
- Jig, Fixture & Tool Design
- CNC machining
- Environmentally Friendly Manufacturing
- Product Quality Control

This is a truly interdisciplinary program, which will provide you with a variety of options in manufacturing. The existing laboratories which can be used in this proposed program include Computer Integrated Manufacturing Lab (CIM lab), Agile Manufacturing and Automated Inspection Lab (AMAIL), Rapid Prototyping Lab, Laser Aided Manufacturing Processes (LAMP) Lab, Augmented Reality Lab, High Pressure Waterjet Lab, Sustainable Design Lab, Laser Welding Lab, Composite Manufacturing Lab, Computer Vision Lab, Lab for Industrial Automation and Flexible Machining, Automated PC Board Milling Machine, Foundry to Melt and Cast Ferrous and Non-ferrous Alloys, Intelligent Control of Machining Lab, Digital Image and Signal Processing Lab, and the Lemay Center of Composite Technologies (in St. Louis).

Mathematics and Statistics

The Department of Mathematics and Statistics offers programs leading to the M.S. in applied mathematics, either with or without a thesis, the Master of Science for Teachers degree, and the Ph.D. in mathematics. The M.S. is recommended, but not required as a prerequisite for the Ph.D. If you intend to pursue the doctorate without obtaining a master's degree, 32 hours of graduate credit are required before you may register as a doctoral candidate. These hours should be selected so that you will have obtained an introduction to modern and linear algebra, analysis, statistics and topology by the end of your first year of graduate study.

The program for the M.S. degree without a thesis must include at least 33 hours of graduate credit, nine hours of which must be lecture courses at the 400-level. For the M.S. degree with thesis, the program must include at least 30 hours of graduate credit, at least six hours of which must be lecture courses at the 400-level and six or more hours of which must be Graduate Research, MATH or STAT 490. Candidates in a non-thesis program must pass a final comprehensive examination while candidates in a thesis must successful pass an oral thesis defense. All M.S. candidates are encouraged to include in their program courses in engineering and science, which are closely related to their research in mathematics or statistics. For those intending to terminate study at the M.S. level, specialization's supporting specific career goals are possible.

The Master of Science for Teachers program is primarily designed for secondary school teachers in the physical sciences and mathematics. The program of study must include at least 32 hours of courses numbered above 200 in science and mathematics, three hours of which must be at the 400-level. Candidates must pass a final comprehensive examination.

A program for the Ph.D. degree includes about 30 hours of breadth in graduate level mathematics and statistics, about 30 hours of courses in or outside of the department representing a field of specialization, and about 30 hours devoted to the dissertation. The specific program for a candidate is designed jointly by the candidate and the candidate's advisory committee. A qualifying examination, usually taken soon after completion of the M.S. degree or equivalent course work, is required. A reading knowledge of one modern foreign language, typically either French, German, or Russian, is required. At times approved by the advisory committee, candidates must pass both written and oral comprehensive examinations. These examinations may cover courses outside the department. The dissertation is expected to represent original research and to meet the standard ordinarily required for publication in one of the journals devoted to reporting research in the selected field.

Fellowships and graduate assistantships are available to well qualified applicants. Detailed information about these opportunities may be obtained from the department chair or the director of the graduate studies. Additional information is available electronically at:

www.umr.edu/~mathstat/

The department faculty and graduate students along with graduate instruction and research activities are housed in the newly renovated Rolla Building. The Rolla Building, erected 1871, was the original home of the University of Missouri School of Mines and Metallurgy.

Mechanical Engineering

The Mechanical Engineering Program in the Mechanical and Aerospace Engineering and Engineering Mechanics Department offers comprehensive graduate education in a number of areas. The principal areas include: energy conversion and utilization, heat and mass transfer, heat transfer in manufacturing and materials processing, compressible fluid mechanics, computer-aided design and manufacturing, manufacturing processes, and systems robotics, design and control of mechanical systems, acoustics, static's and dynamics of structures, and vibrations. A great variety of interdisciplinary programs meeting specific objectives are available. The Mechanical Engineering Program offers the following degrees: master of science, doctor of philosophy, and doctor of engineering in mechanical engineering.

