INSTITUTE FOR COMPUTATIONAL AND MATHEMATICAL ENGINEERING

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Professors (Research): Walter Murray (Management Science and Engineering), Michael A. Saunders (Management Science and Engineering)
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Courses given in Computational and Mathematical Engineering have the subject code CME. For a complete list of subject codes, see Appendix.

The Institute for Computational and Mathematical Engineering's central research mission is to develop sophisticated algorithmic and mathematical tools that impact many applied disciplines. ICME leverages Stanford's strengths in engineering applications and the physical, biological, and earth sciences to guide the development of modern methods for research and education in computational mathematics including mathematical modeling of engineering systems using computer simulation technology and numerical simulation for discovery-driven engineering research, theory, and physical experiments.

ICME's central teaching mission is to ensure that Stanford's computational engineers are well trained in mathematical modeling and computer programming for numerical computation. ICME strives to integrate numerical computation in all its course offerings to facilitate application of mathematical techniques and theories to real world problems.

ICME research covers broad mathematical and computational areas of interest to all engineering departments from discrete mathematics, including computational probability and combinatorial optimization, to numerical solution of partial differential equations representing physical devices. The institute identifies research areas that benefit from a multidisciplinary approach in which computational mathematics plays a key role.

A unique strength of ICME is its multidisciplinary intellectual environment, with attendant interaction among students and faculty with diverse backgrounds and expertise. ICME offers service courses for undergraduates and graduate students to fulfill departmental requirements, core courses for M.S. and Ph.D. students in Scientific Computing and Computational Mathematics, and specialized electives in various application areas.

GRADUATE PROGRAMS

University regulations governing the M.S. and Ph.D. degrees are described in the "Graduate Degrees" section of this bulletin.

MASTER OF SCIENCE

The M.S. degree in Computational and Mathematical Engineering is intended as a terminal professional degree and does not lead to the Ph.D. program. Students interested in the doctoral program should apply directly to the Ph.D. program. Master's students who have maintained a minimum grade point average (GPA) of 3.5 are eligible to take the Ph.D. qualifying exam; those who pass this examination may continue into the Ph.D. program.

The master's program consists of 45 units of course work taken at Stanford. No thesis is required; however, students may become involved in research projects during the master's program, particularly to explore an interest in continuing to the doctoral program. Although there is no specific background requirement, significant exposure to mathematics and engineering course work is necessary for successful completion of the program.

Applications for admission to the M.S. program, including all required supporting documents, must be submitted by January 24, 2006. Exceptions are made for applicants who are already students at Stanford and are applying to the coterminal program. Please contact the department for deadline information.

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/publications/#Coterm.

REQUIREMENTS

A candidate is required to complete a program of 45 units of courses numbered 200 or above. At least, 36 of these must be graded units, passed with a grade point average (GPA) of 3.0 (B) or better. Master's students interested in continuing to the doctoral program must maintain a 3.5 or better grade point average in the program.

Requirement 1—The following courses may be needed as prerequisites for other courses in the program: MATH 41, 42, 51, 52, 53, 103, 113, 220A; CME 100, 102, 104, 108, 200, 204, 302; CS 106A, 106X, 108, 205, 229; ENGR 62; ME 346; MS&E 211, 310, 311, 312, 314, 315; STATS 116 or 202.

Requirement 2—Students must demonstrate breadth of knowledge in the field by completing the following core courses:
CME 302. Numerical Linear Algebra
CME 304. Numerical Optimization
CME 305. Discrete Mathematics and Algorithms
CME 306. Numerical Solution of Partial Differential Equations
CME 308. Stochastic Methods in Engineering
MATH 220A. Partial Differential Equations of Applied Mathematics

Deviations from the core curriculum must be justified in writing and approved by the student's ICME adviser and the chair of the ICME curriculum committee. Courses that are waived may not be counted towards the master's degree.

Requirement 3—12 units of electives in the eight application areas listed below must be completed. Except for the three units of independent research, all courses in this area must be taken for letter grades. The elective course list represents automatically accepted electives within the program and the list is expanded on a continuing basis; the elective part of the ICME program is meant to be broad and inclusive of relevant courses of comparable rigor to ICME courses. Courses outside this list can be accepted as electives subject to approval of the student's ICME adviser and the chair of the ICME curriculum committee.

