AREAS OF STUDY

Aerospace Engineering

The Aerospace Engineering Program in the Department of Mechanical and Aerospace Engineering 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 interdisciplinanury programs meeting specific objectives are available. The Aerospace Engineering Program offers the master of science and doctor of philosophy degrees.

The master of science thesis program 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 the major field of study. In addition, a thesis from research that is equivalent to at least six credit hours in a major area must be prepared. The master of science non-thesis program consists of a minimum of 30 semester hours, including at least 18 hours of course work within the department, of which nine hours must be from the aerospace engineering core curriculum, and at least six hours in mathematics and/or computer science. At least nine credit hours of 400-level course work must be from the major field of study.

The aerospace engineering core curriculum consists of four areas: aerodynamics and propulsion; control/dynamics/stability; materials and structures; and mathematics.

A student pursuing the doctor of philosophy degree normally follows a program of 90 semester hours beyond the B.S. degree or 60 semester hours beyond the M.S. degree. For those with the M.S. degree, the 60 hours will consist of 24 hours of course work and 36 hours of thesis research. The Ph.D. course work must satisfy the departmental core course requirements for the M.S. degree. For the 24 credit hours of course work, a minimum of 12 hours must be taken within the department and at least three hours of mathematics/statistics. At least nine 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 36 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, 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 examination 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 hours must be at the 400-level, and three hours of mathematics/statistics. To pass the qualifying examination, 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 structures, 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, neural 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 Department of Mechanical and Aerospace Engineering has many well equipped laboratories located in the Mechanical Engineering Building and Mechanical Engineering Annex on the main campus, and a subsonic-flow laboratory in an off-campus facility. Some of the specially equipped laboratories on campus 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; 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; and extensive computer facilities including a personal computer laboratory, advanced computer graphics laboratory, computer learning center with engineering work stations. The flight simulator program at UMR incorporates a fixed-base real-time flight simulator with out-the-window display.

Biological Sciences

The department of Biological Sciences offers an interdisciplinary approach to addressing problems in applied and environmental biology. The program emphasizes 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, microcentrifuges, 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, microtiter 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 reagent-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.

Biomaterials

The Biomaterials program is an interdisciplinary program that offers the Master of Science degree in Biomaterials, either with or without a thesis. A baccalaureate degree in any branch of materials science and engineering, biological sciences, chemistry, chemical engineering, mechanical engineering, or other related disciplines is required.

The interdisciplinary program involves the participation of faculty from several academic departments such as Materials Science and Engineering, Biological Sciences, and Mechanical Engineering, and utilizes facilities in several academic departments as well as the Materials Research Center. Application for admission to the program should be made to the appropriate academic department.

With a focus on biomaterials and tissue engineering for biomedical applications, the program emphasizes the synthesis and properties of novel biomaterials, the design and fabrication of scaffolds for tissue engineering of biological tissues, interactions of biomaterials with living systems, and tissue-engineered restoration of biological tissues.

Degree Requirements

The total number of credit hours required for graduation is 30. The M.S. degree with thesis is oriented more toward research. The program requirements are: at least 6 but not more than 12 credit hours devoted to research, 9 credit hours of biomaterials core courses, and the remainder chosen from a list of approved courses with the consent of the advisor. For the M.S. degree without thesis, the program requirements are 9 credit hours of biomaterials core courses, 3 credit hours of practice-oriented research, and the remainder chosen from a list of approved courses with the consent of the advisor.

Financial Assistance

Graduate Research or Teaching Assistantships provide the main source of support for graduate students. Please contact the academic department of interest to apply for an assistantship.

Contact information: Dr. Mohamed N. Rahaman, rahaman@umr.edu; Tel: 573-341-4406; or Dr. Roger F. Brown, rbrown@umr.edu; Tel: 573-341-4860.

Ceramic Engineering

The Ceramic Engineering program is offered in the Department of Materials Science and Engineering.

A baccalaureate degree in ceramic engineering or science, glass science or technology, materials engineering, or materials science is preferred for admission to the departmental graduate program but a background in physics, chemistry, biological sciences, mining and mineral sciences, chemical engineering, or related disciplines are also acceptable. The department offers M.S. and Ph.D. degrees in ceramic engineering, as well as an interdisciplinary M.S. degree in materials engineering, and an M.S. degree in biomaterials.

The department specializes in research in the areas of glass, electronic ceramics, high temperature materials, structural ceramics, composites, biomaterials, and ceramic processing. Fundamental and applied interests include structure and its relation to properties of ceramics and glasses; defect chemistry, thermochemistry, and phase equilibria; electrical, dielectric, optical, thermal and mechanical properties of ceramics; ceramic-ceramic, ceramic-metal, and ceramic-polymer composites; compositional effects on the optical properties and chemical corrosion of glass; glasses for nuclear waste disposal; solid oxide fuel cells; electrically conducting and dielectric ceramics; high temperature superconducting ceramics; ferroelectric ceramics; glasses and ceramics for biomedical applications such as drug delivery and medical implants; and processing, forming, and microstructure control of structural and functional ceramics.

Laboratories are equipped with state-of-the-art facilities and instrumentation for research in ceramic materials. The department has extensive facilities for the synthesis, forming, and fabrication of ceramics and glasses, as well as for the detailed characterization of the electrical, dielectric, and optical properties of ceramics. Major instrumentation for characterizing the structure and composition of ceramics include X-ray diffractometers, thermogravimetric and differential thermal analyzers, FTIR/IR/UV and fluorescence spectrometers, inductively coupled plasma (ICP) atomic emission spectrometer, Auger/ESCA surface analysis equipment, and a nuclear magnetic resonance (NMR) spectrometer. Electron microscopy facilities include high resolution and field emission scanning electron microscopes with EDAX and EBSP capability, and a transmission electron microscope with STEM attachment. A mechanical testing laboratory is available for characterizing mechanical properties under controlled temperature and atmospheric conditions.

The department has a strong affiliation with the Graduate Center for Materials Research at UMR, which provides for interdisciplinary materials research and houses major instrumentation for materials research. Ceramic engineering faculty members are either senior research investigators or research investigators in this nationally recognized center.

The department is home to the Electronic Materials Applied Research Center (EMARC), a state/industry/university research and development center whose main activities include the development of new ceramic and polymer materials as well as associated processing methods for emerging technologies in fuel cells, oxygen permeable membranes, piezoelectric sensors, actuators, and emitters, and thin film structures and devices. The department is a participating institution in an NSF-sponsored Center for Dielectric Studies at the Pennsylvania State University. Dielectric ceramics for high energy density applications form a major focus of the department's research activities in this center.

The department is also a participating site in the NSF/industry/university Center for Glass Research at Alfred University. Faculty and students have research projects to characterize the performance of refractory materials used by the glass industry, to develop sensors to monitor the glass melting environments, and to understand structure-property relationships for different glass compositions.