The master of science thesis program, which is required by the department of on-campus students, consists of a minimum of 30 semester hours, normally including 24 hours of course work with nine hours from mechanical engineering core curriculum and at least a total of six hours in mathematics and/or computer science. At least six credit hours of 400-level course work must be from the mechanical engineering courses. In addition, a thesis from research equivalent to at least six credit hours in your major area must be prepared. A master of science nonthesis program is available to part-time students who are enrolled in the UMR Engineering Education Center in St. Louis. The nonthesis program consists of a minimum of 33 semester hours, normally including 15 hours of course work in a major area and six hours in mathematics and/or computer science, of which 12 hours must be from the mechanical engineering core curriculum. At least nine hours of course work with a minimum of six hours from mechanical engineering/aerospace engineering/ engineering mechanics courses must be at the 400 level. A written comprehensive examination from three out of four areas must be passed. Examination in at least one of the four areas must be from a 400-level course. This program is restricted to part-time students who are enrolled in the UMR Engineering Education Center in St. Louis.

The research areas listed previously are grouped into three core areas mechanics and system design, fluid mechanics, and thermal science.

A candidate for the degree of doctor of engineering must complete the equivalent of three years (six semesters) of full-time work beyond the bachelors's degree for a total of at least 90 hours. The six semesters must include a minimum of two semesters in residence at Rolla with a graduate registration of at least 12 hours per semester. At least two semesters above the M.S. must be in residence at Rolla with a registration of at least six hours per semester. The course work must be directed toward two major engineering areas plus one area from the physical sciences, mathematics, or another field of engineering. In addition, a nontechnical group of courses of nine to 12 hours is required. The formal course work is expected to consist of at least 65 hours (the average is 72 hours). In addition to the formal course work, the candidate is expected to complete an internship with an industrial organization. This internship will consist of a minimum of one year of planned and approved high-level engineering experience. At the end of the internship period, the candidate will prepare a dissertation which will earn from 18 to 25 hours credit and will be included in the total of 90 hours for the degree of doctor of engineering.

A student pursuing the doctor of philosophy degree normally follows a program of 90 credit hours of course work beyond the B.S. or 60 credit hours beyond the M.S. degree. For those with M.S. degree, the 60 hours will consist of 36 credit hours of course work and 24 hours of thesis research. The Ph.D. course work must satisfy the departmental core course requirements for the M.S. degree. For the 36 credit hours of course work, fifteen credit hours must be taken outside the department including at least 12 hours of mathematics and/or computer science. A minimum of 15 credit hours of approved course work must be completed within the department. At least 9 credit hours of course work must be at the 400-level in the major field of study. In addition to these course requirements, a candidate must prepare a dissertation based on analytical and/or experimental

research in a major area. This research must be equivalent to a minimum of 24 credit hours beyond the M.S. degree.

There are no foreign language requirements for the master of science degree, the doctor of engineering degree, and the doctor of philosophy degree in mechanical engineering. However, a reading knowledge of one foreign language, either German, French, or Russian, may be required for the doctor of philosophy degree if the candidate's advisory committee feels that it is necessary.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The qualifying exam consists of taking a minimum of nine credit hours of approved graduate course work at the 300- and 400-level, including six hours in the major field, of which three must be at the 400-level, and three hours of mathematics or computer science. To pass the qualifying exam, a student must have obtained a grade of B or better for all the courses with a GPA of at least 3.25.

The comprehensive examination and the final examination, consisting of the dissertation defense, are conducted according to the rules of the Graduate Faculty, School of Engineering, and the department. The Graduate Faculty has residency requirements which must be satisfied by all doctoral students.

Typical examples of research activities are:

Design and evaluation of acoustic silencers, structural acoustics, aeroacoustics, automotive driveline torsional and bending vibrations, active and passive vibration control, optimization of systems based on structural dynamics or structural performance, kinematics of flexible mechanisms, development of an efficient computer code for structural dynamic analysis, mechanical and thermal stress analysis, elastohydrodynamic lubrication under starved conditions, kinematics of robotic manipulators, and dynamic analysis of the shimmy of airplane landing gears.

