MATHEMATICAL AND COMPUTATIONAL SCIENCE

Courses offered by Mathematical and Computational Science program are listed under the subject code MCS on the Stanford Bulletin's ExploreCourses (http://explorecourses.stanford.edu) website.

This interdisciplinary undergraduate degree program in MCS is administrated by the departments of Mathematics, Computer Science, and Statistics. It provides a core of mathematics basic to all the mathematical sciences and an introduction to concepts and techniques of computation, optimal decision making, probabilistic modeling, and statistical inference.

Using the faculty and courses of the departments listed above, this major prepares students for graduate study or employment in the mathematical and computational sciences or in those areas of applied mathematics which center around the use of computers and are concerned with the problems of the social and management sciences. A biology option is offered for students interested in applications of mathematics, statistics, and computer science to the biological sciences (bioinformatics, computational biology, statistical genetics, neurosciences); and in a similar spirit, an engineering and statistics option.

Undergraduate Mission Statement for Mathematical and Computational Science

The mission of the Mathematical and Computational Science Program is to provide students with a core of mathematics basic to all the mathematical sciences and an introduction to concepts and techniques of computation, optimal decision making, probabilistic modeling and statistical inference. The program is interdisciplinary in its focus, and students are required to complete course work in mathematics, computer science, statistics, and management science and engineering. A computational biology track is available for students interested in biomedical applications. The program prepares students for careers in academic, financial and government settings as well as for study in graduate or professional schools.

Learning Outcomes

The program expects undergraduate majors to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to be able to demonstrate:

1. understanding of principles and tools of statistics.
2. command of optimization and its applications and the ability to analyze and interpret problems from various disciplines.
3. an understanding of computer applications emphasizing modern software engineering principles.
4. an understanding of multivariate calculus, linear algebra, and algebraic and geometric proofs.

Bachelor of Science in Mathematical and Computational Science

The requirement for the bachelor's degree, beyond the University's basic requirements, is an approved course program of 78-84 units, distributed as follows:

		Units
Mathematics (MATH)		28
MATH 41	Calculus [1]	5
MATH 42	Calculus [1]	5
Select one of the following:		5
MATH 51	Linear Algebra and Differential Calculus of Several Variables	
MATH 51H	Honors Multivariable Mathematics	
Select one of the following:		5
MATH 52	Integral Calculus of Several Variables	
MATH 52H	Honors Multivariable Mathematics	
Select one of the following:		5
MATH 53	Ordinary Differential Equations with Linear Algebra	
MATH 53H	Honors Multivariable Mathematics	
Select one of the following:		3
MATH 104	Applied Matrix Theory	
MATH 113	Linear Algebra and Matrix Theory	
Computer Science (CS)		22-24
CS 103	Mathematical Foundations of Computing	5
CS 106A	Programming Methodology [1]	5
and		
CS 106B	Programming Abstractions	5
or		
CS 106X	Programming Abstractions (Accelerated)	5
Select two of the following:		7-9
CME 108	Introduction to Scientific Computing	
CS 107	Computer Organization and Systems	
CS 154	Introduction to Automata and Complexity Theory	
CS 161	Design and Analysis of Algorithms	
CS 181W	Computers, Ethics, and Public Policy	
Management Science and Engineering (MS&E)		7-11
MSE 211	Linear and Nonlinear Optimization	
MSE 221	Stochastic Modeling	
Or select three of the following:		
MSE 111	Introduction to Optimization	
MSE 121	Introduction to Stochastic Modeling	
MSE 211	Linear and Nonlinear Optimization	
MSE 221	Stochastic Modeling	
MSE 251	Stochastic Control	
Statistics (STATS)		11-12
STATS 116	Theory of Probability	5
STATS 200	Introduction to Statistical Inference	3
Select one of the following:		3
STATS 191	Introduction to Applied Statistics	
STATS 203	Introduction to Regression Models and Analysis of Variance	

[1] Students who scored a 5 on both the Calculus AB and BC advanced placement exams (total of 10 units) can be waived out of MATH 41 and MATH 42; A score of 4 or 5 in Computer Science A will receive credit for CS106A (5 units). See also the Registrar's Advanced Placement (https://studentaffairs.stanford.edu/registrar/students/ap) web site (AP (https://studentaffairs.stanford.edu/registrar/students/baccalaureate-credit) or IB (https://studentaffairs.stanford.edu/registrar/students/baccalaureate-credit) exams).