Chemical & Biological Engineering

The Department of Chemical and Biological Engineering offers MS and PhD degrees in chemical engineering with excellent research in fundamentals and applications in biotechnology, nanotechnology, materials and environmental systems.

A baccalaureate degree in chemical engineering from an ABET - approved program with a minimum undergraduate grade point average of 3.0/4.0 or equivalent is generally required for admission to the graduate program. Non-chemical engineering majors may be admitted to the program but will be required to take some prerequisite undergraduate courses.

The Department specializes in research in the areas of fluid mechanics, reaction engineering, biochemical engineering, mass and heat transfer in porous media, transport and interfacial phenomena, computer-aided design, particle characterization, catalysis, statistical mechanics and nanotechnology.

The master of science thesis program consists of a minimum of 30 semester hours, including 18-24 hours of coursework, of which at least 9 credit hours must be at the 400 level with 6 hours taken from the chemical engineering core curriculum consisting of CHE 433 and CHE 445. In addition, a thesis from research that is equivalent to 6-12 credit hours in a major area must be prepared and defended.

A master of science non-thesis program consists of 30 semester hours coursework, including a minimum of 9 credit hours of 400-level coursework with 6 hours

taken from the chemical engineering core curriculum consisting of CHE 433 and CHE 445 and 18 hours of coursework within the department.

A candidate for the PhD degree normally follows a program of 90 semester hours beyond the BS degree or 60 semester hours beyond the MS degree. Research for MS and PhD may be coordinated, or a PhD may be pursued without an MS degree. The PhD coursework must satisfy the departmental core course requirements for the MS degree. In addition to these course requirements, a candidate must prepare and defend a dissertation based on analytical and/or experimental research.

A candidate for the degree of doctor of philosophy must pass a written qualifying examination on chemical reaction engineering, transport phenomena and thermodynamics. A grade of B or better in CHE 383, CHE 433 and CHE 445 will constitute passing the chemical reaction engineering, transport phenomena and thermodynamics portions of the qualifying examination, respectively.

The comprehensive examination, consisting of a written and oral presentation of a research proposal, 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 Department of Chemical and Biological Engineering shares Schrenk Hall, a building of four floors, with the Chemistry and Biological Sciences Departments. 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 simulation, control and optimization; bioconversion; reaction mechanisms and kinetics; fluid mechanics and mixing; thermodynamics; polymers and polymeric materials; freeze drying; adsorption/desorption processes; computer-aided design; interfacial phenomena; transport phenomena; chromatography; characterization of biomolecules; synthesis of nano-particles.

Facilities are available to assist with the construction of special 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 Beckman P/ACE System 2100 capillary electrophoresis instrument, a Hewlett-Packard 5989 Mass Spectrometer with GC and solids inlets, 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 thermogravimetric analyzer (TGA), TA Instruments 2950 TGA, TA Instrument 2920 DSC, 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), refrigerated ultra centrifuges, dispersive optical spectrometers (UV, VIS, Near IR, fluorescence/phosphorescence, 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, and access to the university centralized computing facility. X-ray crystal structure determinations are performed on a Bruker AXS single crystal area detector facility and an Enraf-Nonius CAD-4 diffractometer. Powder, polymer, and liquid crystal. 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, Architectural, and Environmental Engineering

The department offers several areas of specialization. These are construction materials, environmental engineering, geotechnical engineering, hydraulic engineering and engineering hydrology, structural engineering, transportation, construction engineering, and infrastructure engineering. Samples of recent and ongoing funded research are drainage of highway subgrades, determination of gas permeability of fine grained soils, earthquake mitigation of highway structures, determining stream stability and storm water detention in urban watersheds, evaluation of storm water drainage structures on bridges, urban watershed modeling, sediment transport, river mechanics, environmental fluid mechanics, mathematical modelling, constitutive modeling of reinforced concrete structures, collapse studies of building structures and bridges subjected to interacting ground motion, theoretical studies and shake-table tests of various 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 includes analysis, design and control of seismic-resistant structures, design of cold-formed steel structures, design of reinforced and prestressed 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, indoor air pollution, phytoremediation, advanced oxidation processes, bioremediation of metals, pollution control from concentrated animal feed operations, blast loading of structures, traffic operations and safety, armor/anti-armor, and geotechnical engineering problems such as earthquake response of soils and foundations, 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.).

The Department is housed in the Butler-Carlton Civil Engineering Hall. The building provides office space for civil engineering faculty, staff, and graduate students, and contains classrooms and laboratories in which most civil engineering courses are taught. On the premises are a 175-seat auditorium and several smaller auditoria with large-screen video projection capability. The building contains geotechnical laboratories, a water resources laboratory, a bituminous materials testing laboratory, environmental engineering laboratories, structures and materials testing laboratories and a machine shop. Laboratories are used for instruction and research 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. Wireless communication and access to the Internet also available.

The Department is home to the Environmental Research Center, the W.W.Yu Center for Cold-formed Steel Structures, the Missouri DOT Local Technical Assistance Program headquarters, the Natural Hazards Mitigation Institute and a high-bay structural engineering 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. It features a strong floor and a two-story tall reaction wall. A “shake table” simulates earthquake conditions for the evaluation of earthen structures. The Department 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 and 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. Most graduate programs in computer engineering 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 system security/survivability.

Departmental Requirements

Admission requirements: The nominal GPA requirement for admission to the MS degree program in this department is an undergraduate GPA of 3.2 on a 4.0 GPA system. In evaluating the academic performance from universities that may use other grading systems, the department may rely upon statistical data gathered in analyzing academic outcomes for recent graduate students to the extent that such statistical data is available. The department will not offer graduate admissions to students who do not have the equivalent of a four year baccalaureate degree in engineering. As an example we can not accept students who have only a diploma or engineering technology degree.

The school of engineering requires that the sum of GRE-V and GRE-Q be at least 1100 and that the GRE-WR score be at least 3.5. In addition the ECE department recommends a minimum GRE-Q score of 730 and recommends a minimum GRE-WR score of at least 4.5 For applicants who have taken the GRE-A instead of the GRE-WR, the department recommends a GRE-A score of at least 640.

For international students who are required to provide TOEFL scores, this department has no particular preference for the computer based TOEFL or the paper based TOEFL. Minimum recommended scores set by the department are 237 on the computer based TOEFL and 580 on the paper based TOEFL.

Students applying for graduate studies in this department on the basis of degrees in closely related fields may have additional conditions placed on their admission. These conditions are generally imposed to make sure that students lacking a traditional computer engineering degree will have sufficient background to ensure a reasonable chance for academic success.