1. *Aeronautics and Astronautics:*
   AA 214A. Numerical Methods in Fluid Mechanics
   AA 214B. Numerical Computation of Compressible Flow
   AA 214C. Numerical Computation of Viscous Flow
   AA 215A,B. Advanced Computational Fluid Dynamics
   AA 218. Introduction to Symmetry Analysis

2. *Civil and Environmental Engineering:*
   CEE 281. Finite Element Structural Analysis
   CME 208. Mathematical Programming and Combinatorial Optimization
   CME 210. Multiscale Methods in Engineering
   CME 212. Introduction to Large Scale Computing in Engineering
   CME 324. Advanced Methods in Matrix Computation
   CME 326. Numerical Methods for Initial Boundary Value Problems
   CME 342. Parallel Methods in Numerical Analysis
3. *Computer Science:*
   CS 205. Mathematical Methods for Robotics, Vision, and Graphics
   CS 221. Artificial Intelligence: Principles and Techniques
   CS 228. Probabilistic Models in Artificial Intelligence
   CS 229. Machine Learning
   CS 255. Introduction to Cryptography
   CS 261. Optimization and Algorithmic Paradigms
   CS 315A. Parallel Computer Architecture and Programming
   CS 340. Level Set Methods
   CS 348A. Computer Graphics: Geometric Modeling
   CS 365. Randomized Algorithms
4. *Electrical Engineering:*
   EE 222. Applied Quantum Mechanics I
   EE 223. Applied Quantum Mechanics II
   EE 262. Two-Dimensional Imaging
   EE 278. Introduction to Statistical Signal Processing
   EE 292E. Analysis and Control of Markov Chains
   EE 363. Linear Dynamic Systems
   EE 364. Convex Optimization
   EE 376A. Information Theory
5. *Management Science and Engineering:*
   MS&E 220. Probabilistic Analysis
   MS&E 221. Stochastic Modeling
   MS&E 223. Simulation
   MS&E 251. Stochastic Decision Models
   MS&E 310. Linear Programming
   MS&E 313. Vector Space Optimization
   MS&E 316. Pricing Algorithms and the Internet
   MS&E 321. Stochastic Systems
   MS&E 322. Stochastic Calculus and Control
   MS&E 323. Stochastic Simulation
6. *Mechanical Engineering:*
   ME 335A,B,C. Finite Element Analysis
   ME 469A,B. Computational Methods in Fluid Mechanics
   ME 484. Computational Methods in Cardiovascular Bioengineering
7. *Statistics:*
   STATS 227. Statistical Computing
   STATS 237. Time Series Modeling and Forecasting
   STATS 250. Mathematical Finance
   STATS 324. Classical Multivariate and Random Matrix Theory
   STATS 345. Computational Molecular Biology
   STATS 362. Monte Carlo Sampling
   STATS 366. Computational Biology
8. *Other:*
   ENGR 209A. Analysis and Control of Nonlinear Systems
   MATH 220B,C. Partial Differential Equations of Applied Mathematics

Requirement 4—9 units of focused graduate application electives, approved by ICME graduate adviser, in the areas of Engineering, Mathematics, and Physical, Biological, and other quantitative sciences.

Requirement 5—3 units of ICME graduate seminar (CME 500) or other approved seminar sequence.

DOCTOR OF PHILOSOPHY:

Applications to the Ph.D. program and all required supporting documents must be received by January 10, 2006. See http://icme.stanford.edu /admissions/ for up-to-date information.

Admission to the Ph.D. program does not imply that the student is a candidate for the Ph.D. degree. Advancement to candidacy requires superior academic achievement, and completion of the qualifying examination.

Requirements—Ph.D. students must (1) complete a minimum of 135 units of residency at Stanford, including 45 units from the master's program, 27 units of focused electives in an area planned with the student's Ph.D. adviser, 12 units from ICME specialized electives (CME courses numbered 320-380), 60 units of thesis research, and 3 units of free electives; (2) maintain a grade point average (GPA) of 3.5; (3) pass the two qualifying examinations administered by ICME; (4) complete an approved course of study in computational and mathematical engineering; (5) complete an approved program of original research and a written dissertation based on research; and (6) pass an oral examination that is a defense of the dissertation research.

