MATHEMATICAL AND STATISTICAL SCIENCES

Chair: Julien Langou
Associate Chair: Stephen Hartke
Senior Business Operations Coordinator: Miriam Venzor
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Overview

The Department of Mathematical and Statistical Sciences at the University of Colorado Denver offers degrees and certificates at the undergraduate and graduate levels in mathematics, applied mathematics, data science, and statistics through coursework, research and industrial collaboration. Traditional courses such as calculus, linear algebra, probability, statistics and discrete mathematics are offered regularly by the department. In addition, contemporary subjects such as high-performance computing; numerical analysis, optimization, statistical methods, and operations research are also well represented by course offerings and faculty interests. In all of its activities, the department embodies the outlook that mathematics, statistics, computing and data science are powerful tool that can be used to solve problems of immediate and practical importance.

Apart from the specialized mathematical and statistical skills acquired through course work, the degrees and certificates also provide general skills that are valued by many employers. These skills include problem solving, critical thinking, analysis, facility with data, the ability to process quantitative information, and perhaps most important of all, the ability to learn new skills and concepts quickly.

Center for Computational Mathematics

Director: Stephen Hartke
Website: http://ccm.ucdenver.edu/

The Center for Computational Mathematics is composed of faculty members who have an interest in computational mathematics, the study of solving mathematical problems with computers. The center resides in the Department of Mathematical and Statistical Sciences and includes faculty members from various other departments. The primary goal of the center is to foster research in computational mathematics and to maintain a strong educational program at all levels. It has extensive ties with industry along the Front Range and with government laboratories throughout the nation. It offers students an excellent opportunity to receive training and experience in this exciting new field. The center operates several supercomputing clusters.

Math Clinic

Website: https://clas.ucdenver.edu/mathematical-and-statistical-sciences/math-clinic (https://clas.ucdenver.edu/mathematical-and-statistical-sciences/math-clinic/)

Each semester, the mathematical and statistical sciences department conducts math clinics that are open to both undergraduate and graduate students. Each clinic is sponsored by a business, government agency or research organization. The clinic sponsor provides a specific project on which students work with the supervision of a faculty member and a sponsor representative. Every clinic produces a final report to the sponsor and provides participating students with an opportunity to apply mathematics to relevant problems. Recent math clinic sponsors include Raytheon, Lockheed Martin, Xenometrix, Budget Truck Rental and United Launch Alliance.

Statistical Consulting Service

The Department of Mathematical and Statistical Sciences regularly offers a graduate course in statistical consulting in which students work on problems provided by researchers and clients at CU Denver and in the Denver metropolitan area. Potential clients should contact the department at 303-315-1700.

Undergraduate Information

Director: Adam Spiegler
Email: math.advising@ucdenver.edu

The Department of Mathematical and Statistical Sciences offers a BS program that provides broad training in mathematics with the option of specializing in one of four areas of special emphasis, or simply satisfying the requirements without specifying an area. The four areas of emphasis are: applied mathematics, probability and statistics, data science, and economics.

To determine which math course a student should take first, see the Department of Mathematical and Statistical Sciences webpage (www.math.ucdenver.edu (http://www.math.ucdenver.edu)).

Students with potential transfer credit that was not automatically accepted upon admission should request the course be evaluated by following the Transfer Course Evaluation Process (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/#policiestext) as outlined in the College of Liberal Arts Policy section of this catalog. Questions about the transfer evaluation process should be directed to clas.transfer@ucdenver.edu.

Click here (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/#policiestext) to go to information about declaring a major. Once a major is declared, students should contact the Department of Mathematical and Statistical Sciences to meet with a math advisor, and continue to do so at least once per semester. All mathematics majors should visit the CLAS Advising Office (http://catalog.ucdenver.edu/cu-denver/undergraduate/advising-other-student-services/advising/clas-academic-advising-office/) to have graduation requirements checked at a minimum the semester prior to graduation.

Please click here (https://clas.ucdenver.edu/mathematical-and-statistical-sciences/undergraduate-programs/) to learn more about the MATH programs on their website.

Graduation With Honors

The mathematical and statistical sciences department recognizes students who complete the undergraduate program with distinction.

To be eligible for graduation with honors at the *cum laude* level a student must graduate with an overall GPA of 3.2 or better for the last 60 credit hours taken at University of Colorado Denver and either:

- Option 1: Have a GPA of 3.7 or better in upper-division math courses taken at CU Denver, **or**

- Option 2: Have a GPA of 3.5 or better in upper-division math courses taken at CU Denver and must complete an honors project.

To be eligible for graduation with honors at the *magna cum laude* level a student must graduate with an overall GPA of 3.2 or better for the last 60 credit hours taken at University of Colorado Denver and either:

- Option 1: Have a GPA of 3.85 or better in upper-division math courses taken at CU Denver, **or**
- Option 2: Have a GPA of 3.7 or better in upper-division math courses taken at CU Denver and must complete an honors project.

