Mechanical Engineering, Ph.D.

Research and Study

The graduate programs in mechanical engineering educate students in more depth and breadth than is possible at the baccalaureate level. This prepares the graduate to use contemporary methods at advanced levels in professional careers in engineering design, development, teaching, and research. Plans of study for all students are based on their background and career objectives, and are designed according to sound academic practice. Faculty members in the program have teaching and research expertise in energy and power conversion, fluid and thermal sciences, solid mechanics, mechanical systems, and related areas.

Students may develop programs emphasizing fluid mechanics, thermodynamics, heat transfer, fatigue and fracture mechanics, and mechanical systems. Some may pursue more general programs that combine emphases. Others may specialize in interdisciplinary areas (e.g., energy engineering, materials engineering, automatic control, chemical processes), which involve a combination of mechanical engineering departmental courses and appropriate electives from other departments in the College of Engineering and across the University. Doctor of Philosophy programs may center on any one of these areas through choice of appropriate course work and research topic.

The mechanical engineering program offers the following research and study areas.

Fluid Mechanics

The graduate program in fluid mechanics provides a rigorous and broad foundation in theoretical, numerical, and experimental aspects of the subject. It is especially suitable for those seeking careers in teaching and/or research in academic and industrial organizations. The program focuses on fundamental principles and techniques of solving problems in the varied fields of fluids engineering. It emphasizes computer use, both in mathematical modeling of flow phenomena and in acquisition and processing of experimental data.

Although most of the relevant courses are offered by the Department of Mechanical Engineering, students are strongly encouraged to take applied mathematics and classical mechanics courses offered by the Departments of Mathematics and Physics and Astronomy in the College of Liberal Arts and Sciences and by other College of Engineering departments.

Current research projects include computational modeling of viscous and turbulent flows; vortex dynamics; unsteady flows; pulmonary flow; flow separation and control; atmospheric flows; environmental flows; ship hydrodynamics; viscous flow around ships; propulsor flow and propulsor-body interactions; free-surface effects; nonlinear wave theory; biomimetic fluid mechanics; hydraulic turbines; quantitative flow visualization and image processing; computational fluid dynamics; LDV and thermal anemometry for flow analysis; and uncertainty analysis.

Mechanical Systems

The graduate program in mechanical systems is designed to provide students with a broad, strong background in theoretical, computational, experimental, and applied aspects of the subject. It prepares future graduates for careers in industry, teaching, and government. The program emphasizes fundamental principles, computational techniques, multiscale modeling and simulation, and experimentation used to analyze and design mechanical systems. Areas of concentration include reliability-based design and optimization, nanotechnology, tissue mechanics, machine and vehicle dynamics, optimal design, structural sensitivity analysis and optimization, computational solid mechanics, probabilistic mechanics, mechanics of composite materials, reliability, and fatigue and fracture mechanics.

Although most courses relevant to the specialization areas are offered by the Department of Mechanical Engineering, students are encouraged to consider appropriate course work from other areas, including courses offered by other College of Engineering departments and in disciplines such as mathematics, statistics, and physics.

Current research projects include computational mechanics, tissue mechanics, multiphysics, and multiple-scale problems; mechanics of multifunctional composites and nanocomposites, electromagnetic and thermal effects in composites, micromechanical modeling of multiphase composites and nanocomposites, impact and failure of composites, contact mechanics problems with friction and adhesion; stochastic meshfree and finite element methods; design sensitivity analysis of nonlinear structural systems; reliability-based design optimization; surrogate modeling for reliability-based design optimization; shape optimal design of elastoplastic materials; optimal design of metal stamping process; probabilistic and elastic-plastic fracture mechanics; damage tolerant design; fatigue behavior and life prediction under constant and variable amplitude loading; design sensitivity analysis of rigid and flexible mechanical systems; multibody system dynamics, tire dynamics, wheel and rail contact dynamics; wind turbine drivetrain dynamics; and vehicle system dynamics.

Robotics, Controls, and Autonomous Systems

The graduate program in robotics, controls, and autonomous systems provides students with a rigorous foundation on fundamental theoretical and experimental aspects of the subject. It prepares future graduates for careers in industry, teaching, and government. The program addresses challenges in modeling, analysis, design, and control of dynamic systems. Areas of focus include control theory, analysis of linear and nonlinear systems, optimal control theory, planning and control solutions for the operation of autonomous vehicles, artificial intelligence for scientific computing, machine learning, modern robotics, and robotics machine design.

The Department of Mechanical Engineering offers most courses relevant to this specialization area. However, students are encouraged to consider appropriate course work from other areas, including courses offered by other College of Engineering departments and in disciplines such as mathematics, statistics, physics, and computer science.

Current research projects include control of unmanned ground, marine, aerial, and space systems; control of networked systems; motion planning; robot manipulator design; design of robotics rehabilitation devices; human-
robot cooperation and interaction; numerical methods for optimal control; machine learning and artificial intelligence; unmanned systems for Earth observation; and autonomous transportation systems.

