Mathematics

Chair
• Maggy Tomova

Undergraduate major: mathematics (B.A., B.S.)
Undergraduate minor: mathematics
Graduate degrees: M.S. in mathematics; Ph.D. in mathematics
Faculty: https://math.uiowa.edu/people/faculty
Website: https://math.uiowa.edu

Mathematics is a basic tool for understanding modern society as well as a crucial requirement for many careers in science, engineering, business, and the professions. Research in this living, dynamic subject is at the highest level in history. According to CareerCast.com, ranking the best jobs of 2017, “In total, four of the top 10 best jobs are built on math...Mathematician ranks No. 7.”

An undergraduate degree in mathematics prepares students for a variety of careers in government and business, for secondary teaching, for graduate study, and with proper planning, for a variety of professional programs. Graduate study is advisable for some business and governmental positions and for college and university teaching and research. The department also offers a minor and partners with the Departments of Computer Science and Statistics and Actuarial Science to offer the undergraduate Certificate in Large Data Analysis.

Related Certificate: Large Data Analysis

The Certificate in Large Data Analysis can be earned in addition to a B.A. or B.S. degree in mathematics. The certificate focuses on handling, processing, and extracting information from large data sets. As computers have become faster and smaller, more information can be gathered and used for a large range of applications, such as for weather forecasting; identifying people and trends utilizing Facebook or other social media; understanding the genome; and searching for disease causes and cures, as well as many other areas of study. The certificate is interdisciplinary, requiring courses from three areas of study—computer science, mathematics, and statistics. Computer science teaches students how to handle large amounts of data and how to implement the algorithms to process them while statistics helps students to understand what can and cannot be legitimately inferred from the data. Mathematics focuses on algorithms and methods for connecting these important areas of data collection.

Graduate Programs of Study

Majors
• Master of Science in Mathematics
• Doctor of Philosophy in Mathematics

Courses

Credit earned in MATH:0100 Basic Algebra I and MATH:0300 Basic Geometry does not count toward graduation.

The sequences MATH:1850 Calculus I and MATH:1860 Calculus II, and MATH:1550 Engineering Mathematics I: Single Variable Calculus and MATH:1560 Engineering Mathematics II: Multivariable Calculus are similar, but they cover the material in a different order and with different emphases. Students who have taken the first semester of one sequence must consult with their advisor before taking the second semester of the other sequence.

Students who consider taking MATH:1860 Calculus II after MATH:1380 Calculus and Matrix Algebra for Business or MATH:1460 Calculus for the Biological Sciences must consult with their advisor; they also must take a math placement test.

Graduate students may not earn graduate credit in courses numbered below 3000.

Graduate students in mathematics must have departmental approval to earn credit for any of the courses listed below numbered 3000 or above except MATH:3995 Topics in Mathematics. Graduate students in mathematics may not earn credit for MATH:4010 Basic Analysis and MATH:4020 Basic Abstract Algebra. Graduate students in other disciplines may earn credit for any course numbered 3000 or above.

Mathematics Courses

MATH:0100 Basic Algebra I 3 s.h.
Percents, ratio and proportion, algebraic expressions and operations, simple products, linear and quadratic equations, simultaneous equations, exponents and radicals; emphasis on verbal problems. GE: Algebra I - Developmental.

MATH:0300 Basic Geometry 3 s.h.
Angles, triangles, polygons, areas, Pythagorean theorem, similar triangles, circles, loci, related topics. Offered spring semesters. Recommendations: It is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course. GE: Geometry - Developmental.

MATH:1000 First-Year Seminar 1 s.h.
Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities). Requirements: first- or second-semester standing.

MATH:1005 College Algebra 4 s.h.
Algebraic techniques, equations and inequalities, functions and graphs, exponential and logarithmic functions, systems of equations and inequalities. Prerequisites: MATH:0100 with a minimum grade of C- or ALEKS score of 30 or higher. Recommendations: It is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course.
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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tr>
<td>MATH:1010</td>
<td>Trigonometry</td>
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<td>Trigonometric functions, solutions of right and</td>
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<td>oblique triangles, complex numbers. Prerequisites:</td>
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<td>MATH:1340 with a minimum grade of C- or MPT</td>
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<td>Level 3 score of 9 or higher or MATH:1005 with</td>
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<td>a minimum grade of C- or MATH:1380 with a</td>
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<td>minimum grade of C- or ALEKS score of 55 or</td>
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<td>higher. Recommendations: it is strongly</td>
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<td>Formal Reasoning.</td>
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<td>MATH:1020</td>
<td>Elementary Functions</td>
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<td>Functions, relations, coordinate systems;</td>
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<td>properties and graphs of algebraic, trigonometric,</td>
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<td>logarithmic, exponential functions; inverse</td>
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<td>trigonometric functions; properties of lines,</td>
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<td>conic sections. Prerequisites: MATH:1010 with a</td>
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<td>MATH:1120</td>
<td>Logic of Arithmetic</td>
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<td>Mathematical and conceptual foundations of the</td>
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<td>natural numbers used in elementary school</td>
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<td>arithmetic teaching; multiple algorithmic</td>
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<td>approaches to arithmetic and its mathematical</td>
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<td>and contextual relationships, extensions to</td>
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<td>integers, rational and irrational numbers,</td>
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<td>multiple representations. Prerequisites: ALEKS</td>
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<td>score of 30 or higher or MATH:1460 with a</td>
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<td>MATH:1860 with a minimum grade of C- or MATH:1005</td>
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<td>MATH:1130</td>
<td>Theory of Arithmetic</td>
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<td>Sets, cardinalities, reasoning in proofs,</td>
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<td>counterexamples, arithmetic with integers,</td>
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<td>rationals, irrationals, number theory, functions,</td>
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<td>algebraic expressions. Prerequisites: MATH:1550</td>
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<td>MATH:1380 with a minimum grade of C- or MATH:1440</td>
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<td>Formal Reasoning.</td>
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<td>MATH:1140</td>
<td>Mathematical Basis of Elementary Geometry</td>
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<td>Points, lines, planes; measurement, two- and</td>
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<td>three-dimensional coordinate geometry,</td>
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<td>transformational geometry and vectors;</td>
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<td>applications of geometry to solve real-world</td>
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<td>problems. Prerequisites: MPT Level 3 score of 9</td>
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<td>or higher or MATH:1010 with a minimum grade of C-</td>
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<td>test for accurate placement and success in the</td>
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<td>course. GE: Quantitative or Formal Reasoning.</td>
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<td>MATH:1340</td>
<td>Mathematics for Business</td>
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<td>Algebraic techniques, functions and functional</td>
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<td>models, exponential and logarithmic functions</td>
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<td>and models, linear programming, informal</td>
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<td>introduction to calculus; examples and</td>
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<td>applications from management, economic sciences,</td>
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<td>related areas. Prerequisites: MATH:1005 with a</td>
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<td>minimum grade of C- or MPT Level 3 score of 9</td>
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<td>or higher or ALEKS score of 45 or higher.</td>
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<td>MATH:1380</td>
<td>Calculus and Matrix Algebra for Business</td>
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<td>Quantitative methods for treating problems</td>
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<td>arising in management, economic sciences,</td>
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<td>related areas; introduction to differential and</td>
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<td>integral calculus, systems of linear equations</td>
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<td>and matrix operations. Prerequisites: MATH:1340</td>
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<td>with a minimum grade of C- or MPT Level 3 score</td>
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<td>Quantitative or Formal Reasoning.</td>
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<td>MATH:1440</td>
<td>Mathematics for the Biological Sciences</td>
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<td>Relations, functions, coordinate systems,</td>
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<td>graphing, polynomials, trigonometric functions,</td>
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<td>logarithmic and exponential functions;</td>
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<td>discrete mathematics, probability; examples and</td>
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<td>applications from biological sciences. Prerequisites: MATH:1005 with a minimum grade of C- or ALEKS score of 55 or higher or MATH:1010 with a minimum grade of C- or MATH:1340 with a minimum grade of C- or MATH:0100 with a minimum grade of C- or MATH:1440 with a minimum grade of C- or MATH:1850 with a minimum grade of C- or ALEKS score of 65 or higher or MATH:1440 with a minimum grade of C- or MATH:1005 with a minimum grade of C-. Requirements: elementary teacher certificate candidacy or certification. Recommendations: it is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course. GE: Quantitative or Formal Reasoning.</td>
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MATH:1460 Calculus for the Biological Sciences 4 s.h.
One-semester survey of calculus for students in biological or life sciences; non-theoretical treatment of differential and integral calculus; brief introduction to differential equations and probability with calculus, with applications to the life sciences. Prerequisites: MATH:1440 with a minimum grade of C- or MATH:1020 with a minimum grade of C- or MATH:1005 with a minimum grade of C- and MATH:1010 with a minimum grade of C-) or ALEKS score of 70 or higher or (ALEKS score of 55 or higher and MATH:1010 with a minimum grade of C-) or (MATH:1010 with a minimum grade of C- and MATH:1340 with a minimum grade of C-) or MPT Level 3 score of 9 or higher. Recommendations: it is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course. GE: Quantitative or Formal Reasoning.

MATH:1550 Engineering Mathematics I: Single Variable Calculus 4 s.h.
Limits, derivatives, max/min, other applications, mean-value theorem, approximating functions, concavity, curve sketching, exponential models; Riemann sums, fundamental theorem; integration techniques, improper integrals, approximations. Prerequisites: (MATH:1010 with a minimum grade of C- and MATH:1005 with a minimum grade of C-) or MPT Level 3 score of 9 or higher or ALEKS score of 75 or higher or (MATH:1340 with a minimum grade of C-) or MATH:1020 with a minimum grade of C- or (MATH:1340 with a minimum grade of C- and MATH:1010 with a minimum grade of C-) or (MATH:1340 with a minimum grade of C- and MATH:1010 with a minimum grade of C-) or MPT Level 3 score of 9 or higher. Recommendations: it is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course. Recommendations: it is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course. GE: Quantitative or Formal Reasoning.

MATH:1560 Engineering Mathematics II: Multivariable Calculus 4 s.h.
Vector geometry; functions of several variables; polar coordinates; partial derivatives, gradients, directional derivatives; tangent lines and planes; max/min/parametric curves, curvilinear motion; multiple integrals; vector fields, flows; integration on curves, work; divergence, flux, Green's theorem. Prerequisites: MATH:1550 with a minimum grade of C- or MATH:1850 with a minimum grade of C- or MATH:1860 with a minimum grade of C- or MATH:1560 or MATH:1860 or MATH:1560 or MPT Level 3 score of 15 or higher. Requirements: score of 4 or higher on AP Calc (AB) exam, or score of 4 or higher on AP Calc (BC) exam.

MATH:1850 Calculus I 4 s.h.
Fundamental concepts, limits, methods, and techniques of differential calculus of a single variable; definite and indefinite integrals, substitution rule, fundamental theorem of calculus; applications including graphing, extreme values, areas, and volumes. Prerequisites: (MATH:1010 with a minimum grade of C- and MATH:1380 with a minimum grade of C-) or MATH:1460 with a minimum grade of C- or ALEKS score of 75 or higher or MPT Level 3 score of 9 or higher or (ALEKS score of 55 or higher and MATH:1010 with a minimum grade of C-) or MATH:1020 with a minimum grade of C- or (MATH:1340 with a minimum grade of C- and MATH:1010 with a minimum grade of C-) or (MATH:1340 with a minimum grade of C- and MATH:1010 with a minimum grade of C-) or MPT Level 3 score of 9 or higher. Recommendations: it is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course. GE: Quantitative or Formal Reasoning.

MATH:1860 Calculus II 4 s.h.
Techniques of integration including by-parts, trigonometric integrals, trigonometric substitutions, partial fractions, improper integrals; applications (i.e., arclength), area surfaces of revolutions, application to physics; introduction to differential equations; parametric equations and polar coordinates; infinite sequences and series, convergence tests, power series, Taylor polynomials and series. Prerequisites: MATH:1550 with a minimum grade of C- or MATH:1850 with a minimum grade of C- or MPT Level 3 score of 15 or higher. Recommendations: it is strongly recommended that students whose math placement score is older than one year retake the math placement test for accurate placement and success in the course.

MATH:2150 Foundations of Geometry 3 s.h.
Axiomatic development of common foundation for Euclidean, non-Euclidean geometry; constructions of non-Euclidean models, independence of parallel postulate. Prerequisites: MATH:1860 or MATH:1560.

MATH:2550 Engineering Mathematics III: Matrix Algebra 2 s.h.
Applications, computers for matrix calculations; matrix arithmetic; linear independence, basis, subspace (in R2, R3); systems of equations, matrix reduction; rank, dimension; determinants, applications; eigenvalues, eigenvectors; diagonalization, principal axis theorem. Prerequisites: MATH:1850 or MATH:1550 or MATH:1860 or MATH:1560 or MPT Level 3 score of 15 or higher.

MATH:2560 Engineering Mathematics IV: Differential Equations 3 s.h.
Ordinary differential equations and applications; first-order equations; higher order linear equations; systems of linear equations, Laplace transforms; introduction to nonlinear equations and systems, phase plane, stability. Prerequisites: MATH:1560 or MATH:1860 and (MATH:2700 or MATH:2550).

MATH:2700 Introduction to Linear Algebra 4 s.h.
Vector algebra and geometry of three-dimensional Euclidean space and extensions to n-space and vector spaces; lines and planes, matrices, linear transformations, systems of linear equations, reduction to row echelon form, dimension, rank, determinants, eigenvalues and eigenvectors, diagonalization, Principal Axis Theorem. Prerequisites: MATH:1850 or MATH:1550 or MATH:1860 or MATH:1560 or MPT Level 3 score of 15 or higher.

MATH:2850 Calculus III 4 s.h.
Multivariable calculus; vector functions, total differentials, gradient, implicit functions, coordinate systems, Taylor's expansion, extremum, multiple integrals, vector fields, line integrals, surface integrals, and Green's, Stokes', and divergence theorems. Prerequisites: MATH:1860 with a minimum grade of C- or MATH:1560 with a minimum grade of C-.

MATH:2995 Introduction to Research Opportunities 1 s.h.
Modern mathematics research areas and activities; seminar. Prerequisites: (MATH:2700 or MATH:2550) and (MATH:1560 or MATH:1860).
MATH:3550 Engineering Mathematics V: Vector Calculus 3 s.h.
Partial derivatives, max-min problems, integrals along curves, surfaces and solids, vector fields and conservation of energy; curl, divergence, Stokes' theorem and the divergence theorem; the classical partial differential equations and qualitative behavior of their solutions. Prerequisites: MATH:1560 and (MATH:2550 or MATH:2700). Corequisites: MATH:2560.

MATH:3600 Introduction to Ordinary Differential Equations 2-3 s.h.
First-order ordinary differential equations; second-order linear differential equations; series solutions; higher-order linear and matrix differential equations; existence and uniqueness theorems. Prerequisites: (MATH:1560 or MATH:1860) and (MATH:2550 or MATH:2700). Corequisites: MATH:2850 (if not taken as a prerequisite). Requirements: prior or concurrent enrollment in MATH:2850.

MATH:3700 Introduction to Matrix Theory 3 s.h.
Vector algebra and geometry of three-dimensional Euclidean space and extensions to n-space and vector spaces; lines and planes, matrices, linear transformations, systems of linear equations, reduction to row-echelon form, dimension, rank, determinants, eigenvalues and eigenvectors, diagonalization, Principal Axis Theorem. Requirements: graduate standing.

MATH:3720 Introduction to Abstract Algebra I 3 s.h.
Basic logic, proof methods, sets, functions, relations, mathematical induction; gradient transition from familiar number systems to abstract structures—division algorithm, unique factorization theorems; groups, subgroups, quotient groups, homomorphisms. Prerequisites: MATH:2700 or MATH:2550.

MATH:3750 Classical Analysis 3 s.h.
Multivariable calculus; vector functions, total differentials, gradient, implicit functions, coordinate systems, Taylor's expansion, extrema, multiple integrals, vector fields, line integrals, surface integrals, and Green's, Stokes', and divergence theorems. Requirements: graduate standing and one year of calculus.

MATH:3770 Fundamental Properties of Spaces and Functions I 3 s.h.
Elementary topological and analytic properties of real numbers; emphasis on ability to handle definitions, theorems, proofs. Prerequisites: MATH:1560 or MATH:1860. Corequisites: MATH:2700. Requirements: second-semester calculus.

MATH:3800 Elementary Numerical Analysis 3 s.h.
Computer arithmetic, root finding, polynomial approximation, numerical integration, numerical linear algebra, numerical solution of differential equations; use of a higher-level computer language such as Matlab, Python, or Julia. Prerequisites: (MATH:2550 or MATH:2700) and (MATH:1560 or MATH:1860). Same as CS:3700.

MATH:3900 Introduction to Mathematics Research 3 s.h.
Research experience; students study an elementary topic of active research, then work in groups under faculty supervision. Prerequisites: (MATH:2700 or MATH:2550) and (MATH:1860 or MATH:1560).

MATH:3995 Topics in Mathematics 3 s.h.
Varied topics. Recommendations: junior, senior, or graduate standing in mathematics, classics, or related fields.

MATH:3996 Individual Study and Honors in Mathematics arr.

MATH:3997 Readings in Mathematics arr.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH:4210</td>
<td>Foundations of Analysis</td>
<td>4 s.h.</td>
<td>MATH:2700 and MATH:5800 and (MATH:2850 or MATH:3550). Prerequisites: MATH:3770.</td>
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<tr>
<td>MATH:4510</td>
<td>Introduction to Differential Geometry II</td>
<td>3 s.h.</td>
<td>MATH:2850 or MATH:2560.</td>
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<tr>
<td>MATH:4740</td>
<td>Large Data Analysis</td>
<td>3 s.h.</td>
<td>(CS:1210 with a minimum grade of C- or ENGR:2730 with a minimum grade of C-) and (MATH:3800 or MATH:4720).</td>
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<tr>
<td>MATH:4820</td>
<td>Optimization Techniques</td>
<td>3 s.h.</td>
<td>MATH:2700 or MATH:2550) and (ME:4111 or MATH:3800 or MATH:3700) and (MATH:1560 or MATH:2850).</td>
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<tr>
<td>MATH:4860</td>
<td>High Performance and Parallel Computing</td>
<td>3 s.h.</td>
<td>(CS:2210 with a minimum grade of C- or MATH:4050) and CS:2230 with a minimum grade of C-.</td>
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<tr>
<td>MATH:5000</td>
<td>Abstract Algebra I</td>
<td>4 s.h.</td>
<td>MATH:3720 or MATH:4090.</td>
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<tr>
<td>MATH:5010</td>
<td>Abstract Algebra II</td>
<td>4 s.h.</td>
<td>MATH:5000.</td>
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<tr>
<td>MATH:5200</td>
<td>Introduction to Analysis I</td>
<td>4 s.h.</td>
<td>MATH:3770 or MATH:4210. Requirements: MATH:3770 or graduate standing.</td>
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<td>MATH:5210</td>
<td>Introduction to Analysis II</td>
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<tr>
<td>MATH:5400</td>
<td>General Topology</td>
<td>4 s.h.</td>
<td>MATH:3720 or MATH:4090.</td>
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<tr>
<td>MATH:5410</td>
<td>Introduction to Smooth Manifolds</td>
<td>3 s.h.</td>
<td>MATH:2700 and MATH:2850 and MATH:5400.</td>
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<tr>
<td>MATH:5500</td>
<td>Nonlinear Dynamics with Numerical Methods</td>
<td>4 s.h.</td>
<td>MATH:3770.</td>
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</tr>
<tr>
<td>MATH:5510</td>
<td>Partial Differential Equations with Numerical Methods</td>
<td>4 s.h.</td>
<td>MATH:2850 and MATH:3600.</td>
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<tr>
<td>MATH:5700</td>
<td>High Performance and Parallel Computing</td>
<td>3 s.h.</td>
<td>MATH:3770 or MATH:4210.</td>
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<tr>
<td>MATH:5800</td>
<td>Numerical Analysis: Nonlinear Equations and Approximation Theory</td>
<td>4 s.h.</td>
<td>MATH:3720 and MATH:2850 or MATH:3550. Requirements: knowledge of computer programming. Same as CS:5710.</td>
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<tr>
<td>MATH:5810</td>
<td>Numerical Analysis: Differential Equations and Linear Algebra</td>
<td>4 s.h.</td>
<td>MATH:2850 or MATH:2560. Requirements: knowledge of computer programming. Same as CS:5720.</td>
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</tbody>
</table>
MATH:5900 First-Year Graduate Seminar 1 s.h.
Introduction to mathematics graduate program. Requirements: first-year graduate standing in mathematics.

MATH:5950 Qualifying Exam Preparation Seminars 0 s.h.
Exam preparation in pure and applied mathematics.

MATH:6000 Introduction to Algebra I 3 s.h.
Abstract algebra: semigroups, groups, rings, integral domains, polynomial rings, division rings, fields, vector spaces, matrices, modules over rings, lattices, categories. Prerequisites: MATH:5010.

MATH:6010 Introduction to Algebra II 3 s.h.
Continuation of MATH:6000. Prerequisites: MATH:6000.

MATH:6200 Analysis I 3 s.h.
Lebesgue measure and integral, fundamental theorem of calculus, abstract measures and integration, Fubini's theorem, Radon-Nikodym theorem, Riesz representation theorem, L-p spaces. Prerequisites: MATH:5210.

MATH:6210 Analysis II 3 s.h.
Hilbert space, Banach space techniques; Hahn-Banach theorem, open mapping theorem, principle of uniform boundedness; reflexivity, H-p spaces, Paley-Wiener theorem, space of functions analytic on the open unit disk. Prerequisites: MATH:6200.

MATH:6400 Introduction to Algebraic Topology 3 s.h.
Homotopy, fundamental group and covering spaces, CW and simplicial complexes, simplicial homology, Euler characteristic. Prerequisites: MATH:5400.

MATH:6410 Introduction to Differential Topology 3 s.h.
Manifolds, functions: tangent bundle, Morse-Sard theorem, transversality, submanifolds, tubular neighborhoods, normal bundles, vector fields, degree and intersection theory, fixed-point theory, Morse theory. Prerequisites: MATH:5410.

MATH:6500 Differential Geometry I 3 s.h.
Differentiable manifolds, forms, tensors, Riemannian metrics, isometries, connections, geodesics, curvature, related topics. Prerequisites: MATH:5410.

MATH:6510 Differential Geometry II 3 s.h.
Continuation of MATH:6500; varied topics, may include study of existence and uniqueness of solutions to differential equations and systems related to geometry, indefinite metrics, Lie groups, attributes of manifolds with particular curvature properties, global Riemannian geometry, Kahler geometry, applications of differential geometry to other disciplines. Prerequisites: MATH:6500.

MATH:6600 Ordinary Differential Equations I 3 s.h.
Existence, uniqueness, continuous dependence of solutions to initial value problems, variational calculus, Lagrangian and Hamiltonian systems, differential inequalities, perturbation theory, normal forms, invariant manifolds, KAM theory, bifurcation theory, boundary value problems. Prerequisites: MATH:5210.

MATH:6610 Ordinary Differential Equations II 3 s.h.
Continuation of MATH:6600. Prerequisites: MATH:6600.

MATH:6700 Partial Differential Equations I 3 s.h.
Elliptic equations; potential theory, maximum principle, a priori estimate, Dirichlet problem; initial value problem for parabolic equations; hyperbolic equations; Duhamel's principle, Cauchy problem; nonlinear equations, characteristics, canonical form, first-order systems. Prerequisites: MATH:5210.

MATH:6710 Partial Differential Equations II 3 s.h.
Continuation of MATH:6700. Prerequisites: MATH:6700.

MATH:6850 Theoretical Numerical Analysis I 3 s.h.
Theoretical foundations of numerical analysis, within framework of functional analysis; application areas including approximation theory, numerical methods for partial differential equations; integral equations; introduction to functional analysis. Prerequisites: MATH:5200 and MATH:5210 and MATH:5800 and MATH:5810.

MATH:6860 Theoretical Numerical Analysis II 3 s.h.
Continuation of MATH:6850. Prerequisites: MATH:6850.

MATH:7000 Homological Algebra 2-3 s.h.
Modules, tensor products, groups of homomorphisms, categories, functors, homology functors, projective and injective modules, derived functors, torsion and extension functors, homological dimension. Prerequisites: MATH:6010.

MATH:7030 Topics in Algebra 2-3 s.h.
May include algebraic number theory, groups, representation theory, algebras, ideal theory, lattice theory. Prerequisites: MATH:6010.

MATH:7070 Seminar: Algebra arr.

MATH:7080 Seminar: Commutative Ring Theory arr.

MATH:7090 Seminar: Representation Theory arr.

MATH:7200 Functional Analysis I 2-3 s.h.
Locally convex topological vector spaces, duality, tensor products and nuclear spaces; Krein-Millman theorem, Choquet's theorem; geometry of Banach spaces, nonlinear functional analysis; operators on Hilbert spaces, spectral theorem, algebras of operators. Prerequisites: MATH:6210.

MATH:7210 Functional Analysis II 2-3 s.h.
Continuation of MATH:7200. Prerequisites: MATH:7200.

MATH:7250 Topics in Analysis 2-3 s.h.
Measure theory, integration, general topology.


MATH:7400 Topology of Manifolds 3 s.h.
Embedding, knotting, immersions; isotopy, homotopy, regular neighborhoods, engulfing, surgery, cobordism; three-, four-, and higher dimensional manifolds. Prerequisites: MATH:6400 and MATH:6410.

MATH:7450 Topics in Topology 2-3 s.h.
May include homotopy theory, topology of 3-manifolds, 4-manifolds, or higher-dimensional manifolds, knotting and embedding problems, fiber bundles and characteristic classes, K-theory, PL manifolds, infinite-dimensional manifolds.

MATH:7470 Seminar: Topology arr.


MATH:7580 Seminar: Mathematical Physics arr.

MATH:7630 Topics in Mathematical Biology 2-3 s.h.
Application of mathematics to biology.

MATH:7660 Seminar: Nonlinear Dynamics and Differential Equations arr.

MATH:7670 Seminar: Mathematical Biology arr.

MATH:7730 Topics in Partial Differential Equations 2-3 s.h.
Regularity theory, nonlinear analysis in partial differential equations, fluid dynamics, harmonic analysis, conservation laws, other topics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Arrangement</th>
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</thead>
<tbody>
<tr>
<td>MATH:7830</td>
<td>Topics in Applied Mathematics</td>
<td>arr.</td>
</tr>
<tr>
<td></td>
<td>Application of mathematics to other disciplines.</td>
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</tr>
<tr>
<td>MATH:7870</td>
<td>Seminar: Numerical Analysis</td>
<td>arr.</td>
</tr>
<tr>
<td>MATH:7990</td>
<td>Reading Research</td>
<td>arr.</td>
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