Computational and Applied Mathematics

The George R. Brown School of Engineering

Chair
Danny C. Sorensen

Professors
John Edward Akin (joint MEMS)
Michael M. Carroll (joint MEMS)
Steven J. Cox
Matthias Heinkenschloss
Danny C. Sorensen
William W. Symes
Richard A. Tapia
Yin Zhang

Professors Emeriti
Robert E. Bixby
Sam H. Davis (joint CENG)
John E. Dennis
Angelo Miele (joint MEMS)
Paul E. Pfeiffer
Henry Rachford
Chao-Cheng Wang (joint MEMS)

Associate Professor
Liliana Borcea

Assistant Professors
Mark Embree
E. Mckay Hyde
Tim Warburton
Wotao Yin

Adjunct Professors
J. Bee Bednar
Richard Carter
Elmer Eisner
Roland Glowinski
Martin Golubitsky
Donald W. Peaceman
Michael B. Ray

Adjunct Associate Professors
Amr El-Bakry
Scott A. Morton
Michael W. Trosset

Adjunct Assistant Professors
Charles Audet
Fabrizio Gabbiani
Thomas Guerrero
Petr Kloucek
Cassandra M. McZeal
Harel Z. Shouval
Paul D. Smolen
Andreas S. Tolias

Research Professors
Robert E. Bixby
John E. Dennis

Faculty Fellow
Michael Fagan

Instructors
Kirk D. Blazek
Elaine T. Hale
Dmitriy Leykekhman

Degrees Offered: BA, MCAM, MCSE, MA, PhD

Courses within this major can provide foundations applicable to the many fields of engineering, physical sciences, life sciences, behavioral and social sciences, and computer science. Undergraduate majors have considerable freedom to plan a course of study consistent with their particular interests.

The professional degree (MCAM), for persons interested in practicing within this field, emphasizes general applied mathematics, operations research andoptimization, and numerical analysis, while the MA and PhD programsconcentrate on research. Faculty research interests fall in the 4 general areas of numerical analysis and computation; physical mathematics; operations research and optimization; and mathematical modeling in physical, biological, or behavioral sciences.

A further advanced degree program in computational science and engineering (CSE) addresses the current need for sophisticated computation in both engineering and the sciences. Such computation requires an understanding of

parallel and vector capabilities and a range of subjects including visualization, networking, and programming environments. An awareness of a variety of new algorithms and analytic techniques also is essential to maximizing the power of the new computational tools.

A joint MBA/Master of Engineering degree also is available in conjunction with the Jesse H. Jones Graduate School of Management.

Degree Requirements for BA in Computational and Applied Mathematics

For general university requirements, see Graduation Requirements (pages 14–15). Students majoring in computational and applied mathematics are required to complete the 51 semester hours spelled out in the following program of study.

Introductory Courses: Typically completed during the 1st 2 years

MATH 101 *Single Variable Calculus I**
MATH 102 *Single Variable Calculus II*
MATH 212 *Multivariable Calculus*
COMP 110 *Computation in Science and Engineering**
CAAM 210 *Introduction to Engineering Computation*
CAAM 335 *Matrix Analysis*

*Students with prior experience with calculus and/or computational science may petition the department for a waiver.

Entering students should enroll in the most advanced course commensurate with their background; advice is available from the CAAM department during Orientation Week.

Intermediate Courses: Typically completed by the end of the 3rd year

CAAM 336 *Differential Equations in Science and Engineering*
(or STAT 310 *Probability and Statistics* or STAT 331 *Applied Probability)*
CAAM 378 *Introduction to Operations Research and Optimization*
CAAM 401 *Analysis I*
CAAM 402 *Analysis II*

Advanced Courses: Typically completed during the 4th year

CAAM 453 *Numerical Analysis I*
CAAM 454 *Numerical Analysis II*

Electives: 5 courses at 300 level or above; 2 of which must be at the 400-level or above (chosen in consultation with the CAAM undergraduate advisor).

Highly Recommended Electives:

CAAM 415 *Theoretical Neuroscience*
CAAM 420 *Computational Science I*
CAAM 436 *Partial Differential Equations of Mathematical Physics*
CAAM 460 *Optimization Theory*
MATH 423 *Partial Differential Equations*
MATH 425 *Integration Theory*
MATH 427 *Complex Analysis*
STAT 431 *Overview of Mathematical Statistics*

Degree Requirements for MCAM, MA, and PhD in Computational and Applied Mathematics

Admission—Admission to graduate study in computational and applied mathematics is open to qualified students holding bachelor's or master's

degrees (or their equivalent) in engineering; mathematics; or the physical, biological, mathematical, or behavioral sciences. Department faculty evaluate the previous academic record and credentials of each applicant individually. For general information, see Graduate Degrees (pages 57–58) and Admission to Graduate Study (pages 56–57).

Applicants should be aware that it normally takes 2 years to obtain a master's degree and an additional 2 to 4 years for the doctoral degree.

MCAM Program—This professional degree program emphasizes the applied aspects of mathematics. The MCAM degree requires satisfactory completion of at least 30 semester hours of course work approved by the department.

MA Program—For an MA in computational and applied mathematics, students must:

- Complete at least 30 semester hours at the graduate level, including 5 courses in computational and applied mathematics, in addition to thesis work
- Produce an original thesis acceptable to the department
- Perform satisfactorily on a final public oral examination on the thesis

For students working toward the PhD, successful performance on the master's thesis may fulfill the PhD thesis proposal requirements upon approval by the thesis committee.

PhD Program—For a PhD in computational and applied mathematics, students must:

- Complete a course of study approved by the department, including at least 2 courses outside the major area
- Perform satisfactorily on preliminary and qualifying examinations and reviews
- Produce an original thesis acceptable to the department
- Perform satisfactorily on a final public oral examination on the thesis

Financial Assistance—Graduate fellowships, research assistantships, and graduate scholarships are available and are awarded on the basis of merit to qualified students. Current practice in the department is for most doctoral students in good standing to receive some financial aid.

Degree Requirements for MCSE and PhD in Computational Science and Engineering

CSE Program Area—Recognizing the increasing reliance of modern science and engineering on computation as an aid to research, development, and design, the Department of Computational and Applied Mathematics, in conjunction with the Departments of Biochemistry and Cell Biology, Earth Science, Computer Science, Chemical and Biomolecular Engineering, Electrical and Computer Engineering, Environmental Science and Engineering, and Statistics, has established an advanced degree program in computational science and engineering (CSE). The program focuses on modern computational techniques and provides a resource for training and expertise in this area.

The program is administered by a faculty committee chosen by the deans of engineering and natural sciences, with ultimate oversight by the provost. The Computational Science Committee (CSC) helps students design an appropriate course of study and sets the examination requirements.

Students may enter the CSE program either directly or indirectly through one of the participating departments (see list above). In all cases, however, students must fulfill the admissions requirements of 1 department, which is their associated department. Students then meet the normal requirements for graduate study within that department in every way (including teaching and other duties), except that the curriculum and examination requirements are set by the CSC.

MCSE Program—This program's intent is to produce professional experts in scientific computing able to work as part of an interdisciplinary research team. Training is concentrated in state-of-the-art numerical methods, high-performance computer architectures, use of software development tools for parallel and vector computers, and the application of these techniques to at least 1 scientific or engineering area. For general university requirements, see Graduate Degrees (pages 57–58).

Required Courses

CAAM 420 *Computational Science I* (taken as soon as possible)

CAAM 520 *Computational Science II* (taken as soon as possible)

CAAM 551 *Numerical Linear Algebra*

1 course from the following

COMP 412 *Compiler Construction*

(or ELEC 425 *Computer Systems Architecture*)

CAAM 452 *Numerical Methods for Differential Equations*

CAAM 453 *Numerical Analysis I*

CAAM 454 *Numerical Analysis II*

CAAM 464 *Numerical Optimization*

Computational Science Electives

4 courses selected from an approved list of COMP or CAAM courses (at least 2 courses at the 500 level)

Open Electives

2 approved courses other than CAAM or COMP courses at the 300 level or above (a computational project taken within a participating department also satisfies this requirement)

Application Areas

An appropriate sequence of courses from a participating application area at the 300 level or above

For the MCSE degree, students must complete at least 30 semester hours of course work approved by the CSC; no more than 2 of the courses may be taken at the 300 level, taken outside the CSE program area, or satisfied by transfer credit. Each student's program of study must meet the requirements listed below. Modification of requirements can be requested by petition.

PhD Program—Study at the doctoral level seeks to advance the field through original research. For general university requirements, see Graduate Degrees (pages 57–58). For the PhD in computational science and engineering, students must:

- Complete a course of study approved by the CSC, including at least 2 courses outside the major area
- Perform satisfactorily on preliminary and qualifying examinations and reviews
- Produce an original thesis acceptable to the CSC
- Perform satisfactorily on a final public oral examination on the thesis

See CAAM in the Courses of Instruction section.