**Thermal Sciences**

The graduate program in thermal sciences and systems is designed to provide students with a rigorous and broad foundation in theoretical and experimental aspects of the subject. It prepares future graduates for careers in industry, teaching, and government. The program emphasizes fundamentals of thermodynamics and heat transfer, and associated analytical, numerical, and experimental methods used in energy systems. Areas of concentration include fluid mechanics, thermodynamics, heat transfer, phase-change, combustion, and fuel cells.

Most courses relevant to the specialization areas are offered by the Department of Mechanical Engineering. Students are encouraged to balance their programs by supplementing these with appropriate course work from other areas, including courses offered by other College of Engineering departments and in disciplines such as mathematics and physics.

Current research projects include biomass gasification; turbulent flames; combustion of biomass; alternative and renewable fuels; combustion instability; spray atomization and combustion; transport modeling of fuel cells; transport phenomena in materials processing, melting, and solidification; and optical-based diagnostics of complex thermal processes.

### Requirements

The Doctor of Philosophy program in mechanical engineering requires 72 s.h. of graduate credit, including research for the dissertation. A minimum of 42 s.h. must be earned in course work (except thesis research), including at least 18 s.h. in mechanical engineering courses (prefix ME) numbered at the 6000 and 7000 level. At least 12 s.h. of Ph.D. thesis research must be earned in ME:7299 Research: Mechanical Engineering Ph.D. Dissertation, which is graded by a student's advisor. Students must have a final cumulative g.p.a. higher than 3.25 to earn their degree.

Students must have their graduate course plan approved by their advisor prior to registration. They must complete ENGR:7270 Engineering Ethics during their first fall semester of enrollment. All students must register for ME:6191 Graduate Seminar: Mechanical Engineering each fall and spring semester until successful completion of their final examination or thesis defense.

To be formally admitted to the Ph.D. program, students must pass the qualifying examination. This examination is administered by the Graduate Committee and consists of a written exam during the first three weeks of their course work in the spring semester. Upon receiving the M.S. degree in mechanical engineering from The University of Iowa and entering the Ph.D. program, students must take the qualifying examination at its first offering. Students from another institution with a M.S. degree must take the qualifying examination within three semesters (excluding summer session). Those who enter with a B.S. degree must take the qualifying examination within four semesters (excluding summer session).

### Admission

Applicants must meet the admission requirements of the Graduate College; for detailed information about Graduate College policies, see the Manual of Rules and Regulations of the Graduate College on the Graduate College website.

Applicants who have earned a baccalaureate or master's degree in engineering curriculum or in the mathematical or physical sciences are eligible to be considered for admission to graduate study in mechanical engineering. In order to be considered for regular admission, applicants must have a g.p.a. of at least 3.25 on a 4.00 scale on all previous college-level work and Graduate Record Examination (GRE) General Test scores of at least 500 verbal, 750 quantitative, and 4.5 in analytical writing. Students whose first language is not English must score at least 81 (internet-based) on the Test of English as a Foreign language (TOEFL).

Applicants with a lower grade-point average and/or GRE or TOEFL test scores may be considered for conditional admission, under exceptional circumstances. Applicants admitted conditionally must achieve regular standing within one semester (excluding summer sessions) after admission by attaining a g.p.a. of at least 3.00 on their first 9 s.h. at the University of Iowa. The Graduate College cancels registration for the subsequent semester for students who have not submitted their GRE and/or TOEFL scores by the end of the first semester after admission.

### Financial Support

Financial support is available to Ph.D. students, primarily through graduate assistantships in teaching or research from the Department of Mechanical Engineering, the Center for Computer-Aided Design, IIHR—Hydroscience and Engineering, and the National Advanced Driving Simulator. These awards may be made on a semester, academic year, or calendar year basis. Awards and reappointments are competitive and are based on a student's potential contribution to the teaching and research goals of the department. Students who fulfill their assistantship responsibilities and continue to make satisfactory progress toward their degree objective receive preference in new assistantship awards. All applications for financial support should be submitted directly to the department chair.

Students with assistantship appointments of one-quarter-time or more must register for a minimum of 9 s.h. during fall and spring semesters until they have completed 72 s.h. of course and research work beyond the baccalaureate degree. Once they meet these minimums, students must register for a graduate seminar each semester until they have successfully completed their final examination or thesis defense. All registrations should accurately reflect the amount and type of work undertaken, the use of University facilities, and the amount of consultation with the faculty.

### Career Advancement

The engineering profession is a foundation for a variety of careers in industry, medicine, law, government, and consulting.

Engineering Professional Development (EPD) develops and promotes experiential education and professional opportunities for students in the College of Engineering. Professional staff coordinate the college's co-op and internship program, engage in employer outreach, and
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provide opportunities for students to network with employers, including an engineering career fair each semester and other programming related to career development.

EPD also offers individual advising and class presentations on résumé and cover letter preparation, job and internship search strategies, interviewing skills, and job offer evaluation.