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 sponsored by Stanford’s departments of Statistics, Mathematics, Computer Science, and Management Science & Engineering, providing 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. Utilizing 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

Suggested Preparation for the Major

Students ordinarily would have taken two of the required Math courses (MATH 51 Linear Algebra and Differential Calculus of Several Variables/MATH 52 Integral Calculus of Several Variables/MATH 53 Ordinary Differential Equations with Linear Algebra) and one of the required Statistics core courses (STATS 116 Theory of Probability, STATS 191 Introduction to Applied Statistics) before declaring MCS during their freshman or sophomore year.

How to Declare

To declare the major, a student should ordinarily first meet with an MCS peer adviser to create a proposed study plan and with the program director to discuss the major. Students ordinarily have taken two of the required MATH 50 series courses and a core Statistics course prior to declaration. Once the student has created a proposed study plan, they may submit the plan to MCS student services and declare the major through Axess.

Course Requirements for the MCS Bachelor’s Degree

(78-84 units)

<table>
<thead>
<tr>
<th>Mathematics (MATH)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-variable calculus or AP credit.</td>
<td>10</td>
</tr>
<tr>
<td>MATH 19 Calculus</td>
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<tr>
<td>MATH 20 Calculus</td>
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<tr>
<td>MATH 21 Calculus</td>
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</tr>
</tbody>
</table>

Students may choose one of the following sequences:

<table>
<thead>
<tr>
<th>Multivariable Calculus and Linear Algebra</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 51 Linear Algebra and Differential Calculus of Several Variables</td>
<td></td>
</tr>
<tr>
<td>MATH 52 Integral Calculus of Several Variables</td>
<td></td>
</tr>
<tr>
<td>MATH 53 Ordinary Differential Equations with Linear Algebra</td>
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</tbody>
</table>

Modern Mathematics: Continuous Methods (a proof-oriented sequence)

<table>
<thead>
<tr>
<th>Modern Mathematics: Continuous Methods</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>MATH 61CM Modern Mathematics: Continuous Methods</td>
<td></td>
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<tr>
<td>MATH 62CM Modern Mathematics: Continuous Methods</td>
<td></td>
</tr>
<tr>
<td>MATH 63CM Modern Mathematics: Continuous Methods</td>
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</tbody>
</table>

Modern Mathematics: Discrete Methods (a proof-oriented sequence)

<table>
<thead>
<tr>
<th>Modern Mathematics: Discrete Methods</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>MATH 61DM Modern Mathematics: Discrete Methods</td>
<td></td>
</tr>
<tr>
<td>MATH 62DM Modern Mathematics: Discrete Methods</td>
<td></td>
</tr>
<tr>
<td>MATH 63DM Modern Mathematics: Discrete Methods</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 104 Applied Matrix Theory</td>
<td>3</td>
</tr>
<tr>
<td>MATH 113 Linear Algebra and Matrix Theory</td>
<td></td>
</tr>
</tbody>
</table>

Computer Science (CS)

<table>
<thead>
<tr>
<th>Computer Science (CS)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 103 Mathematical Foundations of Computing</td>
<td>5</td>
</tr>
<tr>
<td>CS 106A Programming Methodology</td>
<td>5</td>
</tr>
<tr>
<td>and either CS 106B Programming Abstractions or CS 106X Programming Abstractions (Accelerated)</td>
<td>5</td>
</tr>
</tbody>
</table>

Select two of the following:

<table>
<thead>
<tr>
<th>Computer Science</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 108 Introduction to Scientific Computing</td>
<td>7-9</td>
</tr>
<tr>
<td>CS 107 Computer Organization and Systems</td>
<td></td>
</tr>
<tr>
<td>CS 154 Introduction to Automata and Complexity Theory</td>
<td></td>
</tr>
<tr>
<td>CS 161 Design and Analysis of Algorithms</td>
<td></td>
</tr>
<tr>
<td>CS 181W Computers, Ethics, and Public Policy</td>
<td></td>
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</tbody>
</table>

Management Science and Engineering (MS&E)

<table>
<thead>
<tr>
<th>Management Science and Engineering (MS&amp;E)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 211 Introduction to Optimization (Accelerated)</td>
<td>3-4</td>
</tr>
<tr>
<td>MS&amp;E 221 Stochastic Modeling</td>
<td>3</td>
</tr>
</tbody>
</table>

Or select three of the following:

<table>
<thead>
<tr>
<th>Management Science and Engineering (MS&amp;E)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 111 Introduction to Optimization</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 121 Introduction to Stochastic Modeling</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 211 Introduction to Optimization</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 213 Introduction to Optimization Theory</td>
<td></td>
</tr>
</tbody>
</table>
The University requires students to complete at least one approved Writing in the Major requirement:

Choose one from the MCS-designated WIM courses to fulfill the Writing in the Major requirement:

- 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

WIM courses offered by other majors may be used in cases of specific concentrations (e.g., biology, decision theory). Adviser approval required.

**Mathematical and Computational Science Approved 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:

Choose three courses from the following:

- ECON 102C Advanced Topics in Econometrics
- 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
- MS&E 220 Probabilistic Analysis
- MS&E 223 Simulation
- MS&E 226 "Small" Data: Prediction, Inference, Causality
- MS&E 251 Introduction to Stochastic Control with Applications
- MS&E 334 Topics in Social Data
- MCS 100 Mathematics of Sports
- MATH 104 Applied Matrix Theory
- MATH 106 Functions of a Complex Variable
- MATH 107 Graph Theory
- MATH 108 Introduction to Combinatorics and Its Applications
- MATH 113 Linear Algebra and Matrix Theory
- MATH 114 Introduction to Scientific Computing
- MATH 115 Functions of a Real Variable
- MATH 116 Complex Analysis
- MATH 131P Partial Differential Equations
- MATH 136 Stochastic Processes
- MATH 158 Basic Probability and Stochastic Processes with Engineering Applications
- MATH 159 Discrete Probabilistic Methods
- MATH 171 Fundamental Concepts of Analysis
- MATH 172 Lebesgue Integration and Fourier Analysis
- PHIL 151 Metalogic
- 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 I
- STATS 218 Introduction to Stochastic Processes II
- STATS 219 Stochastic Processes
- STATS 240 Statistical Methods in Finance
- STATS 270 A Course in Bayesian Statistics
- CME 206 Introduction to Numerical Methods for Engineers
- 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 Computational Logic
- 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
Grade and Course 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 3.0 or better in all course work used to fulfill the major requirement.
- Students who earn less than a ‘C+’ in STATS 116 Theory of Probability or STATS 200 Introduction to Statistical Inference must repeat the course.
- Only one MCS core course can be substituted by filing a petition with their adviser (with the exception of STATS 200 Introduction to Statistical Inference which cannot be substituted). The Course Substitution Form (https://mcs.stanford.edu/sites/default/files/mcs-course-substitution_form_0.pdf) must be submitted the quarter prior to enrolling in the course.
- Course transfer credit is subject to department evaluation and to the Office of the Registrar’s external credit evaluation. These courses may result in a replacement course for MCS required course or may establish placement in a higher-level course. Transfer requests must first be submitted to Student Services Center prior to being evaluated by your adviser. Submit the MCS Program Transfer Credit Form (https://mcs.stanford.edu/sites/default/files/mcs Ug Course_equiv_petition_1.pdf) to the student services office.
- At least three quarters before graduation, majors must file with their adviser a plan for completing degree requirements.

Mathematical and Computational Science Biology Track (Option)

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

<table>
<thead>
<tr>
<th>STATLAB Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS/BIO 141</td>
<td>Biostatistics</td>
<td>3-5</td>
</tr>
</tbody>
</table>

Allowable Elective Course Substitutions:
Take three courses from Foundational Biology Core: 10 units

BIO 82 Genetics 3
BIO 83 Biochemistry & Molecular Biology 3
BIO 84 Physiology 3
BIO 85 Evolution 3
BIO 86 Cell Biology 3

Or take two courses from the Biology core and one of the following: 3-4 units

BIO 104 Advance Molecular Biology: Epigenetics and Proteostasis 3
BIO 133 Network analysis for community ecology and conservation research 3
BIO 144 Conservation Biology: A Latin American Perspective 3
BIO 183 Theoretical Population Genetics (offered alternate years) 3
BIO 230 Molecular and Cellular Immunology 3

Honors students select the following three courses: 1-4 units

STATS/BIO 141 Biostatistics
BIO 82 Genetics
BIO 83 Biochemistry & Molecular Biology

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.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
<td>15</td>
</tr>
<tr>
<td>CME 102</td>
<td>Ordinary Differential Equations for Engineers</td>
<td></td>
</tr>
<tr>
<td>CME 104/155B</td>
<td>Linear Algebra and Partial Differential Equations for Engineers</td>
<td></td>
</tr>
<tr>
<td>STATLAB 217</td>
<td>Introduction to Applied Statistics or STATS 203 Introduction to Regression Models and Analysis of Variance from the major’s Statistics core requirement.</td>
<td>3-4</td>
</tr>
</tbody>
</table>

Allowable Elective Course Substitutions:
Select one of the following: 3-4 units

MATH 106 Functions of a Complex Variable 3
MATH 108 Introduction to Combinatorics and Its Applications 3
MATH 116 Complex Analysis 3
PHIL 151 Metalogic 3