Film and nucleate boiling for various surface geometrics over a wide pressure range, thermal contact resistance of bare and bonded interfaces, combined forced and free convective heat transfer, wave and thermal instability, nongray rediative heat transfer in emitting and absorbing media, experimental determination of optimum fin spacing for heat exchangers, coupled heat transfer and mass transfer, condensation, heat transfer in separated flows, heat transfer in metal casting, solidification and welding, heat transfer in porous media, energy requirements of HVAC systems, and simulation of the thermal systems for HVAC.

Heat and mass transfer through air curtains; adaptability of using wood waste as an energy source; engine and fuel research with emphasis on how fuel system variables influence combustion; simulation and measurements of thermal stratification in water reservoir; multidimensional radiative heat transfer; laser interaction problems; measuring the monochromatic extinction coefficient for liquids; single and multiple component heat pipe; simulation of flat plate solar collector; and solar heating and cooling of residential buildings.

Stability of boundary layer-type flow and laminar flow in ducts, free turbulent mixing, computer simulations of separated flows, transport phenomena in environmental systems, aerodynamics applied to wind power generation, viscous effects in transonic flows, two-dimensional scattering in liquids, development of cloud nuclei counters, flame stability in combustion systems, Navier-Stokes simulation of swirling, recirculating flows, jet interaction with a cross flow, development of computer systems and sofware of improving performance of manufacturing systems.

The Mechanical and Aerospace Engineering and Engineering Mechanics complex has many well-equipped laboratories for the Mechanical Engineering Program that are located in the Mechanical Engineering Building and the M.E. Annex on the main campus; and a subsonic-flow laboratory in an off-campus facility. Some of the specially equipped laboratories in the main campus facility include the robotics, computer-aided design, and Computer Numerical Controlled Machine laboratories, a supersonic-flow laboratory with a Mach 4 blow-down wind tunnel, a boiling heat transfer laboratory, a thermal radiation analysis laboratory, a thermal physical properties laboratory, a convective heat transfer laboratory equipped with a differential interferometer, a laser doppler velocimeter, and a hot-wire anemometer system, a lubrication laboratory, and airflow test facility, a solidification and melting laboratory, a laser welding laboratory, and acoustics and vibration laboratory, and extensive computer facilities including a personal computer laboratory, advanced computer graphics laboratory, computer learning center with engineering work stations, and an HP-1000 system for manufacturing and control system studies. Facilities for evaluating fuel and vehicle propulsion systems include engine dynamometers, single and multiple cylinder test engines, emissions measuring instruments, combustion diagnostic system, and chromatographic analysis instrumentation

Metallurgical Engineering

Because of the broad interests of the metallurgical engineering faculty members, the department offers an unusually wide choice of specialization's. These include: physical and mechanical metallurgy, extractive metallurgy, manufacturing metallurgy, and minerals processing. Opportunities also are available for study and research in other specialties and interdisciplinary areas because of research collaborations between faculty in metallurgy and in other engineering and science disciplines.

The principal research interests of the faculty include thermodynamics and kinetics of pyrometallurgical and elctrometallurgical processes; metals casting, joining and forming; metal deposition; high temperature and intermetallic compounds; powder metallurgy; plasma spray; environmental aspects of metal manufacturing; and treatment of metals industry wastes.

Recognizing the educational value of research, the metallurgical engineering faculty requires all M.S. de-

gree candidate to complete a thesis program. Exceptions may be granted in special circumstances.

The department does not have a foreign language requirement for the Ph.D. degree, but candidates must display effective communication skills. These skills will be scrutinized in course work, the qualifying exam, and in the writing and presentation of the dissertation thesis.

McNutt Hall houses most of the offices, classrooms, and laboratories of the department. This structure provides the department with spacious modern housing for both instruction and research. Additional facilities are located in Fulton Hall and the Materials Research Center (MRC).