PH.D. MINOR:

For a minor in Computational and Mathematical Engineering (CME), a doctoral candidate must complete 20 unduplicated units in the program. These should include three ICME core courses and three ICME graduate electives at the 300 level or above. A maximum of two units can be taken as ICME seminar units. All courses excepting the seminar courses must be taken for a letter grade and passed with a grade of 'B' or better. Minor programs must receive approval from the ICME curriculum chair prior to completing any of the ICME graduate electives. Minor programs should be developed in close discussion between the student and their primary Ph.D. adviser.

FINANCIAL ASSISTANCE

The department awards a limited number of fellowships, course assistantships, and research assistantships to incoming graduate students. Applying for such assistance is part of submitting the application for admission to the program.

Students are appointed for half-time assistantships which provides a tuition scholarship at the 8, 9, 10 unit rate during the academic year and a monthly stipend. Half-time appointments generally require 20 hours of work per week. Most course assistantships and research assistantships are awarded to students in the doctoral program in ICME. If the number of Ph.D. students are not sufficient to staff all course and research assistantship positions available, these positions may be open to master's students. However, master's students are not guaranteed financial assistance.

COURSES

CME 100. Vector Calculus for Engineers—(Formerly ENGR 154.) Computation and visualization using MATLAB. Differential vector calculus: analytic geometry in space, functions of several variables, partial derivatives, gradient, unconstrained maxima and minima, Lagrange multipliers. Integral vector calculus: multiple integrals in Cartesian, cylindrical, and spherical coordinates, line integrals, scalar potential, surface integrals, Green's, divergence, and Stokes' theorems. Examples and applications drawn from various engineering fields. Prerequisites: MATH 41 and 42, or 10 units AP credit. GER:DB-Math

5 units, Aut (Darve, Khayms)

CME 102. Ordinary Differential Equations for Engineers—(Formerly ENGR 155A.) Analytical and numerical methods for solving ordinary differential equations arising in engineering applications: Solution of initial and boundary value problems, series solutions, Laplace transforms, and non-linear equations; numerical methods for solving ordinary differential equations, accuracy of numerical methods, linear stability theory, finite differences. Introduction to MATLAB programming as a basic tool kit for computations. Problems from various engineering fields. Prerequisite: CME 100 (formerly ENGR 154) or MATH 51. GER:DB-Math

5 units, Win (Darve)

CME 104. Linear Algebra and Partial Differential Equations for Engineers—(Formerly ENGR 155B.) Linear algebra: matrix operations, systems of algebraic equations, Gaussian elimination, undetermined and overdetermined systems, coupled systems of ordinary differential equations, eigensystem analysis, normal modes. Fourier series with applications, partial differential equations arising in science and engineering, analytical solutions of partial differential equations. Numerical methods for solution of partial differential equations: iterative techniques, stability and convergence, time advancement, implicit methods, von Neumann stability analysis. Examples and applications from various engineering fields. Prerequisite: 102. GER:DB-Math

5 units, Spr (Khayms)

CME 106. Introduction to Probability and Statistics for Engineers—(Formerly ENGR 155C.) Probability: random variables, independence, and conditional probability; discrete and continuous distributions, moments, distributions of several random variables. Topics in mathematical statistics: random sampling, point estimation, confidence intervals, hypothesis testing, non-parametric tests, regression and correlation analyses; applications in engineering, industrial manufacturing, medicine, biology, and other fields. Prerequisite: CME 100 (formerly ENGR 154) or MATH 51. GER:DB-Math

4 units, Win (Khayms)

CME 108. Introduction to Scientific Computing—Numerical computation for mathematical, computational, and physical sciences and engineering: numerical solution of systems of algebraic equations, least squares, quadrature, minimization of a function, banded matrices, nonlinear equations, numerical solution of ordinary and partial differential equations; truncation error, numerical stability for time dependent problems, stiffness, boundary value problems. Prerequisites: CS106A or familiarity with MATLAB; MATH 51, 52, 53; inappropriate for students who have taken CME 102, 104 (formerly ENGR155A,B). GER: DB-EngrAppSci

3-4 units, Win (Golub)

CME 110. Matrix Computations with Applications to Data Mining and IT—Basic matrix factorizations, numerical stability, updating/downdating procedures; data mining and knowledge discovery, application to information retrieval, text mining, search engines, character recognition, medical informatics, bioinformatics. Mathematical, numerical, and statistical techniques. Prerequisites: CS 106A; MATH 103 or 113; or equivalents.

