The Mathematics Department offers the Master of Science in Data Science (online) and graduate-level course work.

**Graduate Faculty**
Chris Ahrendt, Ph.D.
Mohammad Aziz, Ph.D.
Charles Bingen, Ed.D.
Dani Brake, Ph.D.
Abra Brisbin, Ph.D.
Christopher Davis, Ph.D.
Herschel Day, F.S.A.
Colleen Duffy, Ph.D.
Marc R. Goulet, Ph.D.
Jennifer Harrison, Ph.D.
Ryan Harrison, Ph.D.
Christopher S. Hlas, Ph.D.
Marie-Claire Koissi, Ph.D.
Jessica Kraker, Ph.D.
Dandrielle Lewis, Ph.D.
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Carolyn Otto, Ph.D.
Michael Penkava, Ph.D.
Kristopher Presler, F.S.A.
Alexander J. Smith, Ph.D. (Chair)
Simei Tong, Ph.D.
James Walker, D.A.
Vicki Whitledge, Ph.D.

**Graduate Programs**
- Data Science - Master of Science

All 500- and 600-level graduate courses include requirements or assignments which differentiate them from their companionate 300- and 400-level undergraduate offerings. Students who have taken a course at the 300- or 400-level may not include that course at the 500- or 600-level in a graduate program, except in the case of special topics courses when the topic is not the same as that taken at the undergraduate level.

**Data Science (DS)**

**DS 700 Foundations of Data Science (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Introduction to data science and its importance in business decision making.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

**DS 705 Statistical Methods (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Statistical methods and inference procedures presented with an emphasis on applications, computer implementation, and interpretation of results.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

**DS 710 Programming for Data Science (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Introduction to programming languages and packages used in data science.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

**DS 715 Data Warehousing (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Introduction to the concepts and techniques to work with and reason about subject-oriented, integrated, time-variant, and nonvolatile collections of data in support of management’s decision-making process.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

**DS 730 Big Data: High Performance Computing (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Overview of how to process large datasets efficiently, including introduction of non-relational databases.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

**DS 735 Communicating about Data (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Prepares students to master technical, informational, and persuasive communication to meet organizational goals.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

**DS 740 Data Mining (3 crs)**
Prerequisite: Limited to Data Science master’s degree students.
Data mining methods and procedures for diagnostic and predictive analytics.

Attributes: Data Science MS OL Flat Rate Tuition
Grading Basis: A-F Grades Only
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0
Math (MATH)

MATH 507 Mathematics and Music (3 crs)
Prerequisite: MATH 114 (or equivalent) or consent of instructor.
- Cross-listed with MATH 307. Credit may not be earned in both courses.

Using mathematics to understand, appreciate, and create music. Free audio processing software will be emphasized. Rock, jazz, classical, and experimental music will be analyzed. Connections are made to brain science and medicine.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 511 Differential Equations (3 crs)
Prerequisite: MATH 216. Credit may not be earned in both MATH 311/ MATH 511 and MATH 312.
- Cross-listed with MATH 311. Credit may not be earned in both courses.


Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 513 Digital Signal Processing (3 crs)
Prerequisite: MATH 215 or consent of instructor.
- Cross-listed with MATH 313. Credit may not be earned in both courses.

Fundamentals of digital signal processing. Fourier series, Fourier transforms and computerized Fourier transforms (FFTs) are described and applied to the analysis of digitized audio and digitized images.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 514 Discrete Mathematics (3 crs)
Prerequisite: MATH 215 or consent of instructor.
- Cross-listed with MATH 314. Credit may not be earned in both courses.