The UMR electron microscope laboratory is part of the department's facilities and is equipped for both transmission and scanning electron microscopy including energy-dispersive X-ray analysis.

The department foundry has research facilities for green sand casting, centrifugal casting, lost foam casting, and permanent mold casting, together with a variety of metal joining processes.

Other special graduate research equipment includes crystal preparation, characterization, and sectioning equipment; image analysis systems; heat treating; atomic absorption and XRF spectrophotoemters; equipment for hydro and electrometallurgical processing; equipment for most deformation techniques; and for studies of deformation textures. Students of the department also have access to the extensive research equipment in MRC and the Center for Pyrometallurgy, which is housed in Fulton Hall.

The MRC provides electron microscopy facilities, together with extensive capabilities with respect to materials coatings, preparation and analysis. Fulton Hall has both laboratory and pilot plan facilities for pyrometallurgy including an analytical laboratory; apparatus for studying mixing in reactors; a vacuum induction furnace; a plasma smelting furnace; plasma flame spraying unit; and a metal atomizing pilot plant.

The department has good computing facilities with PCs and Macintosh machines, scanning, laser and color printing and network access. A Metallurgical Engineering home page is available at:

http://www.umr.edu/~meteng

Mining Engineering

Mining engineering includes the areas of mining methods, mine planning, rock mechanics, explosives, mine systems analysis, mine plant, mine operations, mine ventilation, coal preparation, and mining economics. The department requires you to complete at least one course in rock mechanics and one course in mathematics beyond calculus.

It is the prerogative of the Advisory Committee to set the foreign language requirement for the Ph.D. for foreign students, English is acceptable if not the mother tongue; for others French, German, Russian, or Spanish will be required as part of the program.

The mining engineering laboratories are equipped for accurately and conveniently conducting graduate-level research. They are located in McNutt Hall on campus, the Rock Mechanics and Explosives Research Center and at the Experimental Mine, the latter facilities are on university property a short distance southwest of the campus. The practical aspects of mining engineering are an integral part of the overall instruction leading to the proper design of underground and open pit mine operations. The coal preparation laboratory is equipped laboratory is equipped to investigate the physical and chemical properties of coal for their effects on mining methods, preparation characteristics, and valuations. A mine ventilation laboratory provides facilities for detailed studies of air-flow and distribution. The rock mechanics laboratory offers modern facilities for the mechanical testing of rocks by universal testing machines, direct shear apparatus, and various nondestructive techniques. A large centrifuge enables model studies. The use of sophisticated rock mechanics computer models are also available.

The experimental mine has more than 1,500 linear feet of horizontal underground passages with an adit and four vertical shafts. Adjacent to it are two quarries. The mine plant has power, compressed air, water supply, trackage, and all other mining equipment necessary for a research project. A high capacity fan provides air for the mine during its operation and actual underground mine conditions for air-flow studies. A portion of the ventilation laboratory which is located on the surface contains up-to-date equipment for mine gas detection, dust counting, air conditioning, and fan performance studies. This facility is used for research directed toward improving basic mining procedures.

Nuclear Engineering

The Department of Nuclear Engineering offer, the master of science, the doctor of engineering, and the doctor of philosophy degrees. To enter our graduate program, you should hold a B.S. degree in some branch of engineering or physical science. The master's degree program is designed to provide you with competence in designing nuclear energy systems and learning their operation based upon your scientific and engineering background. Competence in at least one supporting area (usually your undergraduate major, if other than nuclear engineering) is also required. You may choose an M.S. without thesis requiring 33 hours.

Research areas in which you can specialize are:

- reactor design
- reactor safety
- probabilistic risk assessment
- thermal hydraulics
- radiation effects
- radiation protection
- radiation transport and shielding
- space nuclear power
- materials for nuclear applications
- fuel cycle
- radioactive waste management
- reactor noise analysis
- artificial intelligence
- applications of radioisotopes

In the Ph.D. program, you must complete a research project and write a dissertation of sufficient caliber to demonstrate your capacity to conduct original investigations, to analyze the results critically, and to develop sound conclusions. The dissertation should represent original research acceptable for publication in a refereed journal.