3 units (Golub) alternate years, given 2006-07

CME 200. Linear Algebra with Application to Engineering Computations—(Formerly ME 300A.) Direct and iterative methods to solve linear systems of equations arising in engineering applications. The theory of linear algebra: basis, linear independence, column space, null space, rank; round off errors, pivoting, and ill-conditioned matrices; norms and condition numbers; projections and least squares; eigenvalues, eigenvectors, and their computation; the canonical diagonal form; and functions of a matrix; solution of systems of nonlinear equations arising in engineering applications. Recommended :familiarity with computer programming; MATH 103, 130, or equivalents.

3 units, Aut (Gerritsen)

CME 204. Partial Differential Equations in Engineering—(Formerly ME 300B.) Geometric interpretation of partial differential equations (PDEs) characteristics, solution of first order PDEs and classification of second-order PDEs, self-similarity, separation of variables as applied to parabolic, hyperbolic, and elliptic PDEs, special functions, eigenfunction expansions, the method of characteristics. If time permits, Fourier integrals and transforms, Laplace transforms. Prerequisite: CME 200 (formerly ME 300A), equivalent, or consent of instructor.

3 units, Win (Shaqfeh)

CME 206. Introduction to Numerical Methods for Engineering—(Formerly ME 300C.) Numerical methods from a user's point of view. Lagrange interpolation, splines; Integration: trapezoid, Romberg, Gauss, adaptive quadrature; numerical solution of ordinary differential equations: explicit and implicit methods, multistep methods, Runge-Kutta and predictor-corrector methods, boundary value problems, eigenvalue problems; Systems of differential equations, stiffness. Emphasis is on the analysis of numerical methods for accuracy, stability, and convergence. Introduction to numerical solutions of partial differential equations; Von Neumann stability analysis; alternating direction implicit methods and non-linear equations. Prerequisite: 200 (formerly ME 300A).

3 units, Spr (Farhat)

CME 208. Mathematical Programming and Combinatorial Optimization—(Same as MS&E 112/212.) Combinatorial and mathematical programming (integer and non-linear) techniques for optimization. Topics: linear program duality and LP solvers; integer programming; combinatorial optimization problems on networks including minimum spanning trees, shortest paths, and network flows; matching and assignment problems; dynamic programming; linear approximations to convex programs; NP-completeness. Hands-on exercises. Prerequisites: CS 106A or X; ENGR 62 or MATH 103. GER:DB-EngrAppSci

3 units, Spr (Goel)

CME 210. Multiscale Methods in Engineering—Multigrid methods to solve partial differential equations including anisotropic and nonlinear equations; multilevel adaptive refinement; fast multipole methods based on Taylor expansions, Chebyshev polynomials, plane wave representation, and singular value decomposition; and wavelets for signal and image compression, Haar wavelets, splines, and multiscale representation of curves and surfaces. Prerequisites: numerical methods (iterative solution of linear equations, interpolation, partial differential equations), scientific programming language.

3 units (Darve) not given 2005-06

CME 212. Introduction to Large-Scale Computing in Engineering—Advanced programming methodologies for solving fundamental engineering problems using algorithms with pervasive application across disciplines. Overview of computer systems from a programming perspective including processor architectures, memory hierarchies, machine arithmetic, performance tuning techniques. Algorithms include iterative, direct linear solvers, fft, and divide and conquer strategies for n-body problems. Software development; other practical UNIX tools including shell scripting (bash), vi/emacs, gcc, make, gdb, gprof, rcs, and latex. Prerequisites: 200 (formerly ME 300A), and CS 106X or equivalent level of programming in C/C++.

3 units, Win (Fringer)

CME 291. Master's Research—Students require faculty sponsor.

1-5 units, Aut, Win, Spr, Sum (Staff)

CME 300. Departmental Seminar Series—Required for first-year ICME Ph.D. students; recommended for first-year ICME M.S. students. Presentations about research at Stanford by faculty and researchers from Engineering, H&S, and organizations external to Stanford.

1 unit, Aut, Win, Spr (Murray)

CME 301. Partial Differential Equations of Applied Mathematics—(Enroll in MATH 220A.)

3 units, Aut (Liu)

CME 302. Numerical Linear Algebra—First in a three quarter graduate sequence. Solution of systems of linear equations: direct methods, error analysis, structured matrices; iterative methods and least squares. Parallel techniques. Prerequisites: CME108, MATH 103 or 113.