Introductory course in discrete mathematics. Topics include elementary combinatorics, graph theory, trees, and Boolean algebra. The course emphasizes an algorithmic approach to problem solving.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0
MATH 515 Advanced Calculus I (3 crs)
Prerequisite: MATH 216 and MATH 324/MATH 524.
  • Cross-listed with MATH 315. Credit may not be earned in both courses.
Differential and integral calculus of several variables; vector calculus; line, surface, and space integrals including Green’s theorem, Divergence theorem, and Stokes’ theorem.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 516 Introduction to Real Analysis (3 crs)
Prerequisite: MATH 216 and MATH 324/MATH 524.
  • Cross-listed with MATH 316. Credit may not be earned in both courses.
Real numbers, introductory topological topics, limits, sequences of numbers, continuity, sequences of functions, and series.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 518 Introduction to Complex Variables (3 crs)
Prerequisite: MATH 216
  • Cross-listed with MATH 318. Credit may not be earned in both courses.
Elementary functions of a complex variable, complex integrals, and residue theory.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 524 Linear Algebra (4 crs)
Prerequisite: MATH 215
  • Cross-listed with MATH 324. Credit may not be earned in both courses.
An introductory course in linear algebra including matrix algebra, systems of linear equations, vector spaces, linear transformations, eigenvalues, and applications. Also covers methods of proof and a survey of student-faculty research.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 530 Modern Geometry (4 crs)
Prerequisite: MATH 114
  • Cross-listed with MATH 330. Credit may not be earned in both courses. Requires basic knowledge of Euclidean Geometry.
Contemporary and classical Euclidean geometry, with emphasis on constructions, transformations, and proof. The Mira and geometry software will be used to illustrate these topics. Some non-Euclidean geometry included.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 535 Introduction to Point-Set Topology (3 crs)
Prerequisite: MATH 324/MATH 524
  • Cross-listed with MATH 335. Credit may not be earned in both courses.
Theory of sets, continuity of functions, neighborhoods of points, topological and metric spaces, connectedness and compactness.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 545 Introduction to Probability and Mathematical Statistics (4 crs)
Prerequisite: MATH 215 or concurrent registration. Credit may not be earned in both MATH 345/MATH 545 and MATH 346/MATH 546.
  • Cross-listed with MATH 345. Credit may not be earned in both courses.
MATH 246 may not be taken for credit after or concurrently with MATH 345/MATH 545.
Counting techniques, discrete and continuous random variables, probability distributions, sampling distributions, estimation, hypothesis testing, linear regression, correlation, nonparametric statistics. Students who desire more extensive probability and statistics should take MATH 346/MATH 546, MATH 347/MATH 547.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 546 Introduction to Probability (4 crs)
Prerequisite: MATH 216 or concurrent enrollment. Credit may not be earned in both MATH 345/MATH 545 and MATH 346/MATH 546.
  • Cross-listed with MATH 346. Credit may not be earned in both courses.
Probability in discrete and continuous sample spaces; conditional probability; counting techniques; probability functions; binomial, Poisson, normal distributions; and transformations of variables.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 547 Mathematical Statistics (4 crs)
Prerequisite: MATH 215; MATH 346/MATH 546.
  • Cross-listed with MATH 347. Credit may not be earned in both courses.
MATH 246 may not be taken for credit after or concurrently with MATH 347/MATH 547.
Sampling distributions; estimation and properties; hypothesis testing; analysis of variance; regression; nonparametric tests; and introduction to Bayesian inference.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 2
MATH 551 Numerical Analysis I (3 crs)
Prerequisite: MATH 215
  • Cross-listed with MATH 351. Credit may not be earned in both courses.
Nonlinear equations, interpolation and approximation, least squares, systems of linear equations, and error analysis.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 552 Numerical Analysis II (3 crs)
Prerequisite: MATH 215 and either one of the following: CS 163, CS 170, CS 335, or consent of instructor.
  • Cross-listed with MATH 352. Credit may not be earned in both courses.
Numerical solution of differential equations, numerical differentiation and integration, and the eigenvalue problem.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 554 Introduction to Mathematical Modeling (4 crs)
Prerequisite: MATH 215
  • Cross-listed with MATH 354. Credit may not be earned in both courses.
Introduction to building mathematical models in an applied context, including principles of modeling; project(s) involve modeling open-ended real-world problems. Skills covered may include discrete dynamical systems, differential equations, stochastic models, and linear programming.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 555 Linear Programming (3 crs)
Prerequisite: MATH 215
  • Cross-listed with MATH 355. Credit may not be earned in both courses.
Introductory topics in linear programming including computational development of the simplex method, duality theory of linear programming, dual simplex method, transportation problem, and the use of a linear programming package.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 558 Introduction to Optimization (3 crs)
Prerequisite: MATH 215
  • Cross-listed with MATH 358. Credit may not be earned in both courses.
An introduction to the theory and application of optimization techniques. Analytic and numerical methods for linear and nonlinear problems of both constrained and unconstrained type will be considered.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 625 Abstract Algebra I (3 crs)
Prerequisite: MATH 324/MATH 524
  • Cross-listed with MATH 425. Credit may not be earned in both courses.
An introduction to the abstract concepts of algebra such as groups, rings, and fields. Topics such as direct products, group homomorphisms, factor groups, integral domains, and polynomial rings will be included.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 626 Abstract Algebra II (3 crs)
Prerequisite: MATH 425/MATH 625. No credit if taken after MATH 322.
  • Cross-listed with MATH 426. Credit may not be earned in both courses.
A continuation of Math 425 including more advanced topics from groups, rings, and fields, such as the Sylow theorems, prime and maximal ideals, unique factorization domains, and finite fields.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 650 Foundations of Actuarial Science (4 crs)
Prerequisite: Admission to Actuarial Science program (Code 180-001).
  • Cross-listed with MATH 450. Credit may not be earned in both courses.
Actuarial theory of financial mathematical models for contingent events as applied to insurance, annuities, pensions, and reserving. Together with Math 460, this course prepares students for the actuarial exam covering contingent payments.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 651 Teaching Mathematics with Technology (4 crs)
Prerequisite: ES 203 or ES 210/ES 211 or ES 212; MATH 414. Credit may not be earned in both MATH 451/MATH 651 and MATH 453/MATH 653.
  • Cross-listed with MATH 451. Credit may not be earned in both courses. May not be counted for credit toward a major or minor in mathematics except in mathematics teaching programs.
In this course students will investigate teaching mathematics effectively with technology. Technology used includes graphing calculators, spreadsheets, interactive software, and calculator based laboratories. Topics include functions, statistics, probability, geometry, and mathematical modeling.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 655 Teaching Mathematics with Technology (4 crs)
Prerequisite: ES 203 or ES 210/ES 211 or ES 212; MATH 414. Credit may not be earned in both MATH 451/MATH 651 and MATH 453/MATH 653.
  • Cross-listed with MATH 451. Credit may not be earned in both courses. May not be counted for credit toward a major or minor in mathematics except in mathematics teaching programs.
In this course students will investigate teaching mathematics effectively with technology. Technology used includes graphing calculators, spreadsheets, interactive software, and calculator based laboratories. Topics include functions, statistics, probability, geometry, and mathematical modeling.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0
Mathematics