To be eligible for graduation with honors at the *summa cum laude* level a student must graduate with an overall GPA of 3.2 or better for the last 60 credit hours taken at University of Colorado Denver and satisfy **all** of the following:

- Have a GPA of 3.7 or better in upper-division math courses taken at CU Denver and must complete an honors project.
- When a recommendation for Honors at the Summa Cum Laude level is brought to the department as a motion, a vote will be taken and such a motion must be passed by a two-thirds majority of those voting at the meeting.
- Considerations such as overall quality of the candidate's honors project, outreach, community, other extra-curricular activities relating to mathematics.

Undergraduate Applied Statistics Certificate
Director: Yaning Liu
Email: Yaning.Liu@ucdenver.edu

There is a growing need for qualified statistical analysts of the ever-increasing amounts of data collected in business, industry, and government. The certificate in applied statistics program is designed to give students a strong background in statistical methodology and data analysis in preparation for opportunities in the workforce or for graduate studies. The Department of Mathematical and Statistical Sciences offers certificates in applied statistics at both the undergraduate and graduate levels.

Click here (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/applied-statistics-undergraduate-certificate/) to learn about the Undergraduate Applied Statistics Certificate.

Undergraduate Certificate in Data Science Essentials
Director: Joshua French
Email: joshua.french@ucdenver.edu

Data scientists will have essential competencies in several areas related to analysis of data. In particular, a data scientist should: have strong programming ability in a language popular in data science (e.g., Python, R, Julia); be able to extract, manipulate, and visualize data; have an understanding of probability and statistics in order to quantify uncertainty; be able to build complex models for finding patterns and explaining data. This certificate should provide students with essential skills for introductory data science.

Click here (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/data-science-undergraduate-

certificate/) to learn about the Undergraduate Certificate in Data Science Essentials

Graduate Information

Please go to the Graduate (http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/) catalog to read about our graduate programs.

Programs

- Mathematics, BS (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/mathematics-bs/)
- Mathematics - Applied Option, BS (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/mathematics-applied-option-bs/)
- Mathematics - Data Science Option, BS (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/mathematics-data-science-option-bs/)
- Mathematics - Probability and Statistics Option, BS (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/mathematics-probability-statistics-option-bs/)
- Mathematics, 4+1 BS/ Applied Mathematics, MS (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/5-year-mathematics-bs-applied-mathematics-ms/)
- Mathematics, 4+1 BS/ Statistics, MS (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/5-year-mathematics-bs-statistics-ms/)
- Data Sciences Minor (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/data-sciences-minor/)
- Mathematics Minor (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/mathematics-minor/)
- Applied Statistics Undergraduate Certificate (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/applied-statistics-undergraduate-certificate/)
- Data Science Undergraduate Certificate (http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/mathematical-statistical-sciences/data-science-undergraduate-certificate/)

Faculty
Professors:

Troy Butler, PhD, Colorado State University
Stephen Hartke, PhD, Rutgers University
Julien Langou, PhD, Institute National Polytechnique of Toulouse, France

Jan Mandel, PhD (equivalent), Charles University, Czechoslovakia
Florian Pfender, PhD, Emory University
Stephanie Santorico, PhD, North Carolina State University

Associate Professors:

Stephen Billups, PhD, University of Wisconsin-Madison
Steffen Borgwardt, PhD, Technische Universität München
Joshua French, PhD, Colorado State University
Burton Simon, PhD, University of Michigan
Diana White, PhD, University of Nebraska

Assistant Professors:

Erin Austin, PhD, University of Minnesota
Yaning Liu, PhD, Florida State University
Farhad Pourkamali Anaraki, PhD, University of Colorado Boulder
Emily Speakman, PhD, University of Michigan

Associate Professor, Teaching Track:

Adam Spiegler, PhD, University of Arizona

Assistant Professor, Teaching Track:

Dmitriy Ostrovskiy, PhD, State University of New York at Stony Brook

Senior Instructors:

Michael Kawai, MS, University of Colorado Denver
Gary Olson, MS, University of Colorado Denver
Robert Rostermundt, PhD, University of Colorado Denver
Pamela Whitten, MA, University of Colorado Boulder

Instructors:

Joe Bilello, MS, Long Island University
Daniel Klie, MS, University of Colorado Denver

International College of Beijing Faculty:

Thomas Dunn, PhD, North Dakota State University
Joseph Quarcoo, PhD, University of South Florida

Research Faculty:

Aime Fournier, PhD, Yale University

Emeritus Faculty:

William Briggs, Professor Emeritus, PhD, Harvard University
William E. Cherowitzo, Professor Emeritus, PhD, Columbia University
Kathryn L. Fraughnaugh, Professor Emeritus, PhD, University of Houston
Michael S. Jacobson, Professor Emeritus, PhD, Emory University
Andrew Knyazev, Professor Emeritus, PhD, Russian Academy of Sciences

Lance Lana, Instructor Emeritus, MS, University of Colorado Denver
Weldon A. Lodwick, Professor Emeritus, PhD, Oregon State University
J. Richard Lundgren, Professor Emeritus, PhD, Ohio State University
Stanley E. Payne, Professor Emeritus, PhD, Florida State University