Students seeking admission to the PhD program should meet or exceed all of the above recommendations and should have a graduate GPA of 3.5 or better. All PhD applicants must provide at least three letters of recommendation. Exceptional applicants may apply directly to the PhD program after completing the baccalaureate degree.

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.

Additional Information

Additional information about departmental emphasis areas, requirements, graduate handbook, faculty, research opportunities, financial aid, and facilities can be found by visiting the Department's web page at http://www.ece.umr.edu. We can be contacted by telephone at 573-341-4506 or email at graduate@ece.umr.edu. For information about the UMR Engineering Education Center in St. Louis, visit their web page at http://www.umr.edu/~umreec.

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, machine learning, evolutionary computation), parallel and distributed computing, software engineering and web computing. 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 Computer Science Department at UMR makes use of both its own laboratories as well as university computing facilities. The Department maintains several

laboratories including the following instructional laboratories:

- Instructional Workstation Laboratory that provides Unix workstations
- Instructional PC Laboratory consisting of PC computing platforms
- Computer Science Learning Center

Research laboratories provide support for both undergraduate and graduate students. These laboratories include:

- Software Engineering Laboratory
- Experimental Computation Laboratory
- Intelligent Knowledge Management Laboratory
- Computer Vision and Multimedia Laboratory
- Web and Wireless Computing (W2C)
- Natural Computation Lab

Languages: C++, C, Java, Fortran, CLIPS, Lisp, COBOL, Prolog, CASE tools, and databases (ORACLE). Operating Systems—Unix, DOS, Windows.

Networked computer access is available to all students, faculty and staff.

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 or minimum GRE Quantitative Score of 600 and written score of 3.5.

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 Conditional 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
C or C++ or Java
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. 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. Applications for CS department assistantships can be found on the department's web page or by contacting the department directly (see below).

In addition, research opportunities for advanced students exist in the department and in the UMR Intelligent Systems Center as well as other research labs on campus.

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: csdept@umr.edu

Economics and Finance

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

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. Most graduate programs in electrical engineering normally include some specialization in one or more of the following six emphasis areas of electrical engineering.

Emphasis Areas

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

Electronics topics include circuits and networks containing active devices. Typical applications might include radio frequency amplifiers, oscillators, active filters, and others. These circuits and networks can be either digital or analog in nature.

Communications-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: 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 nonlinear systems, 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. Signals at microwave and millimeter wave frequencies can be effectively used for nondestructive testing (MDT), evaluation (NDE) and inspection (NDI) of a variety of materials ranging from low loss dielectric composites for material property and interior flaw determination to highly conducting materials such as metals for surface cracks detection. High spatial resolution microwave images of composite materials can also be produced when operating in the near-field region of a radiator.

Power 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 Requirements

Admission Requirements: The nominal GPA requirement for admission to the MS degree program in this department is an undergraduate GPA of 3.2 on a 4.0 GPA system. In evaluating the academic performance from universities that may use other grading systems, the department may rely upon statistical data gathered in analyzing academic outcomes for recent graduate students to the extent that such statistical data is available. The department will not offer graduate admissions to students who do not have the equivalent of a four year baccalaureate degree in engineering. As an example we can not accept students who have only a diploma or engineering technology degree.

The school of engineering requires that the sum of GRE-V and GRE-Q be at least 1100 and that the GRE-WR score be at least 3.5. In addition the ECE department recommends a minimum GRE-Q score of 730 and recommends a minimum GRE-WR score of at least 4.5 For applicants who have taken the GRE-A instead of the GRE-WR, the department recommends a GRE-A score of at least 640.

For international students who are required to provide TOEFL scores, this department has no particular preference for the computer based TOEFL or the paper based TOEFL. Minimum recommended scores set by the department are 237 on the computer based TOEFL and 580 on the paper based TOEFL.

Students applying for graduate studies in this department on the basis of degrees in closely related fields may have additional conditions placed on their admission. These conditions are generally imposed to make sure that students lacking a traditional electrical or computer engineering degree will have sufficient background to ensure a reasonable chance for academic success.

Students seeking admission to the PhD program should meet or exceed all of the above recommendations and should have a graduate GPA of 3.5 or better. All PhD applicants must provide at least three letters of recommendation. Exceptional applicants may apply directly to the PhD program after completing the baccalaureate degree.

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 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 and Committee to determine when these expectations are met. Length of research time and/or research credit hours will not automatically satisfy this requirement.

Additional Information

Additional information about departmental emphasis areas, requirements, graduate handbook, faculty, research opportunities, financial aid, and facilities can be found by visiting the Department's web page at http://www.ece.umr.edu. We can be contacted by telephone at 573-341-4506 or email at *graduate @ece.umr.edu*. For information about the UMR Engineering Education Center in St. Louis, visit their web page at http://www.umr.edu/~umreec.

Engineering Management

Engineering Management is the art and science of planning, organizing, allocating resources, and directing and controlling activities. The field of Engineering Management has become recognized as a professional discipline with a critical role in the modern society. The Department of Engineering Management at UMR provides a unique opportunity for innovative and integrated solutions for implementation of diverse management styles by bridging the gap between organization and process.

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 coursework and research designed to expand 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 at the interface between the classical engineering and management disciplines.

The Engineering Management Department has produced over 5277 graduates at the B.S. (2210), M.S. (2896), and Ph.D. (171) level since its inception in 1968. The Engineering Management Department is the only institution in the world that offers B.S., M.S. and PhD degrees in Engineering Management. Graduates have been successful at integrating the various elements of production and service enterprises to produce outstanding results. Over 30% of the B.S. graduates have reached top executive positions by the age of 50.

Typical Specialization Areas and Associate Courses

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

Financial Engineering

- Investment
- Financial Engineering
- Activity Based Accounting and Financial Decision Making
- Economic Decision Analysis
- Engineering Cost Accounting
- Advanced Engineering Economy
- Advanced Finance Management
- Introduction to Intelligent Systems
- Introduction to Neural Networks and Applications
- Data Mining and Knowledge Discovery
- Smart Engineering System Design

Industrial Engineering

- Methods of Industrial Engineering
- Work Design
- Business Logistics Systems Analysis
- Advanced Facilities Planning and Design
- Advanced Engineering Economy
- Industrial System Simulation
- Safety Engineering Management
- Human Factors

Manufacturing Engineering

- Computer Integrated Manufacturing Systems (CIM)
- Lean Manufacturing Systems
- Production Planning – Scheduling
- Interdisciplinary Problems in Manufacturing Automation
- Advanced Manufacturing Systems Integration
- Advanced Production Management
- Value Analysis
- Integrated Process Development

Quality

* Total Quality Management
* Taguchi System of Quality Engineering
* Six Sigma
* Design for Six Sigma
* Reliability
* Statistical Process Control
* Design of Experiments
* Engineering Design Optimization

Systems

* Systems Eng. Analysis I & II
- Systems Architecturing
- Smart Engineering System Design
- Network-Centric Systems and Engineering

Smart Engineering Systems Design

Master of Science

Master of Science

The M.S. degree program is offered on the Rolla campus and several locations including the UMR Engineering Education Center in St. Louis, Fort Leonard Wood, and by Internet throughout the United States and selected international locations. The lectures are archived upon completion of the lecture and all lectures are available to students through streaming video during the semester for review. These courses can be reached from anywhere at any time. It is feasible to obtain a UMR M.S. degree regardless of your location. Some of the current UMR Engineering Management students reside in the Marshal Islands, Australia and South America.