3 units, Aut (Golub)

CME 304. Numerical Optimization—(Same as MS&E 315.) Solution of nonlinear equations; unconstrained optimization; linear programming; quadratic programming; global optimization; general linearly and nonlinearly constrained optimization. Theory and algorithms to solve these problems. Prerequisite: background in analysis and numerical linear algebra.

3 units, Win (Murray)

CME 305. Discrete Mathematics and Algorithms—Topics: enumeration (permutations, stirling numbers, Cayley's theorem) SDR, flows and cuts (deterministic and randomized algorithms), eigenvalues and expansion arguments, asymptotics (NP-hardness and approximation algorithms). Topics illustrated with EE, CS, and bioinformatics applications. Prerequisites: MATH 51 or 103 or equivalents.

3 units, Win (Saberi)

CME 306. Numerical Solution of Partial Differential Equations—Hyperbolic partial differential equations: stability, convergence and qualitative properties; nonplinear hyperbolic equations and systems; combined solution methods from elliptic, parabolic, and hyperbolic problems. Examples include: Burgers equation, Euler equations for compressible flow, Navier-Stokes equations for incompressible flow. Prerequisites: Prerequisites: CME 302, MATH 220A.

3 units, Spr (Fedkiw)

CME 308. Stochastic Methods in Engineering—Review of basic probability; state space models and time series; parameter estimations, prediction, and filtering; Markov chains and processes; stochastic control; and stochastic differential equations. Examples from various engineering disciplines. Prerequisites: exposure to probability; background in real variables and analysis.

3 units, Spr (Glynn)

CME 320. Partial Differential Equations of Applied Mathematics—(Enroll in MATH 220B.)

3 units, Win (Liu)

CME 322. Spectral Methods in Computational Physics—(Formerly ME 408.) Data analysis, spectra and correlations, sampling theorem, nonperiodic data, and windowing; spectral methods for numerical solution of ordinary and partial differential equations; accuracy and computational cost; fast Fourier transform, Galerkin, collocation, and Tau methods; spectral and pseudospectral methods based on Fourier series and eigenfunctions of singular Sturm-Liouville problems; Chebyshev, Legendre, and Laguerre representations; convergence of eigen function expansions; discontinuities and Gibbs phenomenon; aliasing errors and control; efficient implementation of spectral methods; spectral methods for complicated domains; time differencing and numerical stability.

3 units, Aut (Moin)

CME 324. Advanced Methods in Matrix Computation: Iterative Methods—Eigenvalue problems: perturbation theory, Lanczos method, Jacobi method. Parallel implementation. Singular value problems. Generalized eigenvalue problems. Polynomial equations. Prerequisite: CME 302.

3 units, Spr (Golub)

CME 326. Numerical Methods for Initial Boundary Value Problems—Initial boundary value problems are solved in different areas of engineering and science modeling phenomena, such as wave propagation and vibration, and fluid flow. Numerical techniques for such simulations in the context of applications. Emphasis is on stability and convergence theory for methods for hyperbolic and parabolic initial boundary value problems, and the development of efficient methods for these problems.

3 units, Win (Gustaffson)

CME 330. Applied Mathematics in the Chemical and Biological Sciences—Mathematical solution methods via applied problems including chemical reaction sequences, mass and heat transfer in chemical reactors, quantum mechanics, fluid mechanics of reacting systems, and chromotography. Topics include generalized vector space theory, linear operator theory with eigenvalue methods, phase plane methods, perturbation theory (regular and singular), solution of parabolic and elliptic partial differential equations, and transform methods (Laplace and Fourier). Prerequisites: CME 102, CME 104 (formerly ENGR 155A, 155B), or equivalents.

3 units, Aut (Shaqfeh)

CME 332. Computational Methods for Scientific Reasoning and Discovery—Computational approaches to representing, reasoning with, and inferring scientific knowledge. Formation of taxonomies, induction of descriptive laws, and construction of explanatory models. Examples include reconstructions from the history of physics and chemistry, and generation of new results in biology and Earth science. Methods to represent, use, and infer scientific knowledge. Prerequisites: familiarity with artificial intelligence and list processing; ability to think computationally in terms of knowledge structures and mechanisms that operate on them.