Mathematics Courses

MATH 1010 - Mathematics for the Liberal Arts (3 Credits)
Designed to give liberal arts students the skills required to understand and interpret quantitative information that they encounter in the news and in their studies, and to make quantitatively-based decisions in their lives. Topics include a survey of logic and analysis of arguments, identifying fallacies in reasoning, working with numbers and units, linear and exponential relations and essentials of probability and statistics. The emphasis is on applications with case studies in economics, finance, environmental sciences, health, music and science. Note: This course assumes that students have knowledge equivalent to three years of high school mathematics (two years of algebra). Requisite: In order to promote student success, any student who has an ACT MATH score less than 19 (or equivalently an SAT MATH score less than 520) AND a H.S. GPA of less than 3.25 will be required to enroll in the one credit hour co-requisite workshop MATH 1011. Term offered: fall, spring, summer. Max hours: 3 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-MA1
Grading Basis: Letter Grade
In order to promote student success, any student who has an ACT MATH score less than 19 (or equivalently an SAT MATH score less than 520) AND a H.S. GPA of less than 3.25 will be required to enroll in the one credit hour co-requisite workshop MATH 1011.
Additional Information: Denver Core Requirement, Mathematics; GT courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 1011 - Math for Liberal Arts Workshop (1 Credit)
Prepares students for college-level mathematics. Students receive one-on-one and small-group instruction on mathematics topics related to college level mathematics success. Coreq: MATH 1010. Term offered: fall, spring. Max hours: 1 Credit.
Grading Basis: Letter Grade
Coreq: MATH 1010
Typically Offered: Fall, Spring.

MATH 1060 - Finite Mathematics (3 Credits)
This course is designed to introduce students to mathematics topics commonly encountered by business students. This course meets the universities CORE mathematics requirement. The topics include linear equations and inequalities, linear, quadratic, exponential and logarithmic functions, simple, compound and continuous interest, future and present value annuities, amortization, systems of equations, linear programming, logic, sets and probability. Graphing technology is used extensively and business applications are emphasized throughout. Terms offered: Fall and Spring. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Additional Information: Denver Core Requirement, Mathematics.

MATH 1070 - College Algebra for Business (3 Credits)
Covers the same mathematical topics as College Algebra, MATH 1110, but with business applications. Note: Graphics calculator required. Note: Students may not receive credit for this course if they have already received credit for MATH 1110 or MATH 1130. Note: 24 on ACT-Math, 560 on SAT-Math or above average performance in intermediate algebra, algebraic literacy or integrated math are strongly recommended as preparation for this course. Max hours: 3 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-MA1.
Grading Basis: Letter Grade
Additional Information: GT courses GT Pathways, GT-MA1, Mathematics.

MATH 1080 - Calculus for Social Sciences and Business (3 Credits)
A one-semester course in single-variable calculus. Topics include limits, derivatives, differentiation rules, integration and integration rules. Emphasis is on applications to business and social sciences. Note: No knowledge of trigonometry is required. Those planning to take more than one semester of calculus should take MATH 1401 instead of MATH 1080. Prereq: MATH 1070 or MATH 1110 with a C- or higher is required for students to register for this course. No co-credit with MATH 1401. Max hours: 3 Credits.
Grading Basis: Letter Grade
MATH 1070 or MATH 1110 with a C- or higher
Additional Information: GT courses GT Pathways, GT-MA1, Mathematics.

MATH 1108 - Stretch College Algebra-Part 1 (3 Credits)
This course is the first half of a two-semester sequence (consisting of MATH 1108 followed by MATH 1109). The two-semester course sequence is equivalent to MATH 1110 (College Algebra). The topics in algebra are designed for students who intend to take the calculus sequence. An in-depth study of functions, linear and quadratic equations, circles, inequalities, domain & range, piecewise and transformation of functions, mathematical modeling and select other topics are explored. Desmos graphing technology is used extensively and students will review algebraic skills such as factoring and completing the square, graphing techniques and function properties where needed. Applications are emphasized. Note: No co-credit with MATH 1070, MATH 1110 or MATH 1130. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 1109 - Stretch College Algebra-Part 2 (3 Credits)
This course is the second half of a two-semester sequence (consisting of MATH 1108 followed by MATH 1109). The two semester course sequence is equivalent to MATH 1110 (College Algebra). The topics in algebra are designed for students who intend to take the calculus sequence. Data scatter plots and curve fitting, solving equations, polynomial functions, rational functions, exponential and logarithmic functions and selected other topics are explored. Desmos graphing technology is used extensively and students enrolled in MATH 1109 will review algebraic skills such as solving linear and quadratic equations, factoring and completing the square, graphing techniques and function properties where needed. Applications are emphasized. Note: No co-credit with MATH 1070, MATH 1110 or MATH 1130. Prereq: MATH 1108 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Pre: MATH 1108 with C- or higher.
Additional Information: Denver Core Requirement, Mathematics.