The M.S. 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. All students are required to take the following core courses.

EMgt 314 - Management for Engineers

EMgt 361 - Project Management

EMgt 352 - Activity Based Accounting and Financial Decision Making

EMgt 354 - Integrated Product and Process Design

The remaining six courses are taken in a specialization area selected by the student including a minimum 9 hours of four hundred level courses. A graduate student already holding or completing a Masters degree may obtain a second M.S. in Engineering Management by completing at least an additional 24 credits of work.

Some recent Master thesis titles include:

- Impacting Co-Worker Trust Toward Persons with Disabilities
- Collective Behavior in Robots Using Evolutionary Neural Networks
- Intelligent Technical Analysis Using Neural Networks and Fuzzy Logic
- Applying the Six Sigma Methodology to Improve the Admissions Process at UMR
- Strategic Inventory Allocation for Vehicle Rental Agencies
- Design and Development of an Interactive Web-Integrated Flexible Manufacturing Cell Control System
- Investigations in the Design of Products and Factories for End-of-Life Disassembly
- Warranty Cost Prediction using Mahalanobis Distance
- Automotive Braking System Simulation and Optimization

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 student's 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 both a qualifying examination and a comprehensive examination. Ph.D. students must conduct original research under the supervision of a doctoral advisor, and write and successfully defend the dissertation. Some recent Ph.D. dissertation titles include:

- Evolvability in the Phylogeny of the Ontogenesis of Artificial Networks of Spiking Neurons
- Development and Analysis of Intelligent Computation Based Stock Forecasting and Trading
- An Analysis of Intermodal Transportation Mode Selection Considering Stochastic System Parameters
- Development of an ISO 9000 Advisory System
- Surviving the Change to a Competitive Market Place in the Small Local Exchange Carrier Telecommunications Industry
- The Relationship Between R&D Spending and Shareholder Returns in High Technology Industries
- An Analysis of TQM Effects on An Organization's Productivity
- Global Stock Index Forecasting Using Multiple Generalized Regression Neural Networks With A Gating Network
- Factors Leading to Successful Application of Improvement Tools for Quality Management

Criteria for Admission

Admission to the graduate program is limited to applicants with a B.S. degree in engineering, certain physical sciences, mathematics, or computer science, including 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 through courses at UM-Rolla or elsewhere. Specific requirements for the Masters and Ph.D. programs are given below:

M.S. Admission Standards

1. B.S. in Engineering or hard science

2. GPA: Regular status: 3.0 cumulative and 3.0 on last 60 credit hours. Conditional status: 3.0 on last 60 credit hours. Condition: Student must earn B or better in each of first four graduate (300 or 400 level) classes after conditional admission.

3. Graduate Record Exam (GRE): All students must submit current GRE scores.

Regular status: V+Q=1150, A=4.5

Conditional Status: V+Q=1100, A=4.5

Condition: Student must earn B or better in each of first four graduate (300 or 400 level) classes after conditional admission.

4. TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study.

Regular status: 580/237

Conditional status: 560/220

Condition: Student must earn B or better in each of first four graduate (300 or 400 level) classes after conditional admission.

5. Statement of Purpose: All applicants must submit a statement of purpose.

6. Financial Support: Students in conditional status are not eligible for financial support from the department.

Ph.D. Admission Standards

1. B.S. in Engineering

2. GPA: M.S. GPA = 3.5

3. Graduate Record Exam (GRE): All students must submit current GRE scores. V+Q>=1150, A=4.5

4. TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study.

Regular status: 580/237

Conditional status: 560/220

Condition: Student must earn B or better in each of first four graduate (300 or 400 level) classes after conditional admission.

5. Statement of Purpose: All applicants must submit a statement of purpose.

6. Financial Support: Students in conditional status are not eligible for financial support from the department.

Requirements for Completion

Students following their approved program of study will be assured of graduation upon maintenance of good academic standing. A minimum of 30 units of course work from the areas listed below must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a C grade or better in each course. Accumulation of more than 10 hours of C or F results in dismissal from the program. A maximum of nine hours of course work for M.S. degrees may be transferred from universities outside the University of Missouri System. Such credits for transfer must have been registered as graduate courses when they were taken. All courses applied to the degree require prior written advisor approval recorded on the study plan in the student's file. There is no thesis or comprehensive examination requirement. It is the responsibility of each student to apply for graduation with the UMR Registrar's Office during his or her last semester. Assistance on this final step can be provided by the Engineering Management Department's Academic Services & Records office, if necessary. More details about requirements can be found in the University Catalog, and are available from the Engineering Management Graduate Program office.

Departmental Laboratories

The department has several "hands on" laboratories that have both a research and teaching focus. Each labs is directed by faculty that work 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 (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, M.S. and Ph.D. 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. The 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 today 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) (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 include, adaptive global stock management, data mining, artificial life, internet-based pattern recognition, adaptive assessment of system engineering practices, 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 has been established under National Science Foundation and industry grants such as AT&T, Society of Manufacturing Engineering (SME), Halliburton, and Lucent Technologies.. 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. Additional information about SDL and its various activities can be found at www.umr.edu/~sdl.

Design Engineering Center (DEC)

The center is one of the outreach arms 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®, quality engineering, the product development process, and design optimization. Additional information about the center and its various activities can be found at www.umr.edu/~design.

Systems Modeling and Simulation Laboratory

The Systems Modeling and Simulation Laboratory focuses on designing and developing simulation based techniques for the analysis and control of complex enterprise systems, including manufacturing systems. The lab is equipped with the software necessary for designing and implementing simulations of complex systems, including Arena, Arena RT, and Matlab.

Laboratory for Investment and Financial Engineering

The goal of the Laboratory for Investment and Financial Engineering (www.umr.edu/~life) is to develop techniques and computational tools for increasing investment and capital return while managing and reducing financial risk. This involves research into stocks and financial derivatives (options, futures, forwards, swaps), financial risk and uncertainty, financial forecasting, market efficiency and behavioral finance, fundamental and technical analysis, equity valuation, real options, and engineering economics. In cooperation with the Smart Engineering Systems Lab, research in the lab may also involve the use of smart and intelligent systems, such as neural networks, fuzzy logic, genetic and evolutionary algorithms, expert systems, intelligent agents, artificial life, chaos and fractals, and dynamic and complex systems. Data mining, principal component analysis, and various other forms of applied statistics are also used. Members of the lab have access to financial data and various financial modeling software packages.

