Mathematics and Statistics

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Majors

Requirements for All Majors

Total units required: 12 units

- The three-course calculus sequence (9 units)* and an introductory computer science course (3 units)**:

Code	Title	Units
Math 131	Calculus I	3
Math 132	Calculus II	3
Math 233	Calculus III	3
CSE 131	Introduction to Computer Science	3
Total Units		12

* AP credit can be applied, and students who have completed Math 203 Honors Mathematics I and Math 204 Honors Mathematics II will have this requirement waived.

** This course may be waived after consultation with the director of undergraduate studies of the Department of Computer Science & Engineering.

The Major in Mathematical Sciences

Total units required: 24 units of upper-level courses, including the following:

Code	Title	Units
Math 309	Matrix Algebra	3
Math 310	Foundations for Higher Mathematics	3
Math 3200	Elementary to Intermediate Statistics and Data Analysis	3

- One of the following full-year 400-level sequences*:

Code	Title	Units
Math 4111 & Math 4121	Introduction to Analysis and Introduction to Lebesgue Integration	6
Math 4171 & Math 4181	Topology I and Topology II	6
Math 429 & Math 430	Linear Algebra and Modern Algebra	6
Math 449 & Math 450	Numerical Applied Mathematics and Topics in Applied Mathematics	6
Math 494 & Math 439	Mathematical Statistics and Linear Statistical Models	6

* Students whose primary major is secondary education may fulfill this requirement by taking Math 302 Elementary Geometry from an Advanced Point of View and Math 331 Algebraic Systems.

- At least one course from the following list (that has not already been used to fulfill any of the previous requirements listed):

Code	Title	Units
Math 370	Introduction to Combinatorics	3
Math 371	Graph Theory	3
Math 410	Introduction to Fourier Series and Integrals	3
Math 4111	Introduction to Analysis	3
Math 415	Partial Differential Equations	3
Math 416	Complex Variables	3
Math 4171	Topology I	3
Math 429	Linear Algebra	3
Math 434	Survival Analysis	3
Math 4351	Number Theory and Cryptography	3
Math 439	Linear Statistical Models	3
Math 449	Numerical Applied Mathematics	3

The Major in Mathematics

Total units required: 30 units of upper-level courses, including the following:

Code	Title	Units
Math 310	Foundations for Higher Mathematics	3
Math 4111	Introduction to Analysis	3
Math 4121	Introduction to Lebesgue Integration	3
Math 429	Linear Algebra	3
Math 430	Modern Algebra	3
Math 416	Complex Variables	3
Math 4171	Topology I	3
At least one of the following:		
Math 407	An Introduction to Differential Geometry	3
Math 415	Partial Differential Equations	3
Math 4181	Topology II	3
Math 4351	Number Theory and Cryptography	3

The Major in Applied Mathematics

Total units required: 30 units of upper-level courses, including the following:

Code	Title	Units
Math 310	Foundations for Higher Mathematics	3
Math 4111	Introduction to Analysis	3
Math 4121	Introduction to Lebesgue Integration	3
Math 429	Linear Algebra	3
Math 449	Numerical Applied Mathematics	3
Math 450	Topics in Applied Mathematics	3
At least two of the following:		
Math 410	Introduction to Fourier Series and Integrals	3
Math 415	Partial Differential Equations	3
Math 416	Complex Variables	3
Math 4351	Number Theory and Cryptography	3

The Major in Statistics

Total units required: 30 units of upper-level courses, including the following:

Code	Title	Units
Math 309	Matrix Algebra	3
Math 3200	Elementary to Intermediate Statistics and Data Analysis	3
Math 493	Probability	3
Math 494	Mathematical Statistics	3
Math 439	Linear Statistical Models	3
Math 459	Bayesian Statistics	3
or Math 475	Statistical Computation	

- At least two probability or statistics courses at the 400 level or above

The Major in Mathematics and Computer Science

The McKelvey School of Engineering and the College of Arts & Sciences developed a new major that efficiently captures the intersection of the complementary studies of computer science and math.

McKelvey Engineering students who declare this major must fulfill the core course requirements listed below and all other requirements for the Applied Science degree (http://bulletin.wustl.edu/undergrad/engineering/requirements/) in the McKelvey School of Engineering. They must also complete Engr 310 Technical Writing and 8 units of courses designated as NSM (Natural Sciences & Math) from Anthropology (L48 Anthro), Biology and Biomedical Sciences (L41 Biol), Chemisty (L07 Chem), Earth and Planetary Sciences (L19 EPSc), Physics (L31 Physics) or Environmental Studies (L82 EnSt).