MATH 1110 - College Algebra (4 Credits)
Topics in algebra designed for students who intend to take the calculus sequence. Functions, domains, ranges, graphs, data scatter plots and curve fitting, solving equations and systems of equations, polynomial, rational, exponential and logarithmic functions and other topics. Applications are emphasized. Note: Students may not receive credit for this course if they have already received credit for MATH 1070 or MATH 1130. Prereq: MATH 1109 or MATH 1070 or MATH 1110 or MATH 1120 or MATH 1130 or MATH 1401 with a C- or higher OR entry into the MA10 or MA30 or MA01 Student Group OR ALEKS PPL score 46-100. If you have any questions or concerns about this requisite, please notify MATH.Placement@ucdenver.edu. Term offered: fall, spring, summer. Max hours: 4 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-MA1.
Grading Basis: Letter Grade
MATH 1109 or MATH 1070 or MATH 1110 or MATH 1120 or MATH 1130 or MATH 1401 with a C- or higher OR entry into the MA10 or MA30 or MA01 Student Group OR ALEKS PPL score 46-100.
Additional Information: Denver Core Requirement, Mathematics; GT courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 1111 - First Year Seminar (3 Credits)
Restriction: Restricted to Freshman level students. Term offered: Fall. Max hours: 3 Credits.
Grading Basis: Letter Grade
Restriction: Restricted to Freshman level students
Typically Offered: Fall.

MATH 1120 - College Trigonometry (3 Credits)
Topics in trigonometry, analytic geometry, and elementary functions designed for students who intend to take the calculus sequence. Angles and trigonometry functions of acute angles, analytic trigonometry, fundamental trigonometric functions and identities including hyperbolic trigonometry, parametric equations, and polar coordinate system. Graphic calculators and/or computer algebra systems are used extensively. Applications are emphasized. Prereq: MATH 1109 or MATH 1070 or MATH 1110 or MATH 1120 or MATH 1130 or MATH 1401 with a C- or higher OR entry into the MA30 or MA01 Student Group OR ALEKS PPL score 61-100. If you have any questions or concerns about this requisite, please notify MATH.Placement@ucdenver.edu. Students with a grade of B- or better in MATH 1110 or MATH 1070 pass the course at a much higher rate. No co-credit with MATH 1130. Term offered: fall, spring, summer. Max hours: 3 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-MA1.
Grading Basis: Letter Grade
MATH 1109 or MATH 1070 or MATH 1110 or MATH 1120 or MATH 1130 or MATH 1401 with a C- or higher OR entry into the MA30 or MA01 Student Group OR ALEKS PPL score 61-100.
Additional Information: Denver Core Requirement, Mathematics; GT courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 1130 - Precalculus Mathematics (4 Credits)
Condensed treatment of the topics in MATH 1110 and 1120. Prereq: :
MATH 1120 or MATH 1130 or MATH 1401 with a C- or higher OR entry
into the MA30 or MA01 Student Group OR ALEKS PPL score 61-100. If
you have any questions or concerns about this requisite, please notify
MATH.Placement@ucdenver.edu. No co-credit with MATH 1070, 1110 or
1120. Term offered: fall, spring, summer. Max hours: 4 Credits. GT: Course
is approved by the Colorado Dept of Higher Education for statewide
guaranteed transfer, GT-MA1.
Grading Basis: Letter Grade
MATH 1120 or MATH 1130 or MATH 1401 with a C- or higher OR entry
into the MA30 or MA01 Student Group OR ALEKS PPL score 61-100.
Additional Information: Denver Core Requirement, Mathematics; GT
courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 1376 - Programming for Data Science (3 Credits)
The course introduces scientific computing using Python. Topics will
include programming skills such as assignment, control statements,
loops, and functions. Applications will focus on mathematical and data
science topics. Prereq: MATH 1109 or MATH 1110 or MATH 1120 or
MATH 1130 or MATH 1401 or MATH 2830 with a C- or higher OR entry
into the MA30 or MA01 Student Group OR ALEKS PPL score 61-100. Max
hours: 3 Credits.
Grading Basis: Letter Grade
MATH 1109 or MATH 1110 or MATH 1120 or MATH 1130 or MATH 1401
or MATH 2830 with a C- or higher OR entry into the MA30 or MA01
Student Group OR ALEKS PPL score 61-100.

MATH 1401 - Calculus I (4 Credits)
First course of a three-semester sequence (MATH 1401, 2411, 2421)
in calculus. Topics covered include limits, derivatives, applications of
derivatives, and the definite integral. Note: No co-credit with MATH 1080.
Prereq:MATH 1109 or MATH 1070 or MATH 1110 with a C- or higher
and MATH 1120 with a C- or higher or MATH 1130 with a C- or higher or
MATH 1401 with a C- or higher OR entry into the MA01 Student Group OR
ALEKS PPL score 76-100. If you have any questions or concerns about
this requisite, please notify MATH.Placement@ucdenver.edu. Max Hours:
4 Credits.
Grading Basis: Letter Grade
MATH 1109 or MATH 1070 or MATH 1110 with a C- or higher and
MATH 1120 with a C- or higher or MATH 1130 with a C- or higher or
MATH 1401 with a C- or higher OR entry into the MA01 Student Group OR
ALEKS PPL score 76-100.
Additional Information: Denver Core Requirement, Mathematics; GT
courses GT Pathways, GT-MA1, Mathematics.

MATH 1840 - Independent Study. (1-3 Credits)
Department consent required. Repeatable. Max hours: 3 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 3.