English and Technical Communications

The Department of English and Technical Communications 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 Departments 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 spring semester. Late applicants will be considered but cannot be assured of admission. For more information, contact the Department of English.

Environmental Engineering

The Civil, Architecutural, and Environmental 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's 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. 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. 5Those 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 department. The environmental engineering laboratories used for teaching and research total more than 20,000 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 collaborate extensively with faculty and researchers in other departments at UM-Rolla and elsewhere.

Geological Engineering

The Geological Engineering program is offered in the Department of Geological Sciences and 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.

Geology and Geophysics

The Geology and Geophysics program is offered in the Department of Geological Sciences and Engineering.

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 Materials, Energy, and Earth Resources. 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.

Geotechnics

The University of Missouri-Rolla (UMR) is one of the top geotechnology schools in the country. Geotechnical Engineering is one of the Missions of UMR, and has been recognized by receiving Mission Enhancement Funding from the State of Missouri for this purpose. UMR is now pioneering a web based masters of engineering degree in Geotechnics. The upward mobility of professionals in the field requires advanced degrees, but not all are willing or able to take an extended leave of absence to attend UMR. Web based education will allow students to continue their work, while taking virtual classes at their convenience.

Contact information see gtech@umr.edu or visit our website at http://www.umr.edu/~gtech .

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). When the student applies to UMSL, he/she should provide three letters of recomendation and the GRE score.

Information Science and Technology

The School of Management and Information Systems offers an M.S. degree program in Information Science and Technology (IST). Information technology has transformed every aspect of our economy and society. Rapid spread of the technology has generated the need for highly trained professionals to implement and maintain information systems. The M.S. in Information Science and Technology is designed to educate students in the design, development, and successful application of information systems in organizations.

The faculty is active in studying the design and application of the web and has external support for research. Research experiences are integrated into the classroom experience. Specially equipped research laboratories are available to support studies in human-computer interaction and experiments with computer networks, as are general purpose computing laboratories that are available to all students. A large number of computing languages and special-purpose software tools are available on various platforms. While instruc-

tion and research are on the leading edge of information systems, the School endeavors to keep class sizes small to facilitate student and faculty interactions.

Admission Requirements

In addition to those requirements stated in the section of this catalog devoted to Admission and Program Procedures, the School of Management and Information Systems has additional requirements for the M.S. in Information Science and Technology (thesis or nonthesis):

- Complete the general portion of the Graduate Record Examination (GRE) with a minimum Verbal Score of 370, Quantitative Score of 600, and Analytical Score of 3.5 - OR - Complete the Graduate Management Admissions Test (GMAT) with a minimum Total Score of 500 and a minimum 25th percentile score for each of the Verbal, Quantitative, and Analytical Writing Scores
- A minimum TOEFL score of 230 for those students not speaking English as their native language.
- An undergraduate GPA of 3.0/4.0 or better over the last 2 years or successful completion of 12 graduate hours in IST as a Conditional Graduate Student at UMR, with at least a 3.0 GPA.
- Content of the following courses:
    - Programming Language (IST 51/CSc 53)
    - Data Structures (IST 151/CSc 153)
    - Information Systems (IST 141)
    - Computer Architecture (IST 231)
    - Calculus
    - Statistics

Degree 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 (IST 490), 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 at the 400 level).

The following core courses are required of all M.S. students in Information Science and Technology. These courses are designated to insure that all IST masters students study the four information systems perspectives of web design, human perception, application implementation, and organizational systems.

- IST 336 Internet Computing
- IST 355/Psych 314 Human-Computer Interaction
- IST 361/EMgt 361 Information Systems Project Management
- IST 351 Leadership in Technology-Based Organizations

Financial Assistance

Financial assistance is available to graduate students in the form of assistantships and fellowships. Research opportunities for advanced students exist. For applications forms, contact the graduate coordinator.

Additional Information

Visit the School's web page at: http://www.umr.edu/~smis or contact us at 573-341-4482 or email us at: smis@umr.edu

Manufacturing Engineering

The UMR Manufacturing Engineering Education Program offers the interdisciplinary Master of Science (MS) and Master of Engineering (MEng) degrees on campus or through distance learning via the internet. Both degree programs are intended for a student with a BS degree in engineering to learn about modern manufacturing technologies involving computers and automation. Also offered are two graduate manufacturing engineering certificate programs. Manufacturing Systems and CAD/CAM & Rapid Product Realization are for working professionals who want to stay ahead of rapidly changing technology. The Graduate Certificate Program consists of a four-course sequence from existing graduate-level courses. While the students admitted to the Certificate Program will have non-matriculated status, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program if they so choose. The Certificate credits taken by students admitted to the M.S. program will count toward their master's degree.

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 the 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. The following test scores are required:

- A Minimum GRE verbal plus quantitative score of 1100 and a minimum analytical score of 3.5 are required.
- For those not speaking English as their native language, a TOEFL score of 213 computer based or 550 paper based is required.

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/Computer Science or any suggested manufacturing courses, 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 requirements include 12 credit hours from the Manufacturing Core Areas, 6 credit hours of 400 level courses in manufacturing; 3 credit hours of approved Mathematics/Computer Science or any suggested manufacturing courses, 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, 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/~mfge/. 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 and Digital Image and Signal Processing Lab.

Materials Engineering

The Master of Engineering program in Materials, sponsored by the Department of Materials Science and Engineering, offers an interdisciplinary masters degree program without a required research component. The degree requires thirty hours of approved graduate credit, and at present, requires residency on the UMR campus. Up to six credit hours of coursework can be transferred in. Future offering through distance learning is currently being considered.

Entering students will meet the standard admissions requirement as defined in this catalog, and will have a BS degree in engineering or science.

The degree will require the following:

Required courses - 8 credit hours - Cer. 477 and Met. 478

Technical Electives - 12 credit hour minimum - 22 credit hour maximum

Suggested courses include:

Met. E.	305, 307, 311, 313, 321, 329, 331, 333, 355, 358, 359, 363, 367, 375, 381, 385, 403, 414, 421, 427, 429, 451
Cer. E.	306, 331, 333, 338, 364, 369, 371, 405, 416, 418, 423, 450,
Chemistry	381, 484
M.E.	336, 338

The program requires a minimum of six hours in metallurgical and engineering and six hours in ceramic engineering.

Additional Electives (0-10 credit hours)

Up to eight hours may be chosen with approval in areas outside of the approved list of courses.

Up to eight hours of research or independent study can also be included here.

There is no requirement for thesis, internship or other capstone experience.

For additional information, contact the Department of Materials Science and Engineering.

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. in applied mathematics and the Ph.D. in mathematics can be pursued with either a mathematics or a statistics emphasis. 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 de-

gree, 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 if selecting the mathematics emphasis, and to linear algebra, probability mathematical statistics, and statistical inference if chosing the statistics emphasis, 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 program must 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, specializations 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 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 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 Department of Mechanical and Aerospace Engineering offers comprehensive graduate education in a number of areas. The principal areas include: dynamics and controls; heating, ventilation and air-conditioning (HVAC); manufacturing; materials and structures; mechanical design; and thermal and fluid systems. A great variety of interdisciplinary programs meeting specific objectives are available. The Mechanical Engineering Program offers the master of science, doctor of philosophy, and doctor of engineering degrees.

The master of science thesis program consists of a minimum of 30 semester hours, normally including 24 hours of course work with nine hours from the mechanical 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 the major field of study. In addition, a thesis from research that is equivalent to at least six credit hours in a major area must be prepared. A master of science non-thesis program consists of a minimum of 30 semester hours, including at least 21 hours of course work within the department, of which six hours must be from two mechanical engineering areas in the mechanical engineering core curriculum, and at least six hours from outside the department. At least nine credit hours of 400-level course work must be from the major field of study.

The mechanical engineering core curriculum consists of six areas: fluid mechanics; manufacturing; materials and structures; mathematics; mechanics and system design; 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 bachelor's degree for a total of at least 90 semester 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 non-technical group of courses of 9 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 semester hours beyond the B.S. degree or 60 semester hours beyond the M.S. degree. For those with M.S. degree, the 60 hours will consist of 24 hours of course work and 36 hours of thesis research. The Ph.D. course work must

satisfy the departmental core course requirements for the M.S. degree. For the 24 hours of course work, a minimum of 12 hours must be completed within the department and at least three credit hours of mathematics/statistics. At least nine 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 36 hours beyond the M.S. degree.

There are no foreign language requirements for the master of science, doctor of engineering and doctor of philosophy degrees in mechanical engineering. However, a reading knowledge of one foreign language, 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 examination 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 hours must be at the 400-level, and three hours of mathematics/statistics. To pass the qualifying examination, 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.

Some examples of research areas a candidate could specialize in are: acoustics; combustion and I. C. engines; computational fluid dynamics; computer-aided design; design methodology; dynamics and controls; heating, ventilation and air-conditioning (environmental control); heat transfer; laser-aided manufacturing; manufacturing and machining processes; materials and structures; mechanisms and robotics; mechatronics; micro-electromechanical systems (MEMS); thermal-fluid and energy systems; tribology; virtual reality and rapid prototyping.

The Department of Mechanical and Aerospace Engineering has many well-equipped laboratories that are located in the Mechanical Engineering Building and Mechanical Engineering Annex on the main campus, and a subsonic-flow laboratory in an off-campus facility. Some of the specially equipped laboratories on campus include: aerospace flow laboratory; advanced machining laboratory, augmented reality laboratory, composite materials manufacturing and characterization laboratory, computational radiative transfer laboratory, convection heat transfer laboratory, electromechanical transducer development laboratory, environmental control group laboratory, fluid dynamics and combustion laboratories, internal combustion engine and spray laboratories, laboratory for industrial automation and flexible manufacturing, laser-based manufacturing laboratory, rapid prototyping laboratory, radiative heat transfer laboratory, robotics laboratory, structural health monitoring laboratory and welding laboratory.

Metallurgical Engineering

The Metallurgical Engineering Program is offered in the Department of Materials Science and Engineering.

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

The principal research interests of the faculty include metals casting, joining and forming; metal deposition; high temperature and intermetallic compounds; powder metallurgy; plasma spray; thermodynamics and kinetics of pyrometallurgical and electrometallurgical processes; 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. degree candidates to complete a thesis program. Exceptions may be granted in special circumstances. Students interested in a non-thesis masters should consider the Master of Engineering program in Materials.

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, the Materials Research Center (MRC), and facilities acquired from the former U.S. Bureau of Mines Metallurgy Research Center.

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. Friction stir welding and adaptations known as friction stir processing are significant areas of activity.

Other special graduate research equipment includes crystal preparation, characterization, and sectioning equipment; image analysis systems; heat treating; atomic absorption and XRF spectrophotometers; a thin-film sputtering unit, equipment for hydro and electrometallurgical processing; equipment for most deformation techniques; and equipment for thermal spray deposition. Students of the department also have

access to the extensive research equipment in the Materials Research Center (MRC).

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

A Metallurgical Engineering home page is available at: http://www.umr.edu/~meteng

Mining Engineering

The Mining Engineering program is in the Department of Mining and Nuclear Engineering.

Mining engineers design and operate those systems that convert the potential wealth of the earth's crust to the resources upon which humanity depends. A Master of Science, Master of Engineering, Doctor of Philosophy, and Doctor of Engineering degree may be pursued in mining engineering, focusing on nearly any aspect of the minerals industry including mining methods, mine planning, rock mechanics, explosives, mine systems analysis, mine plant, mine operations, mine health and safety, mine ventilation, coal preparation, mining economics, and environmental aspects of mining. For the M.S., Ph.D., and D.Eng. degree, the department requires completion of at least one course in rock mechanics and one course in mathematics beyond calculus. The M.E. degree is distance education-based and requires a problem report or design project rather than a thesis.

Research is greatly enhanced by our laboratories, which are equipped for conveniently and thoroughly conducting graduate level research. They are located in McNutt Hall on campus as well as at the Rock Mechanics and Explosives Research Center and the Experimental Mine, which are on university property a short distance southwest of the campus.

The practical applications of mining engineering are an integral part of the overall instruction leading to improved, well-designed underground and open pit mining operations, including subsystems. The coal preparation laboratory is equipped to investigate the physical and chemical properties of coal for their effects on mining processes, beneficiation, utilization of the product, and valuations of coal properties. A mine ventilation laboratory provides facilities for detailed studies of airflow and air 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. Sophisticated computer models for rock mechanics studies are also available. A state-of-the-art Computer Learning Center supports graduate studies, and a broad suite of mining-related software applications is available.

The experimental mine has more than 1,500 linear feet of horizontal underground passages with two adits and four vertical shafts. Adjacent to it are two quarries. The mine plant has power, compressed air, water supply, track haulage, and much 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 airflow studies. A portion of the ventilation laboratory, located on the surface, contains modern equipment for mine gas detection, dust analyses, air conditioning, and fan performance studies. This facility is also used for hands-on research and various engineering studies.

Nuclear Engineering

The Nuclear Engineering program is in the Department of Mining and Nuclear Engineering.

The Nuclear Engineeirng Program offers 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 required. You may choose an M.S. with or without thesis each requiring 30 hours. Research areas in which you can specialize are:

- reactor design
- reactor safety
- thermal hydraulics
- radiation effects
- radiation protection
- radiation transport and shielding
- space nuclear power
- materials for nuclear applications
- fuel cycle
- radioactive waste management
- applications of radioisotopes
- health physics
- radiation dosimetry

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 research, 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.

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, and materials processing. The reactor facility is equipped with state of the art detection instruments and associated electronics for neutron activation analysis. The facility also hosts new initiatives in remote monitoring applications for nuclear installations and reactor robotics applications.

Radiation Measurements Laboratory

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

Nuclear Materials Laboratory

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 quadruple mass spectrometer.

Computer Laboratory

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 workstations.

Thermal-Fluid Sciences Laboratory

This new lab is dedicated to investigating the fundamental dynamics of single phase and dispersed two-phase flows and heat transfer of energy systems, including nuclear energy systems. In particular, the lab utilizes and develops measurement techniques called particle image velocimetry (PIV) and Ultrasound Doppler velocimetry (UDV). The lab is also exploring application of UDV to bioengineering.

Two-phase Flow and Thermal-Hydraulics Laboratory (TFTL)

The Nuclear Engineering TFTL is designed to perform both fundamental and advanced two-phase flow experiments simulating prototypic nuclear reactor conditions. The TFTL is equipped with state-of-the-art instrumentation such as a micro multi-sensor conductivity probe, a high-speed digital motion-corder, various flow measurement devices, and a data acquisition system and software. Topics of research studied in the TFTL include advanced two-phase flow modeling, two-phase flow characterization in a various flow channel geometry, air-water two-phase bubble jet experiment, secondary flow analysis in liquid film flow, and development of two-phase flow instrumentation.

Petroleum Engineering

The Petroleum Engineering Program is offered in the Department of Geological Sciences and 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.

Physics

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

Most physics graduate students are supported by either Teaching or Research Assistantships, although some Fellowships are available for exceptionally promising students. Most entering graduate students are supported on Teaching Assistantships, and teach in the introductory physics laboratory. Thereafter, they are usually supported as Research Assistants on external research grants.

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 graduate physics electives, such as mathematical physics, solid state physics, quantum statistical mechanics, atomic collisions, subatomic physics, and laser physics. In their second year, Ph.D. students take a qualifying examination based on the material taken from the core courses. Details of the program and course offerings may be obtained by calling 573-341-4702, or emailing the department chairman at physics@umr.edu. Additional information may also be found on the department's web page at http://campus.umr.edu/physics/.

The department's research emphasis includes both fundamental and applied studies in three areas of physics: condensed matter, solid state, and materials physics; cloud, aerosol and environmental physics, and atomic, molecular, and optical physics. Experimental and theoretical research opportunities are available for study in each of these areas. Following their core coursework, graduate students in the department are able to work with faculty on a wide range of problems, including the characterization of magnetic materials, predicting the properties of quantum and classical phase transitions, probing laser excited atomic states, establishing the structure and properties of atmospheric aerosols, investigating electron transport in polymers, determining electron-atom scattering events, characterizing the particulate in rocket engine exhaust, exploring the spin properties of thin magnetic films, computing the electronic structure of new materials, measuring and imaging ion-atom collisions, investigating water and sulfuric acids cluster interactions, analyzing and characterizing nanostructures on surfaces, ascertaining the properties of charged parti-

cles and atoms, and studying the nucleation of vapors into droplets.

The research and computing laboratories of the Physics Department are recently renovated and are continuously being updated. Most of these facilities are in the main Physics Building, but several research studies are being carried out in cloud and aerosol laboratories housed in Norwood Hall. Several faculty working on condensed matter projects make use of extensive instrumentation and materials characterization facilities available in the Materials Research Center. Special facilities include a unique ion-atom accelerator and energy loss spectrometer, 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, femtosecond lasers used to study and probe excited atoms, Auger and XPS surface characterization spectrometers, specially developed instrumentation for use in aircraft to study rocket and aircraft exhaust characteristics, positron-ion scattering facilities, and Mossbauer and x-ray spectrometers.

Systems Engineering

Program Goals and Summary

The program is designed to provide graduate engineers and engineering managers with the advanced knowledge and skills necessary for the conception and implementation of complex systems. The emphasis is on the processes by which complex systems are conceived, planned, designed, built, tested and certified. The systems engineering experience can be applied to defense, space, aircraft, communications, navigation, sensor, computer software, computer hardware, transportation and other aerospace and commercial systems and activities.

Engineers with a firm grounding in an engineering discipline and work experience will learn tools and approaches for confident decision making in the complex technical environment of today's corporations.

A Master of Science degree program consisting of 10 three-credit courses and a Certificate program consisting of 4 three-credit courses are offered. The Certificate program may be followed by 6 additional three-credit courses to complete the M.S. degree program.

Requirements for Admission

A bachelor's degree in an engineering or scientific discipline with a cumulative GPA of at least 3.00 on a 4.00 scale, and a GRE score of 1150 or higher in verbal plus quantative and 4.5 or higher in analytical. Three years of work experience is recommended.

The M.S. program requires the successful completion of the 6 core courses shown and 4 approved specialization track courses. The certificate program requires satisfactory completion of 4 core courses. Under **Systems**, the first three core subjects are: Systems Architecturing, Systems Engineering and Analysis I, and Systems Engineering and Analysis II. These address fundamental systems engineering topics, concepts and principles. Under **Management**, there are three courses, one addressing systems engineering management and the other addressing the organizational aspects of engineering management and final one addressing Economic Decision Analysis to reflect the reality that program decisions must include a proper understanding of economic consequences.

The **Specialization Tracks** provide the practicing engineer with the ability to address his/her technology education needs in the context of the overall Systems Engineering program. Twenty-two are shown below. With the permission and approval of the Program Director, a student may propose a different field other than those shown, or a combination of shown fields, if it meets the program and university criteria.

Master of Science In Systems Engineering Curriculum

CORE Courses

Systems

EMGT 469 - System Architecturing
EMGT 368 - Systems Engineering & Analysis I
EMGT 468 - Systems Engineering & Analysis II

Management

EMGT 361 - Project Management
EMGT 314 - Management for Engineers
EMGT 308 - Economic Decision Analysis

Specialization Tracks

(Choose 4 courses in an area or combination of areas)

Computational Intelligence (9)*, Data Mining and Knowledge Discovery(6)
Contemporary Structural Engineering (13), Geoenvironmental Engineering (9), Geotechnical Earthquake Engineering (8), Infrastructure Renewal (11)
Communication and Signal Processing (8)
Control Systems (6)
Economic Decision Analysis (6)
Finance and Accounting (6)
Technology Management (5), Integrated Enterprise (7) Integrated Flight and Control Systems (5), Structures (10) Human-Computer Integration (4)
Computer Systems (6), Information Systems (6), Software Engineering (6)
Manufacturing Systems (13)
Multimedia (8)
Network Centric Systems (6)
Nuclear Engineering (11)
Quality (7), Reliability (4)
Computational Software Systems (5), Software Engineering (5)
Modeling and Simulation (6), Financial Engineering (4)

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* The number in parenthesis indicates the number of courses available in the specialization track.

Requirements for Completion

M.S. in Systems Engineering

Students following their approved program of study will be assured of graduation upon maintenance of good academic standing. A minimum of 30 units of course work from the areas listed below must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a C grade or better in each course. Accumulation of more than 10 hours of C or F results in dismissal from the program. A maximum of 9 units may be transferred from other graduate programs. All courses applied to the degree require prior written advisor approval recorded on the study plan in the student's file. There is no thesis or comprehensive examination requirement. It is the responsibility of each student to apply for graduation with the UMR Registrar's Office during his or her last semester.

Systems Engineering Certificate Program

The Certificate Program will consist of 4 core courses (Emgt 368, Emgt 468, Emgt 469, and one of the following courses, namely; Emgt 314, Emgt 361, Emgt 308 or Emgt 408). This program is designed to appeal to working professionals. Certificate courses taken for graduate credit will apply to the M.S. degree. A minimum of 12 credits of course work from the areas listed below must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a C grade or better in each course. A maximum of 3 credits may be transferred from other graduate programs. If the four-course sequence is completed with a grade of “B” or better in each of the courses taken, they will be admitted to the MS Program in Systems Engineering. The certificate program may be followed by six additional 3-credit courses to complete the MS degree.

Technical Specialization Tracks

The Technical Specialization courses are electives. Once a specialization track is selected, students choose courses within the track as approved by the Systems Engineering Program Director. The program director can also approve a non-listed course for a specialization track course based on a student's particular need.

Not all courses shown are provided every semester or by distance means. See the Schedule of Classes for the semester of interest for current information.

Artificial/Computational/Intelligence Robotics

Computational Intelligence
CPE 331, CS 345, CS 347, Emgt/CS 378, CS/Emgt 404, CS 447, Emgt 476, Emgt 478, Emgt 479.

Data Mining & Knowledge Discovery
CS 304, CS 303, CS 347, CS/Emgt 404, CS 408, CS 447

Civil Engineering

Contemporary Structural Engineering

CE 319, CE 301 (320), CE 323, CE 326, CE 327, CE 328, CE 375, CE 424, CE 425, CE 426, AE/ME/EM 334, AE/ME/EM 336, AE/ME/EM 431

Geoenvironmental Engineering

CE 314, CE 315, CE 329, CE 360, CE 361, CE 362, CE 363, CE 367, CE 380

Geotechnical Earthquake Engineering

CE 315, CE 316, CE 329, CE 412, CE 413,

Infrastructure Renewal

CE 326, CE 327, CE 328, CE 374, CE 318/EE/AE/ME 329, AE 311/ME 382/EM 381, AE/ME 336, AE/ME 484

Communication Systems

Communication and Signal Processing
EE 243, EE 341, EE 343, EE 345, EE 347, EE 441, EE 443, Stat 414

Control Systems

Control Systems
EE 231, EE 331, EE 333, EE 337, EE 432, EE 438

Finance and Accounting

Finance and Accounting

Emgt 322, Emgt 332, Emgt 352, Emgt 408, Emgt 452, Stat 346

Engineering Management

Integrated Enterprise
Emgt 333, Emgt 352, Emgt 354, Emgt 366, Emgt 433, Emgt 451, Emgt 454

Technology Management
Emgt 320, Emgt 327, Emgt 354, Emgt 420, Emgt 441

Financial Engineering

Emgt 408, Emgt 452, Emgt 480, Emgt 481

Flight Systems

Integrated Flight and Control Systems
EE 331, AE 353, AE 361, AE 381, AE 479

Structures
AE 311, AE 334, AE 336, AE 344, AE 352, AE 408, AE 484, AE 485, AE 487, ME 436

Information Science and Technology

Human-Computer Interaction
IST 385, IST 386, IST 387, IST 480, IST 487

Information Systems and Computer Architecture

Computer Systems
CS 384, CS 385, CS 387, CS 483, CS 485, CS 487

Information Systems
CS 303, CS 304, CS 412, CS 486, CS/Emgt 404, CS 408

Manufacturing Systems

Manufacturing Systems
Emgt 334, Emgt 354, Emgt 364, Emgt 372, Emgt 385 Emgt 472, ME 308, ME 355, ME 368, ME 455, ME 459, Met Eng 307, Met Eng 377

Multi Media

Multi Media
CS 303, CS 304, CS 342, CS 343, CS 401A, CS 408, CS 412, CS 443

Network Centric Systems
CpE 319, CpE 349, EMgt 378, EMgt 419, EMgt 433, EMgt 479

Nuclear Engineering
Nuclear Engineering
NE 205, NE303, NE 307, NE 309, NE 322, NE 323, NE 341, NE 345, NE 423, NE 441, NE 490

Quality and Reliability Engineering

Quality Engineering
Emgt 364, Emgt 375, Emgt 381, Emgt 385, Emgt 387, Emgt 475, Stat 444

Reliability
EE/CpE 317, Emgt 381, EE 403, Stat 470

Software Systems

Computational Software Systems
CS 328, CS 329, CS 355, CS 422, CS 428
Software Engineering
CS 304, CS 306, CS 307, CS 308, CS 406, CS 483

Systems & Design Optimization

Modelling and Simulation
Math 303, Emgt 356, Emgt 374, Emgt 465, Emgt 476, BE 420/ME 461

Sample Curriculum

The first sample curriculum assumes a student is taking 2 courses per semester with a Computational Intelligence Specialty Track and the second one is a second MS degree student with Technology Management Specialization track. Students may take one or two courses per semester at their preference. Summer courses are also available.

MS Student (30 hours)

Spring 1:	Emgt 368, Emgt 314
Fall 1:	Emgt 468, Emgt 361
Spring 2:	Emgt 469, EE 368
Fall 2:	Emgt 308, Emgt 478
Spring 3:	Emgt 378, Emgt 479

2nd MS Student (24 hours)

Spring 1:	Emgt 368, Emgt 314
Fall 1:	Emgt 469, Emgt 327
Spring2:	Emgt 468, Emgt 361
Fall 2:	Emgt 420
Summer 1:	Emgt 308