Arts & Sciences students who declare this major must fulfill the distribution requirements and all other requirements for an AB degree (http://bulletin.wustl.edu/undergrad/artsci/requirements/) in addition to the specific requirements listed below.

Core Course Requirements

Code	Title	Units
Math 131	Calculus I (AP credit may satisfy this requirement)	3
Math 132	Calculus II (AP credit may satisfy this requirement)	3
Math 233	Calculus III	3
CSE 131	Introduction to Computer Science	3
Math 310	Foundations for Higher Mathematics	3
or Math 310W	Foundations for Higher Mathematics with Writing	
or CSE 240	Logic and Discrete Mathematics	
CSE 247	Data Structures and Algorithms	3
Math 309	Matrix Algebra	3
Math 3200	Elementary to Intermediate Statistics and Data Analysis	3
or ESE 326	Probability and Statistics for Engineering	
CSE 347	Analysis of Algorithms	3

Electives

Eight upper-level courses from Math or Computer Science & Engineering can be chosen from an approved list (https://docs.google.com/spreadsheets/d/1nVxiw2jVScJ7tpwThw5OQ6vPiljGmyAi19Q37_RBsxQ/edit/#gid=0), with the following caveats:

- No fewer than three courses can be chosen from each department.
- Up to two preapproved courses from outside both departments can be selected.

The Major in Mathematics and Economics

Required courses:

Code	Title	Units
CSE 131	Introduction to Computer Science	3
Econ 1011	Introduction to Microeconomics	3
Econ 1021	Introduction to Macroeconomics	3
Econ 4011	Intermediate Microeconomic Theory	3
Econ 4021	Intermediate Macroeconomic Theory	3

Econ 413	Introduction to Econometrics	3
or Econ 413W	Introduction to Econometrics with Writing	
Math 131	Calculus I	3
Math 132	Calculus II	3
Math 233	Calculus III	3
Math 309	Matrix Algebra	3
Math 3200	Elementary to Intermediate Statistics and Data Analysis	3
or Math 493	Probability	
Math 310	Foundations for Higher Mathematics	3

Elective courses:

Majors must complete seven electives, with three in each discipline and one from either department.

In Economics:

One of the three electives can be any economics course with Econ 4011 or Econ 4021 as a prerequisite, including from an approved study abroad program. The other two economics electives must come from the following list:

Code	Title	Units
Econ 404	Behavioral Economics and Experimental Economics	3
Econ 407	Market Design	3
Econ 410	Macroeconomics of Inequality	3
Econ 4151	Applied Econometrics	3
Econ 435	Open Economy Macroeconomics	3
Econ 437	The Economics of Financial Intermediation	3
Econ 452	Industrial Organization	3
Econ 460	Urban Economics	3
Econ 467	Game Theory	3
Econ 471	Development Economics	3
Econ 477	Topics in Financial Economics: Asset Pricing	3
Econ 480	Labor Economics	3
Econ 484	Computational Macroeconomics	3

- With instructor permission, students may use any of the following for economics elective credit: Econ 501, Econ 502, Econ 503, Econ 504, Econ 511, or Econ 513.
- Econ 413 may be taken from an approved study abroad program. Consult with Academic Coordinator Dorothy Petersen in the Department of Economics for more information.

In Mathematics:

For Mathematics, the electives can come from the following list:

Code	Title	Units
Math 410	Introduction to Fourier Series and Integrals	3
Math 415	Partial Differential Equations	3
Math 416	Complex Variables	3
Math 4111	Introduction to Analysis	3
Math 4121	Introduction to Lebesgue Integration	3
Math 429	Linear Algebra	3
Math 439	Linear Statistical Models	3
Math 4392	Advanced Linear Statistical Models	3
Math 449	Numerical Applied Mathematics	3
Math 450	Topics in Applied Mathematics	3
Math 460	Multivariate Statistical Analysis	3
Math 461	Time Series Analysis	3
Math 462	Mathematical Foundations of Big Data	3
Math 475	Statistical Computation	3
Math 494	Mathematical Statistics	3
Math 495	Stochastic Processes	3
Math 459	Bayesian Statistics	3

Advising, Questions, and Further Considerations:

- Students may declare a prime or a second major in Math + Economics via L24 (Math) or L11 (Econ), and that will determine their major adviser.
- It is possible to earn the Certificate in Financial Economics in conjunction with this major (prime or second).
- It is possible to graduate with Latin Honors or with "English" honors. Students should refer to the departments' websites or consult with either Professor Blake Thornton (bthornton@wustl.edu) in the Department of Mathematics and Statistics or Academic Coordinator Dorothy Petersen (dottie@wustl.edu) in the Department of Economics for more information.
- Substitutions for mathematics courses and study abroad approval for mathematics courses will be determined by the Department of Mathematics and Statistics.
- Substitutions for economics courses and study abroad approval will be determined by Academic Coordinator Dorothy Petersen in the Department of Economics.
- Substitutions for CSE 131 are subject to approval by the McKelvey School of Engineering.