Writing in the Major Requirement

The University requires students to complete at least one approved writing-intensive course in each of their majors. See the Hume Center for Writing and Speaking (https://undergrad.stanford.edu/tutoring-support/hume-center/writing/writing-major) web site for a full description of the

WIM (https://undergrad.stanford.edu/tutoring-support/hume-center/writing/writing-major/overview-wim-requirement) requirement.

		Units
Choose one from the M&CS designated WIM courses to fulfill the Writing in the Major requirement:		3-4 units
MATH 109	Applied Group Theory	
MATH 110	Applied Number Theory and Field Theory	
MATH 120	Groups and Rings	
MATH 171	Fundamental Concepts of Analysis	
CS 181W	Computers, Ethics, and Public Policy	
STATS 155	Statistical Methods in Computational Genetics	

Mathematical and Computational Science Electives

Choose three courses in Mathematical and Computational Science 100-level or above, at least 3 units each from two different departments. At least one must be from following list:

		Units
Choose three courses from the following:		9 units
ECON 102C	Advanced Topics in Econometrics	
ECON 107	Causal Inference and Program Evaluation	
ECON 140	Introduction to Financial Economics	
ECON 160	Game Theory and Economic Applications	
ECON 179	Experimental Economics	
EE 261	The Fourier Transform and Its Applications	
EE 263	Introduction to Linear Dynamical Systems	
EE 278	Introduction to Statistical Signal Processing	
EE 282	Computer Systems Architecture	
EE 364A	Convex Optimization I	
EE 364B	Convex Optimization II	
MSE 220	Probabilistic Analysis	
MSE 223	Simulation	
MSE 251	Stochastic Control	
MCS 100	Mathematics of Sports	
MATH 104	Applied Matrix Theory	
MATH 106	Functions of a Complex Variable	
MATH 108	Introduction to Combinatorics and Its Applications	
MATH 113	Linear Algebra and Matrix Theory	
MATH 115	Functions of a Real Variable	
MATH 116	Complex Analysis	
MATH 131P	Partial Differential Equations I	
MATH 171	Fundamental Concepts of Analysis	
MATH 172	Lebesgue Integration and Fourier Analysis	
MATH 174	Calculus of Variations	
PHIL 151	Metalogic (Winte)	
STATS 202	Data Mining and Analysis	
STATS 206	Applied Multivariate Analysis	
STATS 207	Introduction to Time Series Analysis	
STATS 208	Introduction to the Bootstrap	
STATS 215	Statistical Models in Biology	
STATS 216	Introduction to Statistical Learning	
STATS 217	Introduction to Stochastic Processes	
STATS 218	Introduction to Stochastic Processes	
STATS 219	Stochastic Processes	
STATS 240	Statistical Methods in Finance	
STATS 270	Bayesian Statistics I	

For Computer Science (CS), electives can include courses not taken as units under the CS list above and the following:

CME 206	Introduction to Numerical Methods for Engineering
CME 211	Software Development for Scientists and Engineers
CME 302	Numerical Linear Algebra
CS 108	Object-Oriented Systems Design
CS 110	Principles of Computer Systems
CS 140	Operating Systems and Systems Programming
CS 143	Compilers
CS 157	Logic and Automated Reasoning
CS 161	Design and Analysis of Algorithms
CS 194	Software Project
CS 221	Artificial Intelligence: Principles and Techniques
CS 223A	Introduction to Robotics
CS 225A	Experimental Robotics
CS 228	Probabilistic Graphical Models: Principles and Techniques
CS 229	Machine Learning
CS 243	Program Analysis and Optimizations
CS 246	Mining Massive Data Sets
CS 248	Interactive Computer Graphics
The following courses are not offered this year but may be used by students who completed them in fulfillment of this requirement:CS 164	

With the adviser's approval, courses other than those offered by the sponsoring departments may be used to fulfill part of the elective requirement. These may be in fields such as biology, economics, electrical engineering, industrial engineering, and medicine, etc., that might be relevant to a mathematical sciences major, depending on a student's interests.

- At least three quarters before graduation, majors must file with their advisers a plan for completing degree requirements.
- All courses used to fulfill major requirements must be taken for a letter grade with the exception of courses offered satisfactory/no credit only.
- The student must have a grade point average (GPA) of 2.0 or better in all course work used to fulfill the major requirement.
- Electives that are not offered this year, but may be offered in subsequent years, are eligible for credit toward the major.

Mathematical and Computational Science Biology Track (Option)

Students in the Biology track take the introductory courses for the Mathematics and Computational Science major with the following allowable substitutions as electives.

		Units
STATS/BIO 141	Biostatistics [1]	3-5
Take three courses from the Biology Core:		10
BIO 41	Genetics, Biochemistry, and Molecular Biology	
BIO 42	Cell Biology and Animal Physiology	
BIO 43	Plant Biology, Evolution, and Ecology	
Or take two courses from the core and one of the following:		3-4
BIO 136	Evolutionary Paleobiology	
BIO 143	Evolution	
BIO 144	Conservation Biology: A Latin American Perspective	
BIO 183	Theoretical Population Genetics	

BIO 230	Molecular and Cellular Immunology	
Honors students select the following three courses:		1-4
STATS 155	Statistical Methods in Computational Genetics	
BIO 113	Fundamentals of Molecular Evolution	
BIO 146	Population Studies	
The following courses are not offered this year but may be used by students who completed them in fulfillment of this requirement: BIO102, 160A & 160B		

[1] Can replace STATS 191 Introduction to Applied Statistics or STATS 203 Introduction to Regression Models and Analysis of Variance

Mathematical and Computational Science Engineering Track (Option)

Students in the Engineering track take the introductory courses for the Mathematics and Computational Sciences major with the following allowable substitutions.

		Units
With consent of an MCS advisor, MATH 51-52-53 series may be substituted for CME 100-102-104. Depending on the exact material taught in relevant years, an additional math course might be necessary [**]		
CME 100	Vector Calculus for Engineers	
CME 102	Ordinary Differential Equations for Engineers	
CME 104/ ENGR 155B	Linear Algebra and Partial Differential Equations for Engineers	
STATS 116 may be replaced by:		3-5
STATS 110	Statistical Methods in Engineering and the Physical Sciences	
STATS 191/STATS 203 may be replaced by:		3-4
STATS 202	Data Mining and Analysis	
Engineering Track Electives:		
Select one of the following:		3-4
MATH 106	Functions of a Complex Variable	
MATH 108	Introduction to Combinatorics and Its Applications	
MATH 116	Complex Analysis	
MATH 118	Mathematics of Computation	
MATH 132	Partial Differential Equations II	
MATH 174	Calculus of Variations	
PHIL 151	Metalogic	
Select two of the following:		3-5
ENGR 15	Dynamics	
ENGR 20	Introduction to Chemical Engineering	
ENGR 25B	Biotechnology	
ENGR 30	Engineering Thermodynamics	
ENGR 40	Introductory Electronics	
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
ENGR 105	Feedback Control Design	

[**] Only M&CS majors pursuing the engineering track may petition their adviser to substitute the required Math series for CME courses listed above.

Mathematical and Computational Science Statistics Track (Option)

Students in the Statistics track take the introductory courses for the Mathematics and Computational Sciences major with the following additional courses - (87 units total)

Required:

		Units
STATS 217	Introduction to Stochastic Processes	3
Advanced CS, such as:		
CS 246	Mining Massive Data Sets	3-4
Advanced MS&E, such as:		
MSE 220	Probabilistic Analysis	3-4
or		
MSE 223	Simulation	
Statistics Track Electives:		
Select three of the following:		9
STATS 202	Data Mining and Analysis	
STATS 206	Applied Multivariate Analysis	
STATS 207	Introduction to Time Series Analysis	
STATS 208	Introduction to the Bootstrap	
STATS 216	Introduction to Statistical Learning	
STATS 219	Stochastic Processes	
STATS 270	Bayesian Statistics I	