Our department has the following laboratory facilities for your use.

Nuclear Reactor

A 200 kW pool-type reactor has been operating since 1961. It has a beam port, a thermal column, and pneumatic transfer tubes. The reactor was refueled with low enriched uranium in the summer of 1992. The reactor is used for reactivity experiments, neutron activation analysis, radiation damage studies, neutron radiography, signal analysis, and materials processing. The reactor facility is equipped with state of the art detection instruments and associated electronics for neutron activation analysis. Recently acquired console equipment is being interfaced with computer data acquisition systems to extend research fields into artificial intelligence, neural networking, and noise analysis.

Radiation Measurements Lab

The laboratory is equipped with modern radiation detection and analysis equipment. The students learn to measure and analyze various forms of radiation sources.

Nuclear Materials Lab

The facilities of the Graduate Center for Materials Research, and metallurgical engineering and nuclear engineering departments are also available for nuclear materials-related research. These facilities include instruments such as scanning electron microscope, a 300 keV EM-340 Phillips transmission electron microscope, an atomic absorption spectrometer, and a quadrupole mass spectrometer.

Computer Lab

You will have the opportunity to use large computer codes commonly used in the nuclear industry for reactor core design, radiation transport, and thermal hydraulics analysis. The nuclear engineering department maintains an excellent laboratory with IBM compatible and Macintosh personal computers, and Hewlett Packard and Sun workstations.

Physics

The Department of Physics offers its graduate students the opportunity to obtain both master of science and doctor of philosophy degrees. The masters degree can be earned with either a thesis or non-thesis option.

Almost all physics graduate students are supported by either teaching assistantships or Research Assistantships. Some fellowships are also available. Most entering graduate students teach in laboratories with the introductory courses. Thereafter, they are commonly supported on research grants obtained by the faculty.

Entering graduate students usually have a physics undergraduate degree; however inquiries from students with other technical degrees and a good mathematics background are encouraged since the program allows minor background deficiencies to be made up.

Each student's graduate degree program is designed around a set of core graduate courses: classical mechanics, quantum mechanics, electricity and magnetism, statistical mechanics, and subatomic physics. The qualifying examination is based on materials taken from these courses. Details on the program and course offering may be obtained by calling or E-mailing the department chairman at: physics@umr.edu. You may also wish to explore the department's web page at:

www.umr.edu/~physics

The department emphasizes both fundamental and applied studies in three areas of physics: condensed matter physics, cloud and aerosal science, and atomic, molecular, and optical physics. A variety of both experimental and theoretical research opportunities are available for study in these areas. Students work with faculty on a wide range of problems. For example, they are currently characterizing magnetic materials, probing laser excited atomic states, establishing the structure and properties of aerosol, investigating electron hopping in compounds, determining electron-atom scattering events, deducing particulate rocket exhaust, exploring the spin properties of thin magnetic films, predicting ion-atom collisions, investigation the interaction of water and sulfuric acids clusters, analyzing and characterizing surfaces, ascertaining the properties of charged particles and atoms, and studying the nucleation of vapors into droplets.

The research and computing laboratories of the Physics Department were recently renovated and are continuously being updated. Most of these facilities are in the main building, but several research studies are being carried out in cloud and aerosol laboratories housed in Norwood Hall. Several other faculty working on condensed matter projects make considerable use of the extensive instrumentation available in the Materials Research Center. Special facilities include a unique ion-atom energy loss accelerator, custom UHV systems for preparing and characterizing *in situ* spin properties of magnetic films, state-of-the-art cloud simulation chambers, developed to study nucleation of vapors and droplets, special lasers used to study and probe excited atoms, Auger and XPS surface characterization spectrometers, specially developed instrumentation for used in aircraft to study rocket and aircraft exhaust characteristics, positron-ion scattering facilities, and Mossbauer and x-ray spectrometers. In addition, the department has several computational laboratories with a variety of workstations and PCs and both an electronic and mechanical shop.