The Bachelor of Science in Data Science

The McKelvey School of Engineering and the College of Arts & Sciences developed a new major that efficiently captures the intersection of mathematics and statistics with computer science for data science. The Bachelor of Science in Data

Science (BSDS) will give students the formal foundation needed to understand the applicability and consequences of the various approaches to analyzing data with a focus on statistical modeling and machine learning.

McKelvey Engineering students who declare this major must fulfill the core course requirements listed below and all other requirements for the Applied Science degree (http://bulletin.wustl.edu/undergrad/engineering/requirements/) in the McKelvey School of Engineering. They must also complete Engr 310 Technical Writing and 8 units of courses designated as NSM (Natural Sciences & Math) from Anthropology (L48 Anthro), Biology and Biomedical Sciences (L41 Biol), Chemistry (L07 Chem), Earth and Planetary Sciences (L19 EPSc), Physics (L31 Physics) or Environmental Studies (L82 EnSt).

Arts & Sciences students who declare this major must fulfill the distribution requirements and all other requirements for an AB degree (http://bulletin.wustl.edu/undergrad/artsci/requirements/) in addition to the specific requirements listed below.

Data Science Core Requirements

Code	Title	Units
Math 131	Calculus I	3
Math 132	Calculus II	3
Math 233	Calculus III	3
CSE 131	Introduction to Computer Science	3
CSE 247	Data Structures and Algorithms	3
CSE 217A	Introduction to Data Science	3
CSE 314A	Data Manipulation and Management	3
Math 309	Matrix Algebra	3
Math 3211	Statistics for Data Science I	3
Math 4211	Statistics for Data Science II	3
Math 439	Linear Statistical Models	3
CSE 417T	Introduction to Machine Learning (or Math 4601)	3

Data Science Technical Electives

Four courses from Mathematics & Statistics or Computer Science & Engineering can be chosen from an approved list (https://docs.google.com/document/d/1NiVuvtLjsdLxde9fdYVNjAkWQFr2ADY-jyIC3yb96wY/edit/), with the following caveats:

- At least one course from Mathematics & Statistics (at the 400 level or above)
- At least one course from CSE (ending in S, T, M, or A)

Ethics and Professional Responsibility Requirement

- One course (3 units) from an approved list (https://docs.google.com/document/d/1dGO9VXCY94IpDrF1oRBm7rWP4lLlUzU7UBsD6WbEmDc/edit/)

Practicum Requirement

- 3 units of CSE 400E Independent Study taken at the same time the student is embedded in a research group (on campus or in a company) or industry, with a sponsor or adviser serving as the student's mentor

Notes to All Majors in Mathematics and Statistics

1. Students who entered Washington University **before fall 2020** should visit the Prior Bulletins (http://bulletin.wustl.edu/prior/) section of this *Bulletin* to view the major requirements that were in place for the appropriate year of matriculation.
2. Upper-level mathematics courses are those with course numbers that begin with a "3" or higher (e.g., Math 3200). Lower-level courses do not count toward upper-level mathematics requirements, even if they are cross-listed as an upper-level course in another department or program. For example, if Math 2200 were cross-listed by another department as 3XXX, then registering for that 3XXX course would not satisfy an upper-level mathematics requirement.
3. All required courses (both lower- and upper-level courses) must be completed with a grade of C- or better.
4. Math 318 and Math 308 cannot both be used to fulfill major requirements.
5. Courses transferred from other accredited colleges and universities with department approval can be counted, with the following caveats:
   a. Courses transferred from a two-year college (e.g., a community college) cannot be used to satisfy upper-level requirements.
   b. At least half the upper-level units required in a major must be earned at Washington University or in a Washington University-approved overseas study program.
   c. Courses from University College cannot be used to fulfill major requirements.
6. At most 3 units of independent study or research work can count toward the major requirements.
7. No **upper-level** course used to satisfy a major requirement can be counted toward the requirements of any other major or minor (i.e,. no double-counting of courses).
8. Certain approved substitutions are found on the Department of Mathematics and Statistics webpage (https://math.wustl.edu/major-and-minor-details/). However, in all cases, at most one substitution can be used that involves a course not home-based in the department.