Select two of the following: 3-5 units

ENGR 15 Dynamics 3
ENGR 20 Introduction to Chemical Engineering 3
ENGR 25B Biotechnology 3
ENGR 40 Introductory Electronics 3
ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis 3

ENGR 105 Feedback Control Design 3

Only M&C&ES 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:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATLAB 217</td>
<td>Introduction to Stochastic Processes I</td>
<td>9</td>
</tr>
</tbody>
</table>

Advanced CS, such as:
In addition to meeting all requirements for the B.S., the student must:

- Complete the MCS Honors Proposal Form (https://mcs.stanford.edu/sites/default/files/mcs_honors_proposal_form_2016-17_2.pdf) no later than the Preliminary Study List deadline of the quarter in which the degree is expected to be conferred. Additional information can be found on the MCS Honors Website (https://mcs.stanford.edu/academics/honors).

Honors Program

The honors program is designed to encourage a more intensive study of mathematical sciences than the B.S. program. Students interested in honors should consult with their adviser no later than winter 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. Students are required to submit an outline describing the concentration for honors work, including the courses they intend to use, two quarters prior to expected degree conferral. An MCS Honors Proposal Form (https://mcs.stanford.edu/sites/default/files/mcs_honors_proposal_form_2016-17_2.pdf) is due no later than the Preliminary Study List deadline of the quarter in which the degree is expected to be conferred. Additional information can be found on the MCS Honors Website. (https://mcs.stanford.edu/academics/honors)

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. Honors statement should be submitted to the adviser by the late application deadline of the student's graduation quarter using the MCS Honors Approval form (https://mcs.stanford.edu/sites/default/files/mcs_honors_approval_form_2016-17_3.pdf).

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 one of the following: Units
  - MATH 51 Linear Algebra and Differential Calculus of Several Variables 3-5
  - MATH 104 Applied Matrix Theory 10

- Select two of the following:
  - CS 106A Programming Methodology
  - CS 106B Programming Abstractions
  - CS 106X Programming Abstractions (Accelerated)

- Select one of the following: Units
  - MS&E 211 Introduction to Optimization 3-4
  - MS&E 221 Stochastic Modeling 8

- Select two of the following: Units
  - STATS 116 Theory of Probability 5
  - STATS 191 Introduction to Applied Statistics
  - 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:

- Select three of the following: Units
  - 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
  - ECON 160 Game Theory and Economic Applications
  - EE 251 The Fourier Transform and Its Applications
  - MS&E 211 Introduction to Optimization
  - MS&E 212 Mathematical Programming and Combinatorial Optimization
  - MS&E 221 Stochastic Modeling
  - MS&E 251 Stochastic Modeling
  - MS&E 255 Introduction to Stochastic Control with Applications
  - 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
  - MATH 171 Fundamental Concepts of Analysis
  - PHIL 151 Metalogic
  - STATS 191 Introduction to Applied Statistics
  - STATS 200 Introduction to Statistical Inference

Suggested electives for students pursuing Honors:

- CME 206 Introduction to Numerical Methods for Engineering 3
- CS/STATS 229 Machine Learning 3
- CS 248 Interactive Computer Graphics 3-4
- EE 364A Convex Optimization I 3
- MATH 171 Fundamental Concepts of Analysis 3
- MATH 172 Lebesgue Integration and Fourier Analysis 3
- MATH 205A Real Analysis 3
- STATS 202 Data Mining and Analysis 3
- STATS 216 Introduction to Statistical Learning 3
- STATS 217 Introduction to Stochastic Processes I 2-3

Allowable Elective Course Substitutions:

Select three of the following:

- 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 A Course in Bayesian Statistics
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
</tr>
<tr>
<td>STATS 203</td>
<td>Introduction to Regression Models and Analysis of Variance</td>
</tr>
<tr>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
</tr>
</tbody>
</table>

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

**Faculty**

*Director: Bradley Efron*

*Faculty Advisers:* Assistant Professor John Duchi, Professor Bradley Efron, Associate Professor David Rogosa, Professor Chiara Sabatti

*Steering Committee:* Takeshi Amemiya (Economics, emeritus), Emmanuel Candès (Mathematics, Statistics), Brian Conrad (Mathematics), Richard Cottle (Management Science and Engineering, emeritus), John Duchi (Electrical Engineering & Statistics), Darrel Duffie (Economics & GSB), Bradley Efron (Statistics), Peter Glynn (Management Science and Engineering), Ramesh Johari (Management Science and Engineering), Percy Liang (Computer Science & Statistics), Parviz Moin (Mechanical Engineering), George Papanicolaou (Mathematics), David Rogosa (Education & Statistics), Tim Roughgarden (Computer Science), Chiara Sabatti (Biomedical Data Science & Statistics), David Siegmund (Statistics), Jonathan Taylor (Statistics), Brian White (Mathematics)