Computational and Applied Mathematics

Department Website: https://cam.uchicago.edu/academics/undergraduate-programs/

Program of Study

The Departments of Computer Science, Mathematics, and Statistics offer a BS in Computational and Applied Mathematics. The program is designed for students who intend to specialize in computational and/or applied mathematics, as well as students who want to acquire a strong quantitative background to be applied in such varied areas as physics, biological sciences, engineering, operations research, economics, and finance.

Summary of Requirements

GENERAL EDUCATION

One of the following sequences: [*]		200
CHEM 12100 & CHEM 12200	Honors General Chemistry I and Honors General Chemistry II (or higher)	
PHYS 13100-13200	Mechanics; Electricity and Magnetism (or higher)	
One of the following sequences: +		200
MATH 13100-13200	Elementary Functions and Calculus I-II [§]	
MATH 15100-15200	Calculus I-II [§]	
MATH 16100-16200	Honors Calculus I-II	
MATH 16110-16210	Honors Calculus I-II (IBL)	
Total Units		400

MAJOR

One of the following: [+]		100
MATH 16300	Honors Calculus III	
MATH 16310	Honors Calculus III (IBL)	
MATH 15910	Introduction to Proofs in Analysis	
One of the following sequences:		300
MATH 20300-20400-20500	Analysis in Rn I-II-III	
MATH 20310-20410-20510	Analysis in Rn I (accelerated); Analysis in Rn II (accelerated); Analysis in Rn III (accelerated)	
MATH 20320-20420-20520	Analysis in Rn I-II-III (IBL)	
MATH 20700-20800-20900	Honors Analysis in Rn I-II-III	
One of the following:		100
STAT 24300	Numerical Linear Algebra	
MATH 20250	Abstract Linear Algebra	
CMSC 14100 & CMSC 14200	Introduction to Computer Science I and Introduction to Computer Science II	200
CMSC 27100	Discrete Mathematics [**]	100
CMSC 27200	Theory of Algorithms	100
MATH 27300	Basic Theory of Ordinary Differential Equations	100
One of the following:		100
MATH 21100	Basic Numerical Analysis	
MATH 21200	Advanced Numerical Analysis	
STAT 24400	Statistical Theory and Methods I	100
or STAT 24410	Statistical Theory and Methods Ia	
STAT 24500	Statistical Theory and Methods II	100
or STAT 24510	Statistical Theory and Methods IIa	
One of the following: [***]		100
STAT 25100	Introduction to Mathematical Probability	
STAT 25150	Introduction to Mathematical Probability-A	

MATH 23500	Markov Chains, Martingales, and Brownian Motion	
STAT 28000	Optimization	100
Three approved electives (see Elective Courses below) (300 units)		300
Total Units		1800

* Students with AP credit for PHYS 12100-12200 may substitute quantitative courses in other scientific departments with permission of the director of undergraduate studies. Since these additional quantitative courses will count toward the physical sciences core, they will be in addition to the other required courses and electives for the CAAM major.

\+ Credit may be granted by examination.

§ Students who take MATH 13100-13200 or MATH 15100-15200 must also take the third quarter of the sequence as a prerequisite for MATH 15910; however, neither MATH 13300 nor MATH 15300 will be counted toward the major.

** Students may substitute a higher-level Computer Science course in discrete mathematics or algorithms with approval of the director of undergraduate studies.

*** Students who take STAT 25100 or STAT 25150 may take MATH 23500 as one of their electives with approval of the director of undergraduate studies. STAT 31200 may be substituted for MATH 23500.

Elective Courses

Students will propose a coherent set of three courses to complete the major program. These will be chosen to complete a specialization. Possibilities include: preparation for PhD programs in applied mathematics, scientific computing, machine learning, operations research, economics and finance, physical sciences, or biological sciences. These are intended to be mathematical and computational courses that complement the program and at least at the mathematical level of the advanced classes in the required courses. The program must be approved by the undergraduate adviser, who will also serve as a resource for suggested mentors and programs in different areas.

Grading

Students must receive quality grades in all courses required in the degree program. To qualify for the BS degree, students must complete the 18 courses above with (1) a GPA of 2.0 or higher and (2) no grade lower than C-.

Double Majoring

Students majoring in Computational and Applied Mathematics may not double major with any of the Mathematics degree options, and are strongly discouraged from double majoring with Computer Science or Statistics.

Honors

A BS with honors in Computational and Applied Mathematics requires an overall GPA of at least 3.0, a GPA in the required courses for the major of at least 3.25, and the completion of an honors paper written under the supervision of a faculty member and approved by the undergraduate adviser for the major. Students planning to complete an honors paper should submit a short proposal to the undergraduate adviser for approval by the Computational and Applied Mathematics board by the end of the student's third year. The proposal must be approved by the board no later than the end of fifth week of the Autumn Quarter of the student's fourth year.

