# Mathematics or Applied Mathematics

A degree in mathematics is useful for those seeking careers in teaching, research, the sciences, or business and government. The traditional mathematics major is particularly appropriate if students plan to teach or enter professional school, or if they seek an interesting major within the liberal arts. The applied mathematics major is suggested if a student plans a career in actuarial work, industrial mathematics or statistics.

The minor in mathematics consists of 21 units of required course work. Please refer to the Degree Requirements section for more information.

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## Degree Requirements

### BS in Mathematics or Applied Mathematics

All University College undergraduate students must satisfy the same general-education requirements (http://bulletin.wustl.edu/undergrad/ucollege/bachelors/#degreerequirements).

Required for all mathematics majors:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 155</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Math 156</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 255</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>Math 256</td>
<td>Calculus IV</td>
<td>3</td>
</tr>
</tbody>
</table>

In addition to the required courses, students should select relevant courses in the social and physical sciences to complement and augment their major.

### Traditional Mathematics Major Requirements

Mathematics majors should take Math 3101 Foundations for Higher Mathematics as one of these courses. In addition to the calculus sequence and Math 3101, 15 units of 300- and 400-level courses must be completed successfully.

A sample of 300- and 400-level courses available:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 301</td>
<td>Matrix Algebra</td>
<td>3</td>
</tr>
<tr>
<td>Math 493</td>
<td>Probability</td>
<td>3</td>
</tr>
<tr>
<td>Math 494</td>
<td>Mathematical Statistics</td>
<td>3</td>
</tr>
</tbody>
</table>

### Applied Mathematics Major Requirements

Applied mathematics majors should take Math 133 Programming with Python. In addition to the calculus sequence and Math 133, 15 units of 300- and 400-level courses must be completed successfully.

A sample of 300- and 400-level courses available:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 305</td>
<td>Probability and Statistics</td>
<td>3</td>
</tr>
<tr>
<td>Math 3091</td>
<td>Matrix Algebra</td>
<td>3</td>
</tr>
<tr>
<td>Math 322</td>
<td>Biostatistics</td>
<td>3</td>
</tr>
<tr>
<td>Math 439</td>
<td>Linear Statistical Methods</td>
<td>3</td>
</tr>
<tr>
<td>Math 475</td>
<td>Statistical Computation</td>
<td>3</td>
</tr>
<tr>
<td>Math 493</td>
<td>Probability</td>
<td>3</td>
</tr>
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<td>Math 494</td>
<td>Mathematical Statistics</td>
<td>3</td>
</tr>
</tbody>
</table>

### The Minor in Mathematics

To earn a minor in mathematics, 21 credits of mathematics courses must be completed, of which at least 9 units must be advanced course work (300-level or above). Suggested course work:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 133</td>
<td>Programming with Python</td>
<td>3</td>
</tr>
<tr>
<td>Math 155</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Math 156</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 255</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>Math 256</td>
<td>Calculus IV</td>
<td>3</td>
</tr>
<tr>
<td>Math 305</td>
<td>Probability and Statistics</td>
<td>3</td>
</tr>
<tr>
<td>Math 205</td>
<td>Applied Statistics</td>
<td>3</td>
</tr>
<tr>
<td>Math 309</td>
<td>Matrix Algebra</td>
<td>3</td>
</tr>
<tr>
<td>or Math 301</td>
<td>Differential Equations</td>
<td></td>
</tr>
</tbody>
</table>

Total Units: 21

## Courses


### U20 Math 1011 Introduction to Statistics

Basic concepts of statistics. Data collection (sampling and designing experiments), data organization (tables, graphs, frequency distributions, numerical summarization of data), statistical inference (elementary probability and hypothesis testing). Prerequisite: high school algebra. Credit 3 units.
U20 Math 133 Programming with Python
An introductory course for students with little or no programming experience. Topics include the software development process, documentation, debugging, and testing within the commonly used Python environment. At the end of the course students should be able to write and debug basic programs to display and interpret data using accepted programming conventions and styles. Credit 3 units.

U20 Math 140 Algebra
The basic rules for operation within the real number system, polynomials, linear and quadratic equations, and inequalities. Prerequisite: one year of high school algebra or equivalent. Credit 3 units.

U20 Math 141 Topics in Precalculus
Topics in algebra, functions, graphs, and logarithmic and exponential functions. U20 141 serves as preparation for the calculus sequence. Prerequisite: U20 140. Credit 3 units.

U20 Math 155 Calculus I
First course in differential calculus covering functions, limits, continuity, derivatives, techniques of differentiation, and applications including maxima and minima of functions, curve sketching, related rates and rectilinear motion, mean value theorem. Prerequisite: U20 141 or equivalent, including trigonometry. Credit 3 units.

U20 Math 156 Calculus II
 Continuation of U20 155, starting with a brief review of definitions and formulas. The concept of the integral; the Fundamental Theorem of Calculus; techniques of integration; application of the integral including areas, volume, and work; differential and integral calculus with elementary transcendental functions. Prerequisite: U20 155 or equivalent. Credit 3 units.

U20 Math 205 Applied Statistics
This is a first course in statistics with examples and applications from a variety of disciplines, and emphasis on the social, behavioral and natural sciences. Students will learn about key topics and statistical methods that may be applied to areas such as economics, mathematics, psychology, business, and health sciences, to name a few. The course will provide a foundation in descriptive and inferential statistics, and in probability. Students will learn numerical and graphical methods of describing data and will study some of the more common distributions. Topics to be covered include hypothesis testing, confidence-interval estimation, correlation, regression, analysis of variance, contingency tables, quality control, and nonparametric statistics. This course may be applied to University College majors in economics, managerial economics, and political science. Students must have access to the internet, have an email account, and have some familiarity with Microsoft Excel to take the course. Prerequisite: College Algebra. Credit 3 units. UColl: OLI

U20 Math 210 The Art of Mathematical Thinking
Mathematics plays an important role in society, from engineering to architecture to the social and behavioral sciences. This course will expose non-math majors to fascinating sides of mathematics that are typically not discussed in standard math courses. Students will learn effective thinking techniques with applications beyond standard mathematics, and discover exciting ideas and new perspectives about the world. We will look at questions like: What do rabbits, piano keyboards, and pine cones have to do with the Parthenon? What do secret codes and bar codes have to do with number systems and prime numbers? What are some uses and misuses of mathematics in everyday life? Why are coincidences not so amazing after all? Prerequisite: proficiency in high school algebra. Credit 3 units. UColl: OLI

U20 Math 224 Advanced Data Visualization (with R)
Visual representations of data are important for conveying complex information simply. There are many packages available in R (such as ggplot2) that can be used to generate plots and graphs of various kinds. Sometimes the default output from a particular command is not the best way to communicate a particular result or trend. This course will help students to learn more about the common ways to display data, as well as how to make changes to the code so that the visualizations are more effective. Visualization techniques involve study from areas such as graphic design, computer science, psychology, and mathematics. Topics include: categorical data, distributions, time series, scatter plots, and maps. Prerequisites: Math 124 and Math 205 or 305 or equivalents. Credit 3 units. UColl: OLH

U20 Math 255 Calculus III
Continuation of U20 156. Vectors in the plane and in space, lines and planes in space, calculus of vector-valued functions, parametric equations, arc length, polar coordinates, infinite series, Taylor’s theorem. Prerequisite: U20 156 or equivalent. Credit 3 units.

U20 Math 256 Calculus IV
Continuation of U20 255. Functions of several variables, partial derivatives, tangent planes, directional derivatives, total differential, multiple integrals, line integrals, and an introduction to elementary differential equations. Prerequisite: U20 255 or equivalent. Credit 3 units.

U20 Math 301 Differential Equations
First course in differential equations with emphasis on linear equations and their applications. Prerequisite: U20 256 or equivalent. Credit 3 units.

U20 Math 305 Probability and Statistics
Discrete and continuous random variables, mean and variance, hypothesis testing and confidence limits, nonparametric methods. Students t'-methods, regression, correlation. Prerequisite: U20 156 or consent of department. Credit 3 units.
U20 Math 308 Mathematics for the Physical Sciences
Continuation of Math 233 emphasizing topics of interest in the physical sciences. Topics in multivariable and vector calculus (div, grad, curl); line, surface integrals and connections to electromagnetism; Fourier series and integrals; boundary value problems (diffusion and wave equations); additional topics if time permits. Students may not receive credit toward a math major or minor for both Math 308 and Math 318. Prerequisites: Math 233 and 217, or permission of instructor. Same as L24 Math 308. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

U20 Math 309 Linear Algebra I
Detailed treatment of the algebra of matrices. Rank and equivalence of matrices. Matrices over a number field. Linear equations and linear dependence. Determinants. Prerequisite: U20 256 or equivalent. Credit 3 units.

U20 Math 3091 Matrix Algebra
An introductory course in linear algebra that focuses on Euclidean n-space, matrices and related computations. Topics include: systems of linear equations, row reduction, matrix operations, determinants, linear independence, dimension, rank, change of basis, diagonalization, eigenvalues, eigenvectors, orthogonality, symmetric matrices, least square approximation, quadratic forms. Introduction to abstract vector spaces. Credit 3 units. Arch: NSM Art: NSM

U20 Math 3101 Foundations for Higher Mathematics
Introduction to the rigorous techniques used in more advanced mathematics. Topics include propositional logic, use of quantifiers, set theory, methods of proof and disproof (counterexamples), foundations of mathematics. Use of these tools in the construction of number systems, and in other areas such as elementary number theory, combinatorial arguments, and elementary proofs in analysis. Prerequisite: Math 256 or permission of the instructor. Credit 3 units.

U20 Math 400 Independent Study
Credit variable, maximum 3 units.

U20 Math 420 Experimental Design
A first course in the design and analysis of experiments, from the point of view of regression. Factorial, randomized block, split-plot, Latin square, and similar design. Prerequisite: CSE 131 or 200, Math 3200, or permission of instructor. Same as U20 Math 520. Credit 3 units. Art: NSM

U20 Math 434 Survival Analysis
Life table analysis and testing, mortality and failure rates, Kaplan-Meier or product-limit estimators, hypothesis testing and estimation in the presence of random arrivals and departures, and the Cox proportional hazards model. Techniques of survival analysis are used in medical research, industrial planning and the insurance industry. Prerequisites: CSE 131 or 200, Math 309 and 3200, or permission of the instructor. Same as L24 Math 434. Credit 3 units. A&S IQ: NSM

U20 Math 439 Linear Statistical Methods
Theory and practice of linear regression, analysis of variance (ANOVA) and their extensions, including testing, estimation, confidence interval procedures, modeling, regression diagnostics and plots, polynomial regression, collinearity and confounding, model selection, geometry of least squares, etc. The theory will be approached mainly from the frequentist perspective, and use of the computer (mostly R) to analyze data will be emphasized. Prerequisites: CSE 131 or 200, Math 3200 and a course in linear algebra (such as Math 309 or 429), or permission of instructor. Same as L24 Math 439. Credit 3 units. A&S IQ: NSM

U20 Math 461 Time Series Analysis
Time series data types; autocorrelation; stationarity and nonstationarity; autoregressive moving average models; model selection methods; bootstrap confidence intervals; trend and seasonality; forecasting; nonlinear time series; filtering and smoothing; autoregressive conditional heteroscedasticity models; multivariate time series; vector autoregression; frequency domain; spectral density; state-space models; Kalman filter. Emphasis on real-world applications and data analysis using statistical software. Prerequisite: Math 493 and either Math 3200 or 494; or permission of the instructor. Some programming experience may also be helpful (consult with the instructor). Same as L24 Math 461. Credit 3 units. A&S IQ: NSM

U20 Math 475 Statistical Computation
Introduction to modern computational statistics. Pseudo-random number generators; inverse transform and rejection sampling. Monte Carlo approximation. Nonparametric bootstrap procedures for bias and variance estimation; bootstrap confidence intervals. Markov chain Monte Carlo methods; Gibbs and Metropolis-Hastings sampling; tuning and convergence diagnostics. Cross-validation. Time permitting, optional topics include numerical analysis in R, density estimation, permutation tests, subsampling, and graphical models. Prior knowledge of R at the level used in Math 494 is required. Prerequisite: Math 233, 309, 493, 494 (not concurrently); acquaintance with fundamentals of programming in R. Same as L24 Math 475. Credit 3 units. A&S IQ: NSM

U20 Math 493 Probability
Mathematical theory and application of probability at the advanced undergraduate level; a calculus-based introduction to probability theory. Topics include the computational basics of probability theory, combinatorial methods, conditional probability including Bayes’ theorem, random variables and distributions, expectations and moments, the classical distributions, and the central limit theorem. Same as L24 Math 593. Credit 3 units.

U20 Math 494 Mathematical Statistics
Theory of estimation, minimum variance and unbiased estimators, maximum likelihood theory, Bayesian estimation, prior and posterior distributions, confidence intervals for general estimators, standard estimators and distributions such as the Student-t and F-distribution from a more advanced viewpoint, hypothesis testing, the Neymann-Pearson Lemma (about best possible tests), linear models, and other topics as time permits. Same as U20 Math 594.
U20 Math 495 Stochastic Processes
Content varies with each offering of the course. Past offerings have included such topics as random walks, Markov chains, Gaussian processes, empirical processes, Markov jump processes, and a short introduction to martingales, Brownian motion and stochastic integrals. Prerequisites: Math 318 and 493, or permission of instructor.
Same as L24 Math 495
Credit 3 units. A&S IQ: NSM Arch: NSM