3 units, Spr (Langley)

CME 334. Advanced Methods in Numerical Optimization—(Same as MS&E 312.) Topics include interior-point methods, relaxation methods for nonlinear discrete optimization, sequential quadratic programming methods, optimal control and decomposition methods. Topic chosen in first class; different topics for individuals or groups possible. Individual or team projects. May be repeated for credit.

3 units, Aut (Murray)

CME 336. Linear and Conic Optimization with Applications—(Same as MS&E 314.) Linear, semidefinite, conic, and convex nonlinear optimization problems as generalizations of classical linear programming. Algorithms include the simplex method, interior-point methods, barrier function methods, cutting plane methods. Related convex analysis, including the separating hyperplane theorem, Farkas lemma, dual cones, optimality conditions, and conic inequalities. Complexity and/or computation efficiency analysis. Applications to max-cut problems, Markov chain mixing times, support vector machines for data mining and classification, graph partitioning, robust portfolio selection, and Euclidean distance geometry. Prerequisite: 211 or equivalent.

3 units (Ye) alternate years, given 2006-07

CME 338. Large-Scale Numerical Optimization—(Same as MS&E 318.) The main algorithms and software for constrained optimization emphasizing the sparse-matrix methods needed for their implementation. Iterative methods for linear equations and least squares. Interior methods. The simplex method. Factorization and updates. The reduced-gradient, augmented Lagrangian, and SQP methods. Recommended: MS&E 310, 311, 312, 314, or 315; CME 108 or 302.

3 units, Spr (Saunders)

CME 340. Computational Methods in Data Mining—Project course. Focus is on very large scale data mining. Topics include computational methods in supervised and unsupervised learning, association mining, and collaborative filtering. Individual or group applications-oriented programming project. Prerequisites: statistics and linear algebra at the level of MATH 103 and STATS 116; programming at the level of CS 108. Recommended: machine learning at the level of CS 229 or STATS 202.

3 units, Spr (Kamvar)

CME 342. Parallel Methods in Numerical Analysis—Emphasis is on techniques for obtaining maximum parallelism in numerical algorithms, especially those occurring when solving matrix problems and partial differential equations, and the subsequent mapping onto the computer. Implementation issues on parallel computers. Topics: parallel architecture, programming models, matrix computations, FFT, fast multiple methods, domain decomposition, and graph partitioning. Prerequisite: 302 or 200 (formerly ME 300A), or consent of instructor. Recommended: differential equations and advanced programming language such as C or C++.

3 units, Spr (Alonso)

CME 344. Pricing Algorithms and the Internet—(Same as MS&E 316.) Market equilibria: existence and efficiency of computation; and prices as duals of linear and convex programs. Applications in the context of the Internet such as routing and congestion control. Market design in electronic commerce. Algorithms for finding game theoretic solution concepts. Internet structure: power-law networks, models, games, and algorithms. Prerequisite: basic algorithms, optimization, and probability theory.

3 units (Saberi) alternate years, given 2006-07

CME 346. Engineering Functional Analysis and Finite Elements—(Enroll in ME 412.)
3 units, Spr (Lew)

CME 348. Computational Molecular Modeling and Parallel Computing—(Enroll in ME 436.)
3 units, Spr (Darve)

CME 349. Models and Algorithms for Nanotechnology—(Enroll in MS&E 319.)
3 units, Win (Goel)

CME 380. Constructing Scientific Simulation Codes—Practical methods for writing and combining software components to generate simulation applications. Practical methodologies for constructing simulation code applications. How to design, write, and combine software components to generate simulation applications. Steering: using a small driver language like Python to script or steer the progress of a code. Data models and formats: how data is represented and shared inside an application and its external representation on disk. Mixed language programming using C, C++, F77, F90, and Python. Rational software engineering including testing, configuration control, code generation and makefiles. Other technologies needed to create real world applications regardless of scientific discipline.
3 units, Aut (Miller)

CME 390. Curricular Practical Training—May be repeated three times for credit.
1 unit, Aut, Win, Spr, Sum (Staff)

CME 400. Ph.D. Research
1-15 units, Aut, Win, Spr, Sum (Staff)

CME 500. Numerical Analysis and Computational and Mathematical Engineering Seminar—Weekly research lectures by experts from academia, national laboratories, industry, and doctoral students. May be repeated for credit.
1 unit, Aut, Win, Spr (Golub)