Mathematics

Chair: Alan Sultan

Graduate Advisor: Scott Wilson

Assistant to the Chair: Steven Kahan

Undergraduate Advisors: Moshe Adrian (Standard), Martin Braun (Applied), Adam Kapelner (Data Science and Statistics), Alan Sultan (Elementary and Secondary Education)

Dept. Office: Kiely 243, 718-997-5800

Distinguished Professor: Jiang; *Professors:* Braun, Hanusa, Klosin, Kramer, R. Miller, Mitra, Ovchinnikov, Ralescu, Saric, Sultan, Terilla, Wilson, Zakeri; *Associate Professors:* Lee, Rothenberg, Sabitova, Sisser; *Assistant Professors:* Adrian, Kapelner, Vlamis, Zeng; *Lecturers:* Broges, Chen, Clarke, Eisen, Erlbaum, Kahan, Koroveshi, D. Miller, Pastore, Spitz; *Administrative Coordinator:* Wen

Laboratory Supervisor: End

College Assistants: Chan, Patto, Rydzewski

Major Offered: Mathematics (State Education Code 26452)

The Department of Mathematics offers a program for those students who have any of the following interests or objectives: the teaching of mathematics in elementary or secondary schools, the study of computer science or the natural sciences, study in the areas of statistics, actuarial work and other applied areas, and college teaching and research in mathematics.

See the Curriculum section of this *Bulletin* for information on basic skills requirements in mathematics.

Department Awards

The Mathematics Department offers the *Eva and Jacob Paulson Memorial Award,* the *Banesh Hoffman Memorial Award,* the *Arthur Sard Memorial Award,* the *Claire and Samuel Jacobs Award,* and the *Mrs. Neela Kulkarni Prize,* all presented to graduating seniors for excellence in mathematics; the *Dr. Nick Metas Memorial Award* for a graduating senior who is beginning a PhD program in pure or applied mathematics; the *S. and D. Kulkarni Memorial Awards* for excellence in complex analysis and in differential geometry; the *Thomas A. Budne Memorial Award,* presented to a non-graduating student for special talent and creativity in mathematics; and the *Joseph Hershenov Prize,* presented to a student tutor in the math department. To be eligible for these awards, a student must have a high GPA in mathematics and must have taken courses beyond the minimum requirement for a major.

THE MAJORS

Students majoring in mathematics may choose from one of the following options: the pure mathematics option, the applied mathematics option, the data science and statistics option, the secondary education option, or the elementary education option. All students must have completed MATH 151 and 152 or the equivalents. (The following sequences of classes are considered the equivalents of MATH 151 and 152: MATH 141, 142, and 143; MATH 131, 132, and 143; MATH 151, 142, and 143; MATH 157 and 158.)

All majors must file an approved concentration form by the end of the upper sophomore semester. The six additional courses required for the major must be part of this concentration form.

The Pure Mathematics Option

See the box on the next page for the specific requirements for this major.

The Applied Mathematics Option

See the box on the next page for the specific requirements for this major.

The Secondary Education Option

See the box on the next page for the specific requirements for this major.

Each student taking this option should consult the Secondary Education and Youth Services Department about requirements for professional education courses leading to teacher certification (718-997-5150). In addition, the student must visit Prof. Alan Sultan (718-997-5800) of the Mathematics Department by the end of the upper sophomore year. Prof. Sultan will meet with the student at least once a year to coordinate the student's program.

The Data Science and Statistics Option

Each student taking this option must visit the Data Science and Statistics advisor by the end of the upper sophomore year. The advisor will meet with the student at least once a year to coordinate the student's program. See the box on the next page for the specific requirements for this major.

The Elementary Education Option

This option is available only to students enrolled in the Elementary and Early Childhood Education program (718-997-5300). See the box on page 284 for the specific requirements for this major. In addition, the student must visit Prof. Alan Sultan (718-997-5800) of the Mathematics Department by the end of the upper sophomore year. Prof. Sultan will meet with the student at least once a year to coordinate the student's program.

Special Requirements

A course given by the Department of Mathematics in which a grade of *D+* or lower is obtained cannot be used for the major without written permission from the chair.

It is recommended, but not required, that students who expect to work for a doctoral degree in mathematics secure as early as possible a reading knowledge of at least two of the following languages: French, German, and Russian.

REQUIREMENTS FOR THE MAJORS IN MATHEMATICS (MAJOR CODE MATH-BA)

All students must have completed MATH 151 and 152 or the equivalent(s).

THE PURE MATHEMATICS OPTION (CONCENTRATION CODE MATH-PURE)

Required: MATH 151 and 152 (or the equivalents), 201 and 202 (or 207), 231, 310, and 333, and eight elective MATH courses at the 200-, 300-, 600-, or 700-level (not including MATH 271, 272, or 385). Two of the following courses may be taken to fulfill elective requirements: CSCI 111, CSCI 320, PHYS 207, PHYS 243. (Some of these elective courses require a prerequisite (CSCI 220 or PHYS 146.4) that does not count toward the math major, but would count toward a major or minor in that subject.)

It is recommended that all pure math majors take computational courses such as MATH 250 or CSCI 111. Students who aim for Honors in Mathematics or who intend to continue their studies toward an eventual master's or PhD degree in mathematics are encouraged to take the more advanced and theoretical 300-, 600-, and 700-level courses.

At least eighteen credits of these required and elective courses must be taken at Queens College.

THE APPLIED MATHEMATICS OPTION (CONCENTRATION CODE MATH-APPL)

Required: MATH 151 and 152 (or the equivalents), 201 and 202 (or 207), 231, 241, CSCI 111 (or MATH 250), six elective MATH courses at the 200-, 300-, 600-, or 700-level (not including MATH 271, 272, or 385), and the courses from one of the following specialization tracks.

Computer Science: Three computer science courses numbered CSCI 211 or higher that each carry 3 or more credits.

Economics: ECON 101, 102, 201 (or 226), and 202 (or 225).

Sciences: Any four courses that carry 3 or more credits from the following list:
BIOL 105 and above
CHEM 113 and above
ENSCI 100 and ENSCI 112 and above
GEOL 101 and above
PHYS 145, 146, and PHYS 221 and above
The set of courses followed must form a meaningful concentration approved by the department.

Psychology: PSYCH 101 and any three psychology courses numbered PSYCH 214 or higher.

Operations Research: Three additional MATH courses to make a total of nine elective courses. The nine courses must include MATH 247 (or 248), 369 (or 633), and 623.

Custom track: A series of courses making up a meaningful program in an area in which mathematics has significant application. This series must be approved by the department.

At least eighteen credits of these required and elective courses must be taken at Queens College.

DATA SCIENCE AND STATISTICS OPTION (CONCENTRATION CODE MATH-DSS)

Required: MATH 151 and 152 (or the equivalents), 201, 231 (or 237), 241, 310 (or 320), 341, 342, 368 (or 621), 369 (or 633); CSCI 111, 212 (or 211); ECON 382, 387; and DATA 205 (or BIOL 230 or MATH 242). We recommend that MATH 241 be taken before DATA 205 (or BIOL 230). There is an additional requirement of three electives from list A and one elective from list B. Note that no course may be counted as both a required and an elective course. At least twenty credits of these required and elective courses must be taken at Queens College.

List A: SOC 235, CSCI 48, CSCI 211, CSCI 212, CSCI 220, CSCI 240, CSCI 313, BUS 386, BIOL 330, PSYCH 323, or one relevant course not on this list (upon prior approval by your advisor).

List B: MATH 202, 220, 223, 232, or any MATH course 310 and above.

The university also has general education requirements. There are many general education courses that involve data science concepts; these can be beneficial for a student choosing the Data Science and Statistics option. We recommend the following courses, listed with the core code(s) that are fulfilled: LCD 101 (SW/LANG/SCI), LCD 102 (LANG), PSCI 100 (USED), PSYCH 101 (SW/SCI), PSYCH 213W (LPS/SW/SCI), and SOC 101 (IS).
Note that LCD 101 and LCD 102 are highly recommended for the student who wishes to learn natural language processing, an important aspect of modern data science.

THE SECONDARY EDUCATION OPTION (CONCENTRATION CODE MATH-SEC)
A co-major in SEYS is required; see SEYS.

Required: MATH 151 and 152 (or the equivalents), 201, 220, 231 (or 237), 241, 333 (or 613), 385, 505 and 518; CSCI 111, CSCI 112 or one of PHYS 121, 145. Three or four additional courses as follows: *Three* additional courses chosen from Lists X and Y below, of which at least *two* must be from List X, *or* four additional courses chosen from Lists X and Y below, of which at least *one* must be from List X.

List X: MATH 310, 317 (or 617), 609, 612, 618, 619, 626, and 634. MATH 310 is recommended for those who expect to teach calculus. Also especially recommended are MATH 317 (or 617), 618, and 619.

LIST Y: MATH 202, 213W, 223, 232, 242, 245, 247, 248, 320 and all 500- and 600-level courses not already used to satisfy the above requirements. MATH 202 is usually required for entry into master's degree programs in mathematics.

A year of college physics is recommended.

Special Requirements

A course given by the Department of Mathematics in which a grade of *D+* or lower is obtained cannot be used for the major without written permission from the chair.

It is recommended, but not required, that students who expect to work for a doctoral degree in mathematics secure as early as possible a reading knowledge of at least two of the following languages: French, German, and Russian.

THE MINOR

A minor in mathematics is offered to any student who completes at least 15 credits in a coherent program of mathematics courses. See the box on this page for the specific requirements for the minor.

The student's program must be approved by the department; a concentration form must be filed with and approved by the department by the end of the student's lower junior semester. An overall GPA of at least 2.0 in courses numbered 171 or higher is required, and no course in which a grade below *C–* is obtained will be recognized as fulfilling the requirements for a minor.

Actuarial Examinations

Those intending to take the Society of Actuaries examinations should take calculus through MATH 201 and MATH 241. In addition, the following courses will be helpful:

- *For Exam P on Probability:* MATH 242, 271, 272, 621, and 633. (MATH 633 is particularly important.)

- *For Exam FM on Financial Mathematics:* MATH 116 and BUS 241. Also recommended is self-study of the Actex Publications text *Mathematics of Investment and Credit* by S. Broverman.

COURSES

All students planning to take a course in calculus should follow the results of the mathematics placement examination. MATH 113 and 114 do *not* prepare students for calculus; they are designed for nonmathematics and nonscience students who want to take a course in mathematics appreciation or in probability and statistics.

In order to register for a course offered by the Department of Mathematics, a student must complete the appropriate prerequisite course(s), if any, with a grade of *C–* or better. This requirement can be waived only upon approval of the chair.

MATH 110. Mathematical Literacy—An Introduction to College Mathematics. 3 hr.; 3 cr. Mathematical literacy necessary for success in today's highly technological society. Students will gain hands-on experience in solving real world problems in such diverse areas as law, medicine, and politics. Applications include analysis of election results and voting schemes, interpretation of medical data, and study of the nature of fair political representation. Mathematical topics covered will include an introduction to probability and statistics through normal curves and confidence intervals; exponential and logistic growth models; and the algebraic skills necessary for all the applications covered. Extensive use will also be made of today's sophisticated graphing calculators. Successful completion of the course satisfies the Basic Skills Requirement in Mathematics and prepares students for MATH 113, 114, 116, and 119. Not open to students who are taking or have received credit, including transfer credit or advanced placement credit, for any precalculus or calculus course. (MQR)

MATH 113. Ideas in Mathematics. 3 hr.; 3 cr. Prereq.: Two and one-half years of high school mathematics including intermediate algebra. A liberal arts mathematics course for nonmathematics, nonscience majors. Will explore several areas of mathematics to give the student an appreciation of the significance of mathematics, both in terms of its applications and of its place in the history of civilization. Subject matter drawn from virtually the entire spectrum of modern mathematics, including such areas as calculus, probability, game theory, number theory, set theory, logic, non-Euclidean geometry, topology, and group theory. Not open to students who have received credit for MATH 201 (unless permission of the chair is obtained). Fall, Spring

MATH 114. Elementary Probability and Statistics. 3 hr.; 3 cr. Prereq.: Two and one-half years of high school mathematics including intermediate algebra. An introduction to mathematical probability and statistics for the general student. Not open to mathematics, physics, or chemistry majors, or to students receiving credit for MATH 114W, 241, 611, 621, or 633. Fall, Spring (MQR)

MATH 114W. Elementary Probability and Statistics. 4 hr.; 4 cr. Prereq.: Two and one-half years of high school mathematics including intermediate algebra and ENGL 110. An introduction to mathematical probability and statistics for the general student with a writing-intensive component. Includes the material in MATH 114, as well as additional topics such as

sampling methods, research design, and composing and conducting surveys, explored through student research and writing assignments. Not open to mathematics, physics, or chemistry majors, or to students receiving credit for MATH 114, 241, 611, 621, or 633. Fall, Spring (MQR)

MATH 115. College Algebra for Precalculus.
3 hr.; 3 cr. Prereq.: Knowledge of elementary algebra. Topics include linear, polynomial, rational, and radical expressions as mathematical models; solving equations and systems of equations that arise through the application of these models. Not open to students who are taking or have received credit, including transfer credit or advanced placement credit, for any precalculus or calculus course.

MATH 116. Mathematics of Finance. 3 hr.; 3 cr. Prereq.: Knowledge of intermediate algebra. Topics include simple interest, compound interest, mortgages, bonds, depreciation, annuities, and life insurance. Fall, Spring

MATH 119. Mathematics for Elementary School Teachers. 3 hr.; 3 cr. This course is designed to make prospective elementary schoolteachers aware of the beauty, meaning, and relevance of mathematics. Topics are taken from those areas of mathematics that are related to the elementary school curriculum, and emphasis is placed on clearing up common misunderstandings of mathematical concepts and results. Fall, Spring (MQR)

MATH 120. Discrete Mathematics for Computer Science. 3 hr.; 3 cr. Prereq.: MATH 122 or the equivalent. This course lays the groundwork for further courses in discrete mathematics and theoretical computer science. Topics include sets, functions, relations, formal logic (propositional and predicate calculus); elementary number theory; elementary combinatorics and discrete probability; introductory abstract algebra, monoids, and groups. Not open to students who have received credit for MATH 220. Fall, Spring (MQR)

MATH 122. Precalculus. 4 hr.; 4 cr. Prereq.: Three years of high school math or MATH 115. This course offers a thorough introduction to the topics required for calculus. Topics include real and complex numbers, algebra of functions, the fundamental theorem of algebra, trigonometry, logarithms, and exponential functions, conic sections, and the use of graphing calculators. Students unsure of their preparation for calculus are advised to take the Queens College mathematics placement test. Not open to students who have received credit, including transfer credit or advanced placement credit, for any calculus course. (MQR)

MATH 128. Mathematical Design. 3 hr.; 3 cr. Prereq.: MATH 115 or the equivalent. Students will program computers to create digital art based on mathematical exploration of two-dimensional geometry. Topics include transformations of the plane, trigonometric functions, polar coordinates, parametric functions, and Mobius transformations. No prior experience in programming is necessary. (MQR)

MATH 131. Calculus with Applications to the Social Sciences I. 3 hr.; 3 cr. Prereq.: MATH 122, or a grade of *A-* or above in MATH 115, or permission of the department. Introduction of the fundamental ideas and techniques of calculus to nonscience students. Special emphasis is given to applications. Topics include functions and graphs; derivatives and differentiation techniques; the marginal concept in economics; optimization methods; compound interest; exponential and logarithmic functions. Not open to students who are taking any other calculus course or have received credit, including transfer credit or advanced placement credit, for any calculus course. Fall, Spring (MQR)

MATH 132. Calculus with Applications to the Social Sciences II. 3 hr.; 3 cr. Prereq.: MATH 131. A continuation of MATH 131. Topics include limits and continuity; mean value theorem; antiderivatives; integrals and integration techniques; applications of the definite integral; the calculus of logarithmic,

exponential, and trigonometric functions. This course prepares students who have taken MATH 131 to continue into MATH 143.

MATH 135W. Writing Workshop. 1 hr.; 1 cr. A one-credit add-on course to a regular subject matter course on a corequisite basis. This course works on writing that is integral to the subject matter of the main course. Corequisite means that all students in the regular course will be in the writing workshop. The combination of a regular course and a writing workshop satisfies one of the college's writing-intensive course requirements. May be repeated for credit.

MATH 141. Calculus/Differentiation. 3 hr.; 3 cr. Prereq.: MATH 122, or placement by departmental exam, or permission of the department. The first part of a three-semester sequence (MATH 141, 142, 143) covering the same material as MATH 151 and 152. Credit is given for each course satisfactorily completed; a student need not take the entire sequence. Not open to students who are taking any other calculus course or have received credit, including transfer credit or advanced placement credit, for any calculus course. Fall, Spring (MQR)

MATH 142. Calculus/Integration. 3 hr.; 3 cr. Prereq.: MATH 141. A continuation of MATH 141. Not open to students who are taking any other calculus course or have received credit, including transfer credit or advanced placement credit, for any calculus course other than MATH 141 or MATH 151. Fall, Spring (MQR)

MATH 143. Calculus/Infinite Series. 3 hr.; 3 cr. Prereq.: MATH 132 or 142. MATH 151 does not satisfy the prerequisite. A continuation of MATH 142. Not open to students who are taking any other calculus course or have received credit, including transfer credit or advanced placement credit, for any calculus course other than MATH 131, MATH 132, MATH 141, MATH 142 or MATH 151. Fall, Spring (MQR)

MATH 151. Calculus/Differentiation and Integration. 4 hr.; 4 cr. Prereq.: Grade of *B-* or above in MATH 122 or permission of the department. The first part of a two-semester sequence (MATH 151 and 152) intended for students who want to study mathematics, physics, chemistry, or engineering. Credit is given for each course satisfactorily completed; a student need not take the entire sequence. Students who want a less rapid introduction to calculus should take MATH 141. Topics include sets, inequalities, straight lines, circles, functions, limits, continuity, the derivative, formulas of differentiation, implicit differentiation, velocity, acceleration, maxima and minima, Rolle's theorem, the mean value theorem, points of inflection, curve sketching, and antiderivatives. Not open to students who are taking any other calculus course or have received credit, including transfer credit or advanced placement credit, for any calculus course. Not open to students who have received either a *D* or *F* in MATH 141. Fall, Spring (MQR)

MATH 152. Calculus/Integration and Infinite Series. 4 hr.; 4 cr. Prereq.: MATH 151. Deals with several aspects of differential and integral calculus. Among the topics studied are the definite integral, applications of the definite integral, the differentiation of logarithmic, exponential, and inverse trigonometric functions, integration, indeterminate forms, improper integrals, infinite series, and expansions of functions. Applications to problems of geometry and physics. Not open to students who are taking any other calculus course or have received credit, including transfer credit or advanced placement credit, for any calculus course other than MATH 151. Fall, Spring (MQR)

MATH 157, 158. Honors Calculus I, II. 4 hr.; 4 cr. each semester. Prereq.: Permission of the chair. Intensive courses that are the first year of a two-year sequence (MATH 157, 158, 207, 208) that will cover elementary and advanced calculus. A rigorous treatment of calculus from a modern point of view is given. The best mathematics students are urged to take this course. Students taking this

course can receive advanced placement credit for calculus courses taken in high school. Not open, without permission of the department chair, to students who have passed MATH 141 or 151. 157–Fall; 158–Spring (MQR)

MATH 190. Studies in Mathematics. MATH 190.1–190.6, 1–6 hr.; 1–6 cr. Prereq.: Permission of the chair. Topic announced in advance. May be repeated for credit if topic is different.[††]

MATH 201. Multivariable Calculus. 4 hr.; 4 cr. Prereq.: MATH 143 or 152. A continuation of the work of MATH 143 or 152. The topics include polar coordinates, vectors, solid analytic geometry, vector-valued functions, double and triple integrals, functions of several variables, partial derivatives. Wherever possible, applications are made to problems of geometry and physics. Fall, Spring (MQR)

MATH 202. Advanced Calculus. 4 hr.; 4 cr. Prereq.: MATH 201 and either MATH 231 or 237, or permission of the chair. Vector-valued functions, higher-order derivatives, maxima and minima of functions of several variables, integrals over paths and surfaces, vector analysis. Fall, Spring (MQR)

MATH 207, 208. Honors Calculus III, IV. 4 lec. hr., 1 conf. hr. and independent work; 5 cr. each sem. Prereq.: MATH 158 or 201 and permission of the chair. Continuation of Honors Calculus I and II (MATH 157, 158), including topics of advanced calculus. 207–Fall; 208–Spring

MATH 220. Discrete Mathematics. 3 hr.; 3 cr. Prereq.: One semester of calculus or permission of the instructor. Topics taken from the subjects of logic and switching circuits, set theory, combinatorics, graph theory, and their applications. Not open to students who have received credit for MATH 120. Fall

MATH 223. Differential Equations with Numerical Methods I. 3 hr.; 3 cr. Prereq.: MATH 201 and 231. First order linear, separable, and exact equations; second order linear equations; series solutions; existence and uniqueness theorem; numerical solutions; applications. Fall, Spring

MATH 224. Differential Equations with Numerical Methods II. 3 hr.; 3 cr. Prereq.: MATH 223, and either MATH 231 or 237. Linear systems of equations; stability of linear systems, orbits, phase portraits, periodic solutions, stability; boundary value problems; applications. Fall

MATH 231. Linear Algebra I. 4 hr.; 4 cr. Prereq.: One semester of calculus. An introduction to linear algebra with emphasis on techniques and applications. Topics to be covered include solutions of systems of linear equations, vector spaces, bases and dimension, linear transformations, matrix algebra, determinants, eigenvalues, and inner products. Not open to students who are enrolled in or who have completed MATH 237. Fall, Spring (MQR)

MATH 232. Linear Algebra II. 3 hr.; 3 cr. Prereq.: MATH 231. A second course in linear algebra. Topics include a continuation of matrices and linear transformations, canonical forms, invariants, equivalence relations, similarity of matrices, eigenvalues and eigenvectors, orthogonal transformations and rigid motions, quadratic forms, bilinear maps, symmetric matrices, reduction of a real quadratic form and applications to conic sections and quadric surfaces. Not open except by permission of the chair to students who are enrolled in or who have completed MATH 237. Fall

MATH 237. Honors Linear Algebra. 4 hr.; 4 cr. Prereq.: Permission of the chair. An intensive course in linear algebra for superior mathematics students. Not open to students who are enrolled in or who have completed MATH 231.[††] (MQR)

MATH 241. Introduction to Probability and Mathematical Statistics. 3 hr.; 3 cr. Prereq. or coreq.: 143 or 152. An introduction to the basic concepts and techniques of probability and statistics with an emphasis on applications. Topics to be covered include the axioms of probability, combinatorial methods, conditional probability, discrete and continuous random variables and distributions, expectations, confidence interval estimations, and tests of hypotheses using the normal, t-, and chi-square distributions. Students taking this course may not subsequently receive credit for MATH 114, except by permission of the chair. Not open to students who are taking or who have received credit for MATH 611. Fall, Spring (MQR)

MATH 242. Methods of Mathematical Statistics. 3 hr.; 3 cr. Prereq.: MATH 241. A study of those methods of mathematical statistics that are most frequently used in the natural and social sciences, as well as actuarial science. Topics include estimation testing of statistical hypotheses, nonparametric tests, analysis of variance, correlation and regression analysis, and other methods of statistical analysis. Fall

MATH 245. Mathematical Models. 3 hr.; 3 cr. Prereq.: MATH 132 or 142 or 152, and permission of the instructor. Construction, analysis, and assessment of mathematical models as they arise in the physical, biological, and social sciences. Specific topics to be announced in advance. May be repeated for credit with permission of the chair. Spring

MATH 247. Linear Programming and Game Theory. 3 hr.; 3 cr. Prereq.: MATH 231 or 237. Methods for handling optimization problems that arise in management, engineering, physical sciences, and social sciences. Topics include convex geometry, the simplex algorithm, duality theory, and the Von Neumann minimax theorem of game theory. Fall

MATH 248. Nonlinear Programming. 3 hr.; 3 cr. Prereq.: MATH 201 and either MATH 231 or 237. Iterative methods for solving nonlinear optimization problems; techniques for handling problems with and without constraints; termination criteria and convergence analysis. Spring

MATH 250. Mathematical Computing. 3 hr.; 3 cr. Prereq.: One semester of calculus. Introduction to a mathematical programming language such as Mathematica, Maple, MATLAB, or Sage. Students will learn algorithmic thinking and apply these ideas to explore problems arising in various areas of mathematics. No prior experience in programming is necessary.

MATH 271. Actuarial Mathematics I. 1 hr.; 1 cr. Prereq.: MATH 241 (or 611); coreq.: MATH 201. The first part of a two-semester sequence. Covers material in calculus-based probability and actuarial mathematics required for Exam P (Probability), an examination given by the Society of Actuaries. Fall

MATH 272. Actuarial Mathematics II. 1 hr.; 1 cr. Prereq.: MATH 271 or permission of the instructor; coreq,: at least one of MATH 633 (preferred), 242 or 621. The second part of a two-semester sequence. Covers material in calculus-based probability (with an emphasis on topics from multivariable calculus such as double integrals) and actuarial mathematics required for Exam P (Probability), an examination given by the Society of Actuaries. Spring

MATH 290. Studies in Mathematics. MATH 290.1–290.6, 1–6 hr.; 1–6 cr. Prereq.: Permission of the chair. Topic announced in advance. May be repeated for credit if topic is different.††

MATH 310. Elementary Real Analysis. 3 hr.; 3 cr. Prereq.: MATH 201. Rigorous introduction to functions of a real variable. Topics include real numbers and the completeness property; limits of sequences; elementary topological concepts; continuity and uniform continuity; sequences and series of functions, derivatives; Taylor's theorem; the Riemann integral. Fall

MATH 317. Foundations of Analysis. 3 hr.; 3 cr. Prereq.: MATH 201. Language of logic and set theory; relations and functions; Peano systems; iterative processes; the natural numbers; integers and integral domains; rational numbers and fields; completeness and the real numbers; alternative characterizations of the real numbers; Archimedean order. Undergraduate students may elect MATH 617 in place of MATH 317. Students may not take both courses. Spring

MATH 320. Introduction to Point Set Topology. 3 hr.; 3 cr. Prereq. or coreq.: MATH 201. Presents the basic concepts and some of the fundamental results of point-set topology. Spring

MATH 328. Introduction to Partial Differential Equations. 3 hr.; 3 cr. Prereq.: MATH 223. Topics covered include partial differential equations, Fourier series, and boundary value problems. Spring

MATH 333. Introduction to Algebraic Structures. 3 hr.; 3 cr. Prereq.: MATH 231. Theory of groups, including cyclic and permutation groups, homomorphisms, normal and factor groups. Theory of rings, integral domains, field of quotients, maximal and prime ideals, rings of polynomials, field extensions. Students may not take both MATH 333 and 613. Fall

MATH 337. Honors Abstract Algebra. 3 hr.; 3 cr. Prereq.: Permission of the chair. An intensive course for students intending to do advanced work related to mathematics. Definitions, examples, and basic properties of groups, rings, fields, and vector spaces. (Credit may not be received for both MATH 337 and either MATH 333 or 613. It is suggested that students needing a slower presentation of abstract algebra register for MATH 333 or 613 instead.)††

MATH 341. Bayesian Models in Data Science and Predictive Analytics. 3 hr.; 3 cr. Prereq.: MATH 241; coreq.: MATH 231. Statistical modeling using the Bayesian framework: estimation, confidence sets, hypothesis testing, prediction, and computing. Emphasis on real-world applications in econometrics. Spring

MATH 342. Data Science via Machine Learning and Statistical Modeling. 4 hr. lec.; 2 hr. lab; 4 cr. Prereq.: MATH 231, MATH 241, CSCI 111 (or equivalent). Philosophy of modeling and learning using data. Prediction using linear, polynomial, interaction regressions, and machine learning, including neural nets and random forests. Probability estimation with asymmetric cost classification. Underfitting versus overfitting and R-squared. Model validation. Correlation versus causation. Interpretations of linear model coefficients. Formal instruction of statistical computing. Data manipulation and visualization using modern libraries. Spring

MATH 368. Advanced Probability. 3 hr.; 3 cr. Prereq.: MATH 201, 231, and 241. Binomial, Poisson, normal, and other distributions. Random variables. Laws of large numbers. Generating functions. Central limit theorem. Not open to students who are taking or who have received credit for MATH 621. Students cannot receive credit for both MATH 368 and MATH 621.