Additional Information

Additional Requirements

- All mathematics majors must take Math 131 Calculus I, Math 132 Calculus II, and Math 233 Calculus III. There are other ways to fulfill this requirement, including AP credit and Math 203 Honors Mathematics I-Math 204 Honors Mathematics II. Some students may obtain a waiver if they took similar courses before coming to Washington University.
- All required courses must be completed with a letter grade of C- or better.
- University College courses cannot be counted toward major requirements.
- No double-counting of upper-level courses with other majors or minors is allowed.
- At most 3 units for independent study or research work can count toward the major requirements.
- At most 3 units from a different department at Washington University can count toward the major requirements.
- Courses transferred from other accredited colleges and universities can be counted toward a major or minor with departmental approval.
- At least half of the upper-level credits required in a mathematics major or minor program must be fulfilled by Department of Mathematics and Statistics courses taken at Washington University or in Washington University–approved overseas study programs.
- A student cannot declare more than one major or minor in the department.

Course Substitutions

At most one approved substitution can be made using a course not home-based in the Department of Mathematics and Statistics. Please note the policy that at most one course from a different department at Washington University can count toward a major or minor.

- ESE 326 can be taken in place of Math 3200. ESE 326 and Math 3200 cannot both count toward a major or minor.
- Any course from another department that is cross-listed as a mathematics L24 course can count as an upper-level elective. Examples include L24 501C, L24 440C, and L24 403C. Such L24 courses always end with a "C."
- The following courses can count as upper-level mathematics electives:
  - L30 Phil 401, Phil 403, and Phil 404
  - Econ 4151 (this course can count as a statistics elective)
  - ESE 319, ESE 403, and E35 ESE 411

Courses in Probability and Statistics

The major and minor in statistics require electives in probability and statistics. Below is the list of allowed such courses:

- Math 3200 Elementary to Intermediate Statistics and Data Analysis
- Math 322 Biostatistics
- Math 420 Experimental Design
- Math 434 Survival Analysis
- Math 439 Linear Statistical Models
- Math 4392 Advanced Linear Statistical Models
- Math 459 Bayesian Statistics
- Math 460 Multivariate Statistical Analysis
- Math 461 Time Series Analysis
- Math 462 Mathematical Foundations of Big Data
- Math 475 Statistical Computation
- Math 493 Probability
- Math 494 Mathematical Statistics
- Math 495 Stochastic Processes
- Math 496: Topics In Statistics

Distinctions in Mathematical Sciences, Mathematics, Applied Mathematics and Statistics

Distinction

- Complete at least 33 units of upper-level mathematics and/or statistics courses.
- The GPA for these 33 upper-level units must be at least 3.7. If more than 33 units are taken for a letter grade, then the courses with the lowest grades can be omitted when computing GPA for this purpose.
- Complete at least five courses, each with a B or better, at level 400+.
- All of these courses must be classroom courses (not independent study or study for honors), and they must all be taken for a letter grade.

High Distinction

- Complete all requirements for Distinction.
- Complete an honors thesis.

Highest Distinction

- Complete at least five courses, each with a grade of B+ or better, at the 400 level or higher.
- Complete one of the two paths described below:
  - **Graduate Qualifier Path:** Graduate qualifier courses in mathematics and statistics are two-semester sequences that start in the fall. In mathematics, a two-semester graduate qualifier sequence has a qualifier exam at the end of each semester. In statistics, a two-semester sequence has a qualifier exam only at the end of the sequence in spring.
    Students must complete and pass one of the following:
    a. Two semesters of qualifier courses* and their corresponding exams in mathematics (These courses can involve a single year-long sequence or be the first semesters of two different sequences.)
    b. One full-year qualifier course sequence* and its corresponding exam in statistics
  - **Course Work Path:**
    1. Complete at least 42 units of upper-level mathematics and/or statistics courses. The GPA for these 42 upper-level units must be at least 3.7. If more than 42 units are taken for a letter grade, then the courses with the lowest grades can be omitted when computing GPA for this purpose.
    2. Complete at least nine total courses at the 400 level or above, all with a B+ or better. These can include the five courses taken for distinction. All of these courses must be classroom courses (not independent study or study for honors), and they must all be taken for a letter grade.

* These qualifier courses can count toward the additional course requirements for Distinction.