Honors Program

The honors program is designed to encourage a more intensive study of mathematical sciences than the B.S. program. In addition to meeting all requirements for the B.S., the student must:

1. Maintain an average letter grade equivalent to at least a 3.5 in all academic work.
2. Complete at least 15 units in mathematical sciences in addition to the requirements for the major listed above. Include in these 15 units at least one of the following:
   a. An approved upper-level or graduate course
   b. Participation in a small group seminar
   c. At least 3 units of directed reading
3. Prepare a statement describing major area of concentration for honors work.
4. Describe how each course selected added to the student's knowledge and understanding in area chosen for concentration.
5. Students interested in honors should consult with their adviser by last quarter of their junior year to prepare their program of study. Honors work may be concentrated in fields such as biological sciences, environment, physics, etc.
6. Suggested electives for students pursuing Honors: CME 206, CS 229, CS 248, EE 364, MATH 171, MATH 172, STATS 202, STATS 216, STATS 217.

Minor in Mathematical and Computational Science

The minor in Mathematical and Computational Science is intended to provide an experience of the four constituent areas: Computer Science, Mathematics, Management Science and Engineering, and Statistics. Five basic courses are required:

Select two of the following:		10
CS 106A	Programming Methodology	
and		

CS 106B	Programming Abstractions	
or		
CS 106X	Programming Abstractions (Accelerated)	
Select one of the following:		3-5
MATH 51	Linear Algebra and Differential Calculus of Several Variables	
or		
MATH 104	Applied Matrix Theory	
Select one of the following:		3-4
MSE 211	Linear and Nonlinear Optimization	
or		
MSE 221	Stochastic Modeling	
Select two of the following:		8
STATS 116	Theory of Probability	
and either		
STATS 191	Introduction to Applied Statistics	
or		
STATS 200	Introduction to Statistical Inference	

In addition to the above, the minor requires three courses from the following, two of which must be in different departments:

		Units
Select three of the following:		9
CME 108	Introduction to Scientific Computing	
CS 103	Mathematical Foundations of Computing	
CS 107	Computer Organization and Systems	
CS 154	Introduction to Automata and Complexity Theory	
CS 161	Design and Analysis of Algorithms	
EE 261	The Fourier Transform and Its Applications	
ECON 160	Game Theory and Economic Applications	
MSE 251	Stochastic Control	
MATH 104	Applied Matrix Theory	
MATH 106	Functions of a Complex Variable	
MATH 108	Introduction to Combinatorics and Its Applications	
MATH 109	Applied Group Theory	
MATH 110	Applied Number Theory and Field Theory	
MATH 115	Functions of a Real Variable	
MATH 131P	Partial Differential Equations I	
MATH 171	Fundamental Concepts of Analysis	
MATH 174	Calculus of Variations	
PHIL 151	Metalogic	
STATS 191	Introduction to Applied Statistics	
STATS 200	Introduction to Statistical Inference	
STATS 202	Data Mining and Analysis	
STATS 203	Introduction to Regression Models and Analysis of Variance	
STATS 217	Introduction to Stochastic Processes	

Other upper-division courses appropriate to the program major may be substituted with consent of the program director. Undergraduate majors in the constituent programs may not count courses in their own departments.

Co-Directors: Bradley Efron, Susan Holmes

Steering Committee: Takeshi Amemiya (Economics, emeritus), Emmanuel Candes (Mathematics, Statistics), Gunnar Carlsson (Mathematics), Richard Cottle (Management Science and Engineering, emeritus), Bradley Efron (Statistics), Margot Gerritsen (ICME), Peter Glynn (Management Science and Engineering), Susan Holmes (Statistics), Lester Mackey (Statistics), Parviz Moin (Engineering), George Papanicolaou (Mathematics), Eric Roberts (Computer Science), David Rogosa (Education), Tim Roughgarden (Computer Science), Chiara Sabatti (Statistics), Amin Saberi (Management Science and Engineering), David Siegmund (Statistics), Jonathan Taylor (Statistics), Brian White (Mathematics).