MATH 2411 - Calculus II (4 Credits)
The second of a three-semester sequence (MATH 1401, 2411, 2421)
in calculus. Topics covered include exponential, logarithmic, and
trigonometric functions, techniques of integration, indeterminate forms,
improper integrals and infinite series. Prereq: C- or better in MATH 1401.
Note: Students with a grade of B- or better in MATH 1401 pass this
course at a much higher rate. Term offered: fall, spring, summer. Max
hours: 4 Credits. GT: Course is approved by the Colorado Dept of Higher
Education for statewide guaranteed transfer, GT-MA1.
Grading Basis: Letter Grade
Prereq: C- or better in MATH 1401
Additional Information: Denver Core Requirement, Mathematics; GT
courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 2421 - Calculus III (4 Credits)
The third of a three-semester sequence in Calculus (MATH 1401, 2411
and 2421). Topics include vectors, vector-valued functions, partial
differentiation, differentiation, multiple integration, and vector calculus.
Prereq: C- or better in MATH 2411. Note: Students with a grade of B-
or better in MATH 2411 pass this course at a much higher rate. Term
offered: fall, spring, summer. Max hours: 4 Credits. GT: Course is approved
by the Colorado Dept of Higher Education for statewide guaranteed
transfer, GT-MA1
Grading Basis: Letter Grade
Prereq: C- or better in MATH 2411
Additional Information: Denver Core Requirement, Mathematics; GT
courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 2810 - Topics (1-3 Credits)
Topics in mathematics with various subtitles reflecting course content.
Prereq: permission of instructor. Repeatable. Max Hours: 6 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 6.

MATH 2830 - Introductory Statistics (3 Credits)
Basic statistical concepts, summarizing data, probability concepts,
distributions, confidence intervals, hypothesis testing. Note: This course
assumes that students have knowledge equivalent to three years of high
school mathematics (two years of algebra), intermediate algebra, or
Algebraic Literacy at a Colorado Community College at the start of class.
Students who have a grade of B- or better in one of these courses pass at
a much higher rate. Term offered: fall, spring, summer. Requisite: In order
to promote student success, any student who has an ACT MATH score
less than 19 (or equivalently an SAT MATH score less than 520) AND
a H.S. GPA of less than 3.25 will be required to enroll in the one credit
hour co-requisite workshop MATH 2831. Max hours: 3 Credits. GT: Course
is approved by the Colorado Dept of Higher Education for statewide
guaranteed transfer, GT-MA1.
Grading Basis: Letter Grade
In order to promote student success, any student who has an ACT MATH
score less than 19 (or equivalently an SAT MATH score less than 520)
AND a H.S. GPA of less than 3.25 will be required to enroll in the one
credit hour co-requisite workshop MATH 2831.
Additional Information: Denver Core Requirement, Mathematics; GT
courses GT Pathways, GT-MA1, Mathematics.
Typically Offered: Fall, Spring, Summer.

MATH 2831 - Introductory Statistics Workshop (1 Credit)
Prepares students for college-level mathematics. Students receive one-on-one and small-group instruction on mathematics topics related to college level mathematics success. Coreq: MATH 2830. Term offered: fall, spring. Max hours: 1 Credit.
Grading Basis: Letter Grade
Co-requisite: MATH 2830
Typically Offered: Fall, Spring.

MATH 2939 - Internship (1-3 Credits)
Experiences involving application of specific, relevant concepts and skills in supervised employment situations. Note: students must work with the Experiential Learning Center advising to complete a course contract and gain approval. Prereq: 15 hours of 2.75 GPA. Repeatable. Max Hours: 9 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 9.

MATH 3000 - Introduction to Abstract Mathematics (3 Credits)
Students learn to prove and critique proofs of theorems by studying elementary topics in abstract mathematics, including logic, sets, functions, equivalence relations and elementary combinatorics. Coreq: MATH 2421 or MATH 3191. Note: This course assumes that students have taken MATH 2411 or equivalent. Students who have a grade of B- or better in MATH 2411 pass at a much higher rate. Max hours: 3 Credits.
Grading Basis: Letter Grade
Coreq: MATH 2421 or MATH 3191

MATH 3041 - Fundamental Mathematics: Algebra, Probability and Data Analysis (3 Credits)
This course is particularly pertinent to prospective elementary teachers, involving algebra, probability and data analysis from a modern approach. Its primary emphasis is asking and answering questions intelligently about our world through the use of algebra, probability, and data analysis. Explorations focus on representing, analyzing, generalizing, formalizing, and communicating patterns and the chances of future events. Mathematics content will be presented in a problem solving and exploratory context, using appropriate instructional tools. This course will not satisfy the requirements for a major in Mathematics. Prereq: MTED 3040 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MTED 3040 with a C- or higher.
Additional Information: Denver Core Requirement, Mathematics.

MATH 3191 - Applied Linear Algebra (3 Credits)
Linear algebra is the mathematics of vectors and matrices and is fundamental for the representation and manipulation of data. List of topics covered: Definition and use of vectors and matrices, Matrix algebra, Systems of linear equations, Reduced Row Echelon Form, Trace and determinant, Linear independence and span, Basis and dimension, Null space and range, Rank theorem, Vector spaces and linear transformations, Eigenvalues and Eigenvectors, Diagonalization, Inner products, Orthogonal projections, Gram-Schmidt algorithm, Diagonalization of symmetric matrices, Singular value decomposition. Applications such as computer graphics, machine learning, Markov chains, and data reduction are considered. Note: No co-credit with MATH 3195. Prereq: MATH 1401 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 1401 with a C- or higher

MATH 3195 - Linear Algebra and Differential Equations (4 Credits)
Presents the essential ideas and methods of linear algebra and differential equations, emphasizing the connections between and the applications of both subjects. The course is designed for students in the sciences and engineering. This course will not satisfy the requirements for a major in Mathematics. Note: No co-credit with MATH 3200 and MATH 3191. Prereq: MATH 2411 with a C- or higher. Max hours: 4 Credits.
Grading Basis: Letter Grade
Prereq: C- or better in MATH 2411

MATH 3200 - Elementary Differential Equations (3 Credits)
First and second order differential equations, Laplace transforms, systems of equations, with an emphasis on modeling and applications. Note: No co-credit with MATH 3195. Prereq: MATH 2411 with a C- or higher. Coreq: MATH 3191. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prerequisite: MATH 2411 with a C- or higher, Co-requisite MATH 3191.

MATH 3301 - Introduction to Optimization (3 Credits)
Introduces a mathematical approach for decision-making in practice based on optimization. Students will learn to model, analyze and solve a variety of problems from deterministic operations using both continuous and discrete mathematical programming algorithms and software. Note: this course assumes that students have taken MATH 3191 or MATH 3195 or equivalent. Students who have received a grade of B- or better in MATH 3191 or 3195 pass this course at a much higher rate. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 3310 - Introduction to Real Analysis I (3 Credits)
This is a proof-based course that rigorously covers fundamental topics involving the real number system, sequences of real numbers, and functions of real numbers. Prereq: Grade of C- or better in MATH 2411 OR Grade of A- or better in MATH 1401. Coreq: MATH 2411. Cross-listed with MCKE 5310. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: Grade of C- or better in MATH 2411 OR Grade of A- or better in MATH 1401. Coreq: MATH 2411.

MATH 3376 - Data Wrangling & Visualization (3 Credits)
The course provides an introduction to obtaining, restructuring, and visualizing complex data sets. Students will learn to manipulate many data types, store data in a variety of structures, and construct static and dynamic plots in a variety of contexts. Students earning a B- or better in Math 1376 or 4387 are more likely to be successful in this course than students earning lower grades. Prereq: MATH 1376 or MATH 4387 or CSCI 1410/1411 with a C- or higher and MATH 2830 or MATH 3382 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 1376 or MATH 4387 or CSCI 1410/1411 with a C- or higher and MATH 2830 or MATH 3382 with a C- or higher

MATH 3382 - Statistical Theory (3 Credits)
Probability, random variables, properties of distributions, bootstrap methods, maximum likelihood and method of moments estimation, properties of estimators, classical methods for confidence intervals and hypothesis testing. Prereq: MATH 2421 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 2421 with a C- or higher.

MATH 3440 - Introduction to Symbolic Logic (3 Credits)
Covers truth functional and quantificational logic through polyadic first order predicate calculus and theory of identity. Attention is given to such problems in metatheory as proofs of the completeness and consistency of systems of logic. Cross-listed with PHIL 3440. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 3800 - Probability and Statistics for Engineers (3 Credits)
Basic probability theory, discrete and continuous random variables, point and interval estimation, test of hypotheses, and simple linear regression. Note: no co-credit with MATH 3810. This course will not satisfy the requirement for a major in Mathematics. Note: This course assumes that students have taken MATH 2411 and have either previously taken MATH 2421 or are taking MATH 2421 the same semester as MATH 3800. Students who have a grade of B- or better in MATH 2411 pass this course at a much higher rate. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 3810 - Introduction to Probability (3 Credits)
Fundamentals of probability theory with connection to practical application through simulation. Topics include: Axioms of probability, conditional probability, independence, law of total probability, Bayes theorem, random variables, probability distributions, expected value and variance. Important distributions such as binomial, normal, exponential, and Poisson distributions. Joint and conditional distributions, conditional expectation and variance, functions of random variables. Laws of large numbers (weak and strong), Central Limit Theorem. An emphasis will be placed on using simulation to solve problems. Note: No co-credit with MATH 3800. Coreq: MATH 2421. Max hours: 3 Credits.
Grading Basis: Letter Grade
Coreq: MATH 2421.

MATH 3939 - Internship (1-3 Credits)
Designed experiences involving application of specific, relevant concepts and skills in supervised employment situations. Note: students must work with the Experiential Learning Center advising to complete a course contract and gain approval. Prereq: Junior standing or higher. Repeatable. Max Hours: 9 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 9.
Prereq: junior standing or higher

MATH 4010 - History of Mathematics (3 Credits)
A history of the development of mathematical techniques and ideas from early civilization to the present, including the inter-relationships of mathematics and sciences. Prereq: MATH 2411 with a C- or higher. Coreq: MATH 3000 or 3191. Cross-listed with MATH 5010. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 2411 with a C- or higher Coreq: MATH 3000 or 3191

MATH 4027 - Topics in Mathematics (3 Credits)
Special topics in mathematics will be covered; consult 'Schedule Planner' for current topics and prerequisites. Repeatable. Max hours: 12 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 12.

MATH 4110 - Theory of Numbers (3 Credits)
Every other year. Topics include divisibility, prime numbers, congruencies, number theoretic functions, quadratic reciprocity, and special diophantine equations, with applications in engineering. Prereq: Grade of C- or better in MATH 3000. Note: Students who have a grade of B- or better in MATH 3000 pass this course at a much higher rate. Cross-listed with MATH 5110. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: Grade of C- or better in MATH 3000

MATH 4140 - Introduction to Modern Algebra (3 Credits)
Studies the fundamental algebraic structures used in modern mathematics. Topics include groups, rings, fields and polynomials. Note: This course assumes that students have taken MATH 3000 or equivalent and either MATH 3191 or MATH 3195. Students who have a grade of B- or better in these courses pass at a much higher rate. Cross-listed with MCKE 5140. Prereq: MATH 3000 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 3000 with a C- or higher.

MATH 4320 - Introduction to Real Analysis II (3 Credits)
Convergence, uniform convergence; Taylor's theorem; calculus of several variables including continuity, differentiation and integration; Picard's theorem in ordinary differential equations and Fourier series. Prereq: MATH 3310 with a C- or higher. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 3310 with a C- or higher.

MATH 4337 - Intro to Statistical and Machine Learning (3 Credits)
This is an applied, hands-on course in statistical and machine learning. This course will introduce students to the general framework, best practices, model training, and assessment for machine learning methods from the viewpoint of statistics. Both supervised and unsupervised methods are covered including penalized regression, knearest neighbors, clustering, and neural networks. Additional machine learning topics such as random forests and support vector machines are included as time permits. Ultimately, students will learn how and why to use a particular method, how to validate and explain the results, and apply the methods to real data. Note: It is recommended that students are comfortable learning a statistical computing language such as R or Python as these will be taught alongside the course material. Students with minimal programming experience should expect to spend more time learning the programming language throughout the course. Prereq: MATH 4387 or MATH 5387 or MATH 4830 or MATH 5830 or BIOL 3763 with a C- or higher. Students who have completed a different statistics course that contains regression and computing may seek instructor permission to enroll. Cross-listed with MATH 5337. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 4387 or MATH 5387or MATH 4830 or MATH 5830 or BIOL 3763 with a C- or higher.

MATH 4387 - Applied Regression Analysis (3 Credits)
Topics include simple and multiple linear regression, model diagnostics and remediation, and model selection. Emphasis is on practical aspects and applications of linear models to the analysis of data in business, engineering and behavioral, biological and physical sciences. Prereq: Grade of C- (1.7) or better in MATH 3191 and in MATH 3800 or 4820 or 3382. Note: Students who have a grade of B- or better in MATH 3191, an A in MATH 3800 or a B- or better in MATH 4820 pass this course at a much higher rate. Cross-listed with MATH 5387. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: Grade of C- (1.7) or better in MATH 3191 and in MATH 3800 or 4820 or 3382

MATH 4388 - Machine Learning Methods (3 Credits)
Regression, neural networks, clustering, support vector machines, random forests, and other prediction/classification techniques will be used to solve supervised and unsupervised learning problems. This course will connect each topic with the underlying mathematical foundation such as optimization methods and statistical inference. A key focus is deriving the methods and their properties to guide proper application. Students will learn how to apply methods using standard libraries from Python, R, or Matlab. Prereq: MATH 1376 or MATH 3250 and MATH 3382 or MATH 3800 and MATH 3191 or MATH 3195, all with a C- or higher. Cross-listed with MATH 5388. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 1376 or MATH 3250 and MATH 3382 or MATH 3800 and MATH 3191 or MATH 3195, all with a C- or higher.

MATH 4390 - Game Theory (3 Credits)
Zero-sum and non-zero-sum games; Nash equilibrium and the principle of indifference; Shapley value and other concepts of fair division; Evolutionary game theory, ESS, and evolutionary population dynamics. Applications in economics, business, and biology. Note: This course assumes that students have programming experience (e.g. MATLAB), and have taken MATH 2421, 3191 and 3200 or MATH 3195, MATH 3800 or 3810, or equivalent. Students who have a grade of B- or better in these courses pass this course at a much higher rate. Cross-listed with MATH 5390. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 4408 - Applied Graph Theory (3 Credits)
Introduces discrete structures and applications of graph theory to computer science, engineering, operations research, social science, and biology. Topics include connectivity, coloring, trees, Euler and Hamiltonian paths and circuits, matching and covering problems, shortest route and network flows. Prereq: MATH 2511 or CSCI 2511 or MATH 3000 with a C- or higher. Note: This course assumes that students have taken MATH/CSCI 2511 or MATH 3000. Students who have a grade of B- or better in MATH/CSCI 2511 or MATH 3000 pass this course at a much higher rate. Cross-listed with CSCI 4408 and MCKE 5408. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 2511 or CSCI 2511 or MATH 3000 with a C- or higher.

MATH 4409 - Applied Combinatorics (3 Credits)
Every other year. Major emphasis is on applied combinatorics and combinatorial algorithms, with applications in computer science and operations. Topics include general counting methods, generating functions, recurrence relations, inclusion-exclusion, and block designs. Prereq: MATH 3000 with a C- or higher. Note: This course assumes that students have taken MATH 3000. Students who have a grade of B- or better in MATH 3000 pass this course at a much higher rate. Cross-listed with MCKE 5409. Max Hours: 3 Credits.
Grading Basis: Letter Grade
Prerequisite: MATH 3000 with a C- or higher.

MATH 4450 - Complex Variables (3 Credits)
Infrequent. Topics include complex algebra, Cauchy-Riemann equations, Laurent expansions, theory of residues, complex integration, and introduction to conformal mapping. Note: This course assumes that students have taken MATH 2421 and MATH 3000. Students who have a grade of B- or better in MATH 2421 and MATH 3000 pass this course at a much higher rate. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 4650 - Numerical Analysis I (3 Credits)
A first semester course in numerical methods and analysis fundamental to many algorithms encountered in scientific computing, data science, machine learning, and computational models in science and engineering. Rounding errors and numerical stability of algorithms; solution of linear and nonlinear equations; data modeling with interpolation and least-squares; and optimization methods. This course assumes that students have the equivalent of differential and integral calculus (e.g., MATH 2411), linear algebra (e.g., MATH 3191 or 3195), and computer programming (e.g., MATH 1376 or CSCI 1410). Prereq: MATH 3191 or MATH 3195 with a C- or higher. Cross-listed with CSCI 4650, 5660, and MATH 5660. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 3191 or MATH 3195 with a C- or higher.

MATH 4660 - Numerical Analysis II (3 Credits)
A second semester course in numerical methods and analysis fundamental to many algorithms encountered in scientific computing, data science, machine learning, and computational models in science and engineering. Numerical differentiation and integration; random numbers and stochastic modeling; Fast Fourier Transform; data compression; eigenvalues and singular value decompositions with application to regression and dimension reduction. This course assumes that students have the equivalent of differential and integral calculus (e.g., MATH 2411), linear algebra (e.g., MATH 3191 or 3195), and computer programming (e.g., MATH 1376 or CS 1410). Prereq: MATH 3191 and MATH 3200 with a C- or higher or MATH 3195 with a C- or higher. Cross-listed with MATH 5661, CSCI 4660 and 5661. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 3191 and MATH 3200 with a C- or higher or MATH 3195 with a C- or higher.

MATH 4733 - Partial Differential Equations (3 Credits)
Initial/Boundary value problems for first-order, wave, heat and Laplace equations; maximum principles; Fourier series and applications. Note: It is recommended that students have either taken MATH 3000 or have experience with partial differential equations in engineering or physics. Students who have a grade of B- or better in MATH 2421 and MATH 3200 pass this course at a much higher rate. Prereq: MATH 2421 AND either MATH 3191 and MATH 3200 OR MATH 3195 with a C- or higher. Cross-listed with MATH 5733. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 2421 AND either MATH 3191 and MATH 3200 OR MATH 3195 with a C- or higher.

MATH 4779 - Math Clinic (3 Credits)
The clinic is intended to illustrate the applicability and utility of mathematical concepts. Research problems investigated originate from a variety of sources--industry, government agencies, educational institutions, or nonprofit organizations. Prereq: MATH 3191, either MATH 1376 or CSCI 1410/1411, and 6 additional credit hours in upper-division MATH courses, all with C- or higher. Cross-listed with MATH 5779. Repeatable. Max Hours: 99 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 99.
Prereq: MATH 3191, either MATH 1376 or CSCI 1410/1411, and 6 additional credit hours in upper-division MATH courses, all with C- or higher.

MATH 4792 - Probabilistic Modeling (3 Credits)
Every other year. Markov chains; Poisson processes, continuous
time Markov chains, elementary topics in queuing theory, and some
mathematical aspects of Monte Carlo simulation, including random
variate generation, variance reduction, and output analysis. Note: This
course assumes that students have taken MATH 3810 or 5310 and have
some programming experience. Students who have a grade of B- or better
in MATH 3810 or 5310 pass this course at a much higher rate. Cross-
listed with MATH 5792. Max hours: 3 Credits.
Grading Basis: Letter Grade

MATH 4830 - Applied Statistics (3 Credits)
Review of estimation, confidence intervals and hypothesis testing;
Anova; categorical data analysis; non-parametric tests; linear and logistic
regression. No co-credit with MATH 4387 or 5387. This course will not
satisfy the requirements for a major in Mathematics. Cross-listed with
MATH 5830. Prereq: MATH 2830 with a C- or higher. Max hours: 3 Credits.
Grading Basis: Letter Grade
Prereq: MATH 2830 with a C- or higher.

MATH 4840 - Independent Study (1-3 Credits)
Variable credit depending on the student's needs. Offered for the
advanced student who desires to pursue a specific topic in considerable
depth. Note: Supervision by a full-time faculty member is necessary,
and the dean's office must concur. Students may register for this course
more than once with departmental approval. Repeatable. Max Hours: 12
Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 12.

MATH 4880 - Directed Research (1-6 Credits)
Students will engage in original research projects supervised and
mentored by faculty. Students must work with faculty prior to registration
to develop a proposal for their project and receive permission to take this
course. Repeatable. Max Hours: 6 Credits.
Grading Basis: Letter Grade
Repeatable. Max Credits: 6.