Distinctions in Mathematics and Computer Science

Distinction

- For Distinction in Mathematics and Computer Science, a student must take an additional two electives, for a total of 10 electives.
- The student's GPA in the 10 electives must be at least 3.7. If the student takes additional courses that satisfy these requirements, then the courses with the lowest grades may be omitted when calculating GPA for this purpose.
- The student must complete at least four courses from the list of approved courses, each with a grade of B or better. These courses can be in either department (i.e., Mathematics and Statistics or Computer Science & Engineering). The list of courses will be maintained by both departments. Current approved courses include the following:
  - Math 4111, Math 4351, Math 429, Math 439, Math 4392, Math 449, Math 450, Math 456, Math 459, Math 461, Math 475, Math 494, Math 470, Math 4111, Math 4121, Math 4171, Math 4181
  - CSE 411A, CSE 416A, CSE 417T, CSE 427S, CSE 442T, CSE 468T, CSE 511A, CSE 513T, CSE 514A, CSE 515T, CSE 516A, CSE 517A, CSE 518A, CSE 541T, CSE 543T, CSE 544T, CSE 546T, CSE 547T, CSE 554A, CSE 581T, CSE 587A

High Distinction

- Complete all requirements for Distinction.
- Complete an honors thesis in either department (Mathematics and Statistics or Computer Science & Engineering).

Highest Distinction

- Complete the requirements for High Distinction.
- Complete one of the two options described below:
  - **Qual Option:** Complete two semesters of graduate course work and qualifier exams in the Department of Mathematics and Statistics, as described above for Highest Distinction for mathematics and statistics majors.
  - **Course Option:** Complete three additional electives, for a total of 13. As with Distinction, the student's GPA in the 13 electives must be at least 3.7, and additional courses beyond 13 can be disregarded when calculating the GPA. The 13 electives must include at least eight courses selected from the list under Distinction, each with a grade of B+ or better. At least two of these eight courses must be from each department (Mathematics and Statistics and Computer Science & Engineering).

Latin Honors

At the time of graduation, the Department of Mathematics and Statistics will recommend that a candidate receive Latin Honors (cum laude, magna cum laude, or summa cum laude) if that student has completed the department's requirements for High Distinction or Highest Distinction in Mathematics, each of which requires an Honors Thesis. The College of Arts & Sciences will then approve the recommendation if the student's final cumulative overall GPA is at least 3.65 (subject to change by the College).

The Honors Thesis

Arts & Sciences mathematics and statistics majors who want to be candidates for Latin Honors, High Distinction, or Highest Distinction must complete an honors thesis. Writing an honors thesis involves a considerable amount of independent work, reading, creating mathematics, writing a paper that meets acceptable professional standards, and making an oral presentation of results.

Types of Projects

An honors thesis can take three forms:

1. A thesis that presents significant work by the student on one or more nontrivial mathematics problems.
2. A project in mathematical or applied statistics that involves an in-depth analysis of a large data set. To do an honors thesis involving data analysis, it is usually necessary to have completed Math 3200-Math 493-Math 494 by the end of the junior year and to have the ability to work with statistical software such as SAS, R, or Python.
3. A substantial expository paper that follows independent study on an advanced topic under the guidance of a department faculty member. Such a report would involve the careful presentation of ideas and the synthesis of materials from several sources.

Process and Suggested Timeline

Junior Year, Spring Semester:

1. Talk with a faculty adviser about possible projects.
2. Complete the Honors Proposal Form and submit it to Blake Thornton.

Senior Year:

1. By the end of January, provide the adviser with a draft abstract and outline of the paper.
2. By the end of February, submit a rough draft, including an abstract, to the adviser.
3. The student and the adviser should agree on a date that the writing will be complete and on a data and time for the oral presentation in mid-March (the deadline is March 31).

Departmental Prizes

Each year, the department considers graduating majors for three departmental prizes. Recipients are recognized at an annual awards ceremony in April, where they each receive a certificate and a set of honors cords to be worn as part of the academic dress at Commencement. Awards are noted on the student's permanent university record.

Ross Middlemiss Prize

The Ross Middlemiss Prize is awarded to a graduating math major with an outstanding record. The award was established by former Professor Ross Middlemiss, who taught at Washington University for 40 years. From 1936 through the 1960s, Middlemiss authored several books, including a widely popular calculus text that was used in University College courses until the late 1970s.

Putnam Exam Prize

The Putnam Exam Prize is awarded to a graduating senior who has participated regularly in the Putnam Exam Competition and done exceptionally well throughout their time at Washington University.

Martin Silverstein Award

The Martin Silverstein Award was established in memory of Professor Martin Silverstein, who, until his death in 2004, was a pioneer in work at the interface of probability theory and harmonic analysis. Each year, the department considers for this award students in any major track, but especially those with strengths in probability or statistics.

Brian Blank Award

The Brian Blank Award was established in memory of Professor Brian Blank, who passed away in 2018. Each year, the Department of Mathematics and Statistics selects for this prize distinguished junior(s) majoring in mathematics and statistics.