MATH 369. Advanced Statistics. 3 hr.; 3 cr. Prereq.: MATH 201, 231, and 241. Advanced topics in statistics, including statistical inference. Not open to students who are taking or who have received credit for MATH 633. Students cannot receive credit for both MATH 369 and MATH 633.

MATH 385, 385W. Mathematical Foundations of the Secondary School Curriculum. 6 hr.; 4 cr. Prereq.: MATH 201, SEYS 201, 221 and permission of the instructor. Designed to give prospective secondary school mathematics teachers an understanding of the mathematics they will be teaching as well as the

history of mathematics. An examination will be made of the thought underlying the secondary curriculum, from a consideration of the nature of mathematics and mathematical thought to the construction of simple mathematical models drawn from secondary school topics. Students work in small groups to create and implement lessons. Spring

MATH 390. Studies in Mathematics. MATH 390.1–390.6, 1–6 hr.; 1–6 cr. Prereq.: 3.0 department average or permission of the department. The topic will be announced in advance. This course may be repeated for credit provided the topic is not the same.[††]

MATH 391, 392. Special Problems. MATH 391.1–391.5, 1–5 hr.; 1–5 cr., MATH 392.1–392.5, 1–5 hr.; 1–5 cr. each sem. Prereq.: Junior or senior standing and permission of the chair. Each student works on a minor research problem under the supervision of a member of the department. Only students of exceptional mathematical ability and promise are admitted to the course.[††]

MATH 395. Honors Seminar I. MATH 395.1–395.6, 1–6 hr.; 1–6 cr.. Prereq.: Permission of the instructor. A specific area of current research interest will be studied. As the specific material covered may vary from year to year, this course may be taken for credit more than once if the subject matter changes.[††]

MATH 396. Honors Seminar II. MATH 396.3–396.6, 3–6 hr.; 3–6 cr. Prereq.: MATH 395. Continuation of MATH 395.[††]

THE FOLLOWING GRADUATE COURSES ARE OPEN TO QUALIFIED UNDERGRADUATE STUDENTS

Consult the *Graduate Bulletin* for course descriptions and information.

MATH 503.	**Mathematics from an Algorithmic Standpoint.**
MATH 505.	**Mathematical Problem-Solving.**
MATH 509.	**Set Theory and Logic.**
MATH 518.	**College Geometry.**
MATH 524.	**History of Mathematics.**
MATH 525.	**History of Modern Mathematics.**
MATH 550.	**Studies in Mathematics.**
MATH 555.	**Mathematics of Games & Puzzles.**
MATH 601.	**Discrete Mathematics for Computer Science.**
MATH 609.	**Introduction to Set Theory.**
MATH 612.	**Projective Geometry.**
MATH 613.	**Algebraic Structures.**
MATH 614.	**Functions of Real Variables.**
MATH 616.	**Ordinary Differential Equations.**
MATH 617.	**Number Systems.**
MATH 618.	**Foundations of Geometry.**
MATH 619.	**Theory of Numbers.**
MATH 621.	**Probability.**
MATH 623.	**Operations Research (Probability Methods).**
MATH 624.	**Numerical Analysis I.**
MATH 625.	**Numerical Analysis II.**
MATH 626.	**Mathematics and Logic.**
MATH 628.	**Functions of a Complex Variable.**
MATH 630.	**Differential Topology.**
MATH 631.	**Differential Geometry.**
MATH 632.	**Differential Forms.**
MATH 633.	**Statistical Inference.**
MATH 634.	**Theory of Graphs.**
MATH 635.	**Stochastic Processes.**
MATH 636.	**Combinatorial Theory.**
MATH 650.	**Studies in Mathematics.**