MATH 656 Operations Research (2-3 crs)
Prerequisite: MATH 215
- Cross-listed with MATH 456. Credit may not be earned in both courses. Students who have earned credit in an upper division linear programming course may earn only two credits in this course. This two-credit option is available only to those who have taken such a course. For students earning two credits due to this restriction, attendance will be optional during the linear programming unit.

An introduction to the theory and application of operations research techniques. Several important topics including linear programming, inventory models, waiting time models, and replacement models will be discussed.

Grading Basis: No S/U Grade Option

MATH 660 Continent Payment Analysis (4 crs)
Prerequisite: MATH 450/MATH 650 and Admission to the Actuarial Science Program (Code 180-001).
- Cross-listed with MATH 460. Credit may not be earned in both courses.

Actuarial theory of reserves, multiple life models, multiple decrement models. Poisson processes, and multi-state transition models. Together with Math 450, this course prepares students for the actuarial exam covering contingent payments.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 662 History of Mathematics (3 crs)
Prerequisite: MATH 114
- Cross-listed with MATH 462. Credit may not be earned in both courses.

A study of mathematics from a historical point of view beginning with the work of the early Greek mathematicians and including selected mathematicians and periods of mathematical development up to the present.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 670 Mathematical Models for Financial Economics (4 crs)
Prerequisite: Admission to the Actuarial Science Program (Code 180-001).
- Cross-listed with MATH 470. Credit may not be earned in both courses.

An introduction to financial derivatives including forwards and options with coverage of binomial, Black-Scholes, and lognormal pricing models.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 675 Actuarial Foundations of Short-Term Coverages (4 crs)
Prerequisite: MATH 347. Admission to Actuarial Science program. No credit if taken after MATH 491 when offered as Introduction to Credibility & Loss Models
- Cross-listed with MATH 475. Credit may not be earned in both courses.

An introduction to ratemaking and reserving for short-term insurance coverages; credibility theory; and actuarial models for frequency, severity, and aggregate distributions.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 4
Lab/Studio Hours: 0

MATH 691 Special Topics (1-3 crs)
- Cross-listed with MATH 491.

A variable content course designed to allow a breadth of study through investigation of mathematical topics not covered in other courses. Special interests of instructors will be utilized to provide topics.

Repeat: Course may be repeated for a maximum of 9 credits
Grading Basis: No S/U Grade Option

MATH 694 Mathematics Seminar (1 cr)
- Cross-listed with MATH 494.

An intensive study of selected topics in mathematics. The exact topics to be studied will vary according to the interests of the professor and the seminar participants.

Repeat: Course may be repeated
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 1
Lab/Studio Hours: 0

MATH 704 Mathematics for Middle School Teachers (3 crs)
Topics include number and number sense, probability, statistics, reasoning, problem solving, patterns and functions, geometry, measurement, and algebra.

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 707 Current Issues in Mathematics Teaching (3 crs)
A particular current trend in mathematics education will be the theme for each offering. Focus will be on mathematical content necessary to design instruction and develop curriculum. Nonthematic issues will also be discussed.

Repeat: Course may be repeated
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 708 Mathematics for Middle School Teachers (3 crs)

Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0
MATH 710 Selected Topics in Calculus (1-3 crs)
Prerequisite: Minimum eight credits of Calculus or consent of instructor
Consent: Instructor Consent Required
An in-depth investigation of elementary calculus from an advanced viewpoint, including functions, limits, continuity, integrals, derivatives, and related applications.
Grading Basis: No S/U Grade Option

MATH 719 Introduction to Real Analysis (3 crs)
Prerequisite: MATH 215
Selected topics including sets, the real number system, mappings, sequences, limits, continuity, the derivative, and the integral.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 721 Foundations of Algebra (3 crs)
Prerequisite: MATH 425/MATH 625
Set theory, mappings, the integers, groups, rings, and vector spaces.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 731 Vector Methods in Geometry (3 crs)
Applications of vector methods to Euclidean geometry.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 732 Advanced Geometry (3 crs)
Prerequisite: One course in Calculus
Advanced study of geometry including Euclidean, non-Euclidean, projective, and affine geometries.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 742 Logic and Mathematics (3 crs)
Symbolic logic and its use in mathematics, including proof, demonstration, and applications in abstract mathematical systems.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 748 Applied Statistical Procedures (3 crs)
Prerequisite: MATH 246 or consent of instructor.
Includes methods of estimation, parametric and non-parametric tests of significance, linear regression and correlation, and analysis of variance for one-way or two-way crossed classified data. Applications include the use of computers.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 749 Probability and Statistics Workshop (3 crs)
Consent: Instructor Consent Required
Applications of probability and statistics which can be used by the secondary school teacher to motivate and enrich traditional mathematics classes and as topics in upper-level classes where some course content in probability or statistics is desired.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 751 Technology in Mathematics (3 crs)
Prerequisite: MATH 216
Requires basic knowledge of Euclidean geometry.
The use of graphing calculators and computer software to enhance understanding of mathematical concepts and to formulate statements of theorems and solutions to problems is explored.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 755 Linear and Nonlinear Programming (3 crs)
Prerequisite: MATH 216 and MATH 324/MATH 524.
Introductory topics in linear and nonlinear programming including the simplex method for solving a linear program and Wolf's method for solving a quadratic program; and duality theory for linear, quadratic, and nonlinear programming.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 765 Number Theory (3 crs)
Foundations of number theory emphasizing congruences, selected number theoretic functions, Diophantine equations, continued fractions, and other classical problems.
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0
Mathematics

MATH 791 Special Topics (3 crs)
Prerequisite: Limited to MAT/MST MATH or MEPD program.
- Permission of academic program adviser required.

A variable content course designed to allow breadth of study through investigation of mathematical topics not covered in other courses.

Repeat: Course may be repeated for a maximum of 12 credits
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 3
Lab/Studio Hours: 0

MATH 793 Directed Studies (1-3 crs)
Permits students to undertake independent studies under the direction of a graduate faculty member.

Repeat: Course may be repeated
Grading Basis: No S/U Grade Option

MATH 794 Graduate Mathematics Seminar (1 cr)
Consent: Instructor Consent Required
Lab/Studio Hours: 0

Repeat: Course may be repeated
Grading Basis: No S/U Grade Option
Lecture/Discussion Hours: 1

MATH 795 Research Paper (1-2 crs)
Consent: Instructor Consent Required

Repeat: Course may be repeated
Grading Basis: PR Only Grade Basis

MATH 797 Independent Study (1-3 crs)
Consent: Department Consent Required
Individual project under the direction of a faculty member.

Repeat: Course may be repeated
Grading Basis: No S/U Grade Option

MATH 799 Thesis (1-6 crs)
Consent: Instructor Consent Required
- Full-time equivalent.

A description of acceptable topics and the precise nature of the thesis requirement is provided in the departmental program descriptions.

Repeat: Course may be repeated
Grading Basis: PR Only Grade Basis