Computational and Applied Math Courses

CAAM 21450. Applied Partial Differential Equations. 100 Units.
Partial differential equations (PDEs) are used to model applications in a wide variety of fields: fluid dynamics, optics, atomic and plasma physics, elasticity, chemical reactions, climate modeling, stock markets, etc. The study of their mathematical structure and solution methods remains at the forefront of applied mathematics. The course concentrates on deriving an important set of examples of PDEs from simple physical models, which are often closely related to those describing more complex physical systems. The course will also cover analytical methods and tools for solving these PDEs; such as separation of variables, Fourier series and transforms, Sturm-Liouville theory, and Green's functions. The course is suitable for graduate students and advanced undergraduates in science, engineering, and applied mathematics.
Terms Offered: TBD
Prerequisite(s): Instructor consent.
Equivalent Course(s): STAT 31450, CAAM 31450

CAAM 21460. Applied Fourier Analysis. 100 Units.
Decompositions of functions into frequency components via the Fourier transform, and related sparse representations, are fundamental tools in applied mathematics. These ideas have been important in applications to signal processing, imaging, and the quantitative and qualitative analysis of a broad range of mathematical models of data (including modern approaches to machine learning) and physical systems. Topics to be covered in this course include an overview of classical ideas related to Fourier series and the Fourier transform, wavelet

representations of functions and the framework of multiresolution analysis, and applications throughout computational and applied mathematics.
Terms Offered: Spring
Prerequisite(s): Graduate student in the Physical Sciences Division or consent of instructor.
Equivalent Course(s): STAT 31460, CAAM 31460

CAAM 21470. Applied Complex Analysis. 100 Units.
Complex analysis is a beautiful and deep theory for the calculus of functions of complex variables. It also presents a very useful set of tools for finding exact expressions, asymptotic expansions, approximations and even numerical schemes that are useful throughout applied mathematics and engineering. In this class we will cover the basic complex analytic tools and theorems needed to explore these applications, with the goal of using what we learn to understand and solve problems involving Fourier or Laplace transforms. Depending on time, the topics in the class will include: analytic functions, series, complex integration, Cauchy's formula, the maximum-modulus theorem, residue theory, and the argument principle.
Terms Offered: Spring
Equivalent Course(s): STAT 31470, CAAM 31470

CAAM 24310. Numerical Linear Algebra: An Introduction to Computation. 100 Units.
Computation is an essential topic across the physical and social sciences, in statistics, data science, and machine learning. Numerical linear algebra is the essential language of computation. Through a series of hands-on applications, students will implement and evaluate the essential algorithms used to solve linear systems and least squares problems, perform regression, orthogonalize bases, decompose signals via the FFT and related transforms, and perform matrix factorizations. We will focus on the computational complexity and stability of each algorithm, as well as its practical uses. Example applications include iterative optimizers used to solve large systems arising in engineering, spectral embedding methods for dimension reduction (PCA, MDS, and diffusion maps), and linear methods for classification and clustering. Examples will be presented as interactive coding notebooks available through a web browser. Prior coding experience is strongly encouraged, though students looking for an introduction to Jupyter notebooks and Python are welcome to enroll.
Terms Offered: Spring
Prerequisite(s): STAT 24300 or an equivalent introductory linear algebra class. Coding experience in Python, Matlab, R, or Julia is strongly recommended.
Equivalent Course(s): STAT 24310

CAAM 28000. Optimization. 100 Units.
This is an introductory course on optimization that will cover the rudiments of unconstrained and constrained optimization of a real-valued multivariate function. The focus is on the settings where this function is, respectively, linear, quadratic, convex, or differentiable. Time permitting, topics such as nonsmooth, integer, vector, and dynamic optimization may be briefly addressed. Materials will include basic duality theory, optimality conditions, and intractability results, as well as algorithms and applications.
Instructor(s): L. Lim Terms Offered: Spring
Prerequisite(s): (MATH 20500 or MATH 20510 or MATH 20520 or MATH 20800) and (STAT 24300 or MATH 20250 or MATH 20700)
Equivalent Course(s): STAT 28000

CAAM 28200. Dynamical Systems with Applications. 100 Units.
This course is concerned with the analysis of nonlinear dynamical systems arising in the context of mathematical modeling. The focus is on qualitative analysis of solutions as trajectories in phase space, including the role of invariant manifolds as organizers of behavior. Local and global bifurcations, which occur as system parameters change, will be highlighted, along with other dimension reduction methods that arise when there is a natural time-scale separation. Concepts of bi-stability, spontaneous oscillations, and chaotic dynamics will be explored through investigation of conceptual mathematical models arising in the physical and biological sciences.
Instructor(s): Mary Silber Terms Offered: TBD
Prerequisite(s): MATH 27300 or (Multivariable calculus (MATH 18400 or 19520 or 20000 or 20400 or 20410 or PHYS 22100 or equivalent), AND linear algebra, including eigenvalues & eigenvectors (MATH 18600 or 19620 or 20250 or 20700 or STAT 24300)). Previous knowledge of elementary differential equations is helpful but not required.
Equivalent Course(s): STAT 28200, STAT 31405, CAAM 31405