MATHEMATICS

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The Department of Mathematics offers a bachelor of arts in mathematics, bachelor of arts in mathematics with concentration in finance, bachelors of science in mathematics, and bachelor of science in mathematics with concentration in artificial intelligence. These programs provide a strong foundation in theoretical and applied mathematics with particular emphasis on the development of logical and analytical problem-solving skills. This major is often combined with a major or minor in natural sciences, computer science, business and related fields. It is an excellent preparation for graduate school in quantitative subjects. Math majors find jobs in academia, high-tech industry, financial industry and government agencies, with positions including research mathematician, applied mathematician, engineer, data analyst, computer programmer, financial analyst, economist, actuary and teacher.

Majors

Bachelor of Arts

Bachelor of Arts Major Requirements

(183 credits required for the degree (http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofarts/))

This degree requires completion of 48 credits of MATH courses numbered 1951 or higher, including at least 20 credits at the 3000-level or higher. The following courses are required:

Code	Title	Credits
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
or MATH 1962	Honors Calculus II	
MATH 1953	Calculus III	4
or MATH 1963	Honors Calculus III	
MATH 2060	Elements of Linear Algebra	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4
MATH 2200	Mathematical Reasoning & Proof	4
MATH 3161	Introduction to Real Analysis	4
MATH 3170	Introduction to Abstract Algebra	4
Additional Courses		12
Total Credits		**48**

Note

- In addition, students must complete the ETS Major Field Test in Mathematics as instructed by the department, and satisfy all requirements for the Bachelor of Arts degree as outlined in the University of Denver Undergraduate Bulletin.
- It is recommended that students take MATH 3151 Advanced Linear Algebra after MATH 2200 Mathematical Reasoning & Proof but before MATH 3161 Introduction to Real Analysis and MATH 3170 Introduction to Abstract Algebra.

Bachelor of Arts with a Concentration in Finance

Bachelor of Arts with a Concentration in Finance Major Requirements

(183 credits required for the degree (http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofarts/))

This degree requires completion of 48 credits of MATH courses numbered 1951 or higher, including at least 20 credits at the 3000-level or higher. In addition, ACTG 2200, FIN 2800 and at least 12 credits in FIN courses at the 3000-level or higher are required. Students should work with Daniels advisors in order to make appropriate choices. The following courses are required:

Code	Title	Credits
Mathematics [1]		
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4

or MATH 1962	Honors Calculus II	
MATH 1953	Calculus III	4
or MATH 1963	Honors Calculus III	
MATH 2060	Elements of Linear Algebra	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4
MATH 2200	Mathematical Reasoning & Proof	4
MATH 3080	Introduction to Probability	4
MATH 3161	Introduction to Real Analysis	4
Select one of the following:		4
MATH 3170	Introduction to Abstract Algebra	
MATH 3151	Advanced Linear Algebra	
Math Electives		8
Business [2]		
ACTG 2200	Introduction to Financial Reporting	4
FIN 2800	Financial Decision Making	4
FIN Electives		12
Total Credits		**68**

Notes

- In addition, students must complete the ETS Major Field Test in Mathematics as instructed by the department, and satisfy all requirements for the Bachelor of Arts degree with concentration in Finance as outlined in the University of Denver Undergraduate Bulletin.
- Students may enroll in ACTG 2200 Introduction to Financial Reporting only if they are formally enrolled in this degree, have completed MATH 2200 Mathematical Reasoning & Proof and have Microsoft Excel certification.
- Students in this program should work with Daniels advisors in order to make appropriate choices for 3000-level FIN electives, and ensure that prerequisites are followed.
- Students in this degree are not eligible for a Finance minor. Good choices for complementary minors include economics, statistics, or computer science.

Bachelor of Science

Bachelor of Science Major Requirements

(183 credits required for the degree (http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofscience/))

This degree requires completion of 52 credits of MATH courses numbered 1951 or higher, including at least 24 credits at the 3000-level or higher. The following courses are required:

Code	Title	Credits
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
or MATH 1962	Honors Calculus II	
MATH 1953	Calculus III	4
or MATH 1963	Honors Calculus III	
MATH 2060	Elements of Linear Algebra	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4
MATH 2200	Mathematical Reasoning & Proof	4
MATH 3161	Introduction to Real Analysis	4
MATH 3170	Introduction to Abstract Algebra	4
A MATH course at the 3000-level or higher that (a) is different from MATH 3161 and MATH 3170 and (b) has either MATH 2200 or another 3000-level MATH course as a prerequisite.		4
Additional courses		12
Total Credits		**52**

Notes

- In addition, students must complete the ETS Major Field Test in Mathematics as instructed by the department, and satisfy all requirements for the Bachelor of Science degree as outlined in the University of Denver Undergraduate Bulletin.

- It is recommended that students take MATH 3151 Advanced Linear Algebra after MATH 2200 Mathematical Reasoning & Proof but before MATH 3161 Introduction to Real Analysis and MATH 3170 Introduction to Abstract Algebra.
- Students are encouraged to complete the analysis sequence MATH 3161 Introduction to Real Analysis, MATH 3162 Introduction to Real Analysis II, MATH 3110 Topology, or the algebra sequence MATH 3170 Introduction to Abstract Algebra, MATH 3166 Group Theory, MATH 3176 Rings and Fields.

Bachelor of Science with a Concentration in Artificial Intelligence

Bachelor of Science with a Concentration in Artificial Intelligence Major Requirements

(183 credits required for the degree)

This degree requires completion of 56 credits of MATH courses numbers 1951 or higher, including 28 credits at the 3000-level or higher.

Code	Title	Credits
Required Courses		
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
MATH 1953	Calculus III	4
MATH 2060	Elements of Linear Algebra	4
MATH 2070	Introduction to Differential Equations	4
MATH 2080	Calculus of Several Variables	4
MATH 2200	Mathematical Reasoning & Proof	4
MATH 3080	Introduction to Probability	4
MATH 3151	Advanced Linear Algebra	4
MATH 3161	Introduction to Real Analysis	4
MATH 3170	Introduction to Abstract Algebra	4
MATH 3600	Numerical Analysis	4
Additional two Math of AI topics courses from among the following		8
MATH 3605	Mathematics of Complex Networks	
MATH 3610	Machine Learning: Linear Models and Regression	
MATH 3615	Statistics and Stochastic Methods	
Total Credits		**56**

Notes

- Students need to satisfy a programming requirement that can be satisfied by COMP 1351, COMP 1671, or by the new proposed course MATH 1800 Programing for Mathematicians
- It is recommended that students take MATH 3151 Advanced Linear Algebra after MATH 2200 Mathematical Reasoning & Proof but before MATH 3161 Introduction to Real Analysis and MATH 3170 Introduction to Abstract Algebra.
- In addition, students must complete the ETS Major Field Test in Mathematics as instructed by the department and satisfy all requirements for the Bachelor of Science degree with concentration in Artificial Intelligence as outlined in the University of Denver Undergraduate Bulletin.

Secondary Major

Secondary Major

48 credits. Same requirements as for BA degree.

Minor

Minor Requirements

This minor requires completion of at least 20 credits in MATH courses numbered 1951 or higher. COMP 2300 Discrete Structures in Computer Science may be counted toward the math minor. Courses not covered by these requirements must be approved in writing by a mathematics faculty advisor.

Requirements for Distinction in the Major in Mathematics

- Complete at least one of the following tracks with a GPA of 3.5 or more:
  - Analysis Track: MATH 3161 Introduction to Real Analysis, MATH 3162 Introduction to Real Analysis II, MATH 3110 Topology.
  - Algebra Track: MATH 3170 Introduction to Abstract Algebra, MATH 3166 Group Theory, MATH 3176 Rings and Fields.
- Complete an honor thesis.

The course plans below are intended to give students an example of how they might complete their degree requirements in four years. All of the required courses are included, but the quarters in which certain courses are taken can vary significantly from student to student.

For the first quarter of the first year, math majors are typically advised to take an FSEM, at least one math course (MATH 1951, or something else depending on credit earned through examinations (http://bulletin.du.edu/undergraduate/undergraduateprograms/examinations/)) and enough other credits so that the student is enrolled in 16 or more credits total. Those additional other credits may include common curriculum courses, courses in a second major or minor, or electives.

Bachelor of Arts in Mathematics

First Year

Fall	Credits	Winter	Credits	Spring	Credits
FSEM 1111	4	WRIT 1122	4	WRIT 1133	4
MATH 1951	4	MATH 1952	4	MATH 1953	4
SI: Natural	4	SI: Natural	4	SI: Natural	4
AI: Society	4	SI: Society	4	AI: Society	4
	16		**16**		**16**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
MATH 2060	4	MATH 2070	4	MATH 2080	4
MATH 2200	4	SI: Society	4	MATH 3151[1]	4
Language sequence	4	Language sequence	4	Language sequence	4
Minor	4	Minor	4	Minor	4
		INTZ 2501[3]	1-2		
	16		**17-18**		**16**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
Study Abroad	16	MATH 3170[2]	4	MATH 3161[2]	4
		Minor	4	Minor	4
		Elective	4	Elective	4
		Elective	4	Elective	4
	16		**16**		**16**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits
ASEM	4	MATH Elective	4	MATH Elective	4
Elective	4	Elective	4	Elective	4
Elective	4	Elective	4	Elective	4
Elective	4	Elective	4	Elective	4
	16		**16**		**16**

Total Credits: 193-194

1 MATH 3151 is not required, but is recommended after taking MATH 2200 but before taking MATH 3161 or MATH 3170

2 Besides MATH 3161 and MATH 3170, an additional 12 MATH credits at the 3000-level are required

3 INTZ 2501 (http://bulletin.du.edu/search/?P=INTZ%202501) is required for any student who studies abroad, and may be taken in any quarter within the year prior to studying abroad

Bachelor of Science in Mathematics

First Year

Fall	Credits	Winter	Credits	Spring	Credits
FSEM 1111	4	WRIT 1122	4	WRIT 1133	4
MATH 1951	4	MATH 1952	4	MATH 1953	4
SI: Natural	4	SI: Natural	4	SI: Natural	4
AI: Society	4	SI: Society	4	AI: Society	4
	16		**16**		**16**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
MATH 2060	4	MATH 2070	0-4	MATH 2080	4

MATH 2200	4	SI: Society	4	MATH 3151[3]	4
Language sequence	4	Language sequence	4	Language sequence	4
Minor 1[1]	4	Minor 1	4	Minor 1	4
		INTZ 2501[2]	1-2		
	16		**13-18**		**16**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
Study Abroad	16	MATH 3170[4]	4	MATH 3161[4]	4
		Minor 1	4	Minor 1	4
		Minor 2	4	Minor 2	4
		Elective	4	Elective	4
	16		**16**		**16**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits
ASEM	4	MATH Elective	4	MATH Elective	4
MATH Elective	4	Minor 2	4	Minor 2	4
Minor 2	4	Elective	4	Elective	4
Elective	4	Elective	4	Elective	4
	16		**16**		**16**

Total Credits: 189-194

1 For the BS, one of the two minors must come from a BS-granting department (e.g., a Natural Science or Computer Science).

2 INTZ 2501 (http://bulletin.du.edu/search/?P=INTZ%202501) is required for any student who studies abroad, and may be taken in any quarter within the year prior to studying abroad.

3 MATH 3151 is not required, but is recommended after taking MATH 2200 but before taking MATH 3161 or MATH 3170.

4 Besides MATH 3161 and MATH 3170, an additional 16 MATH credits at the 3000-level are required. One of these 16 credits, four must be from a course that has either MATH 2200 or another 3000-level MATH course as a prerequisite.

Students are encouraged to complete the analysis sequence MATH 3161 (http://bulletin.du.edu/search/?P=MATH%203161) Introduction to Real Analysis, MATH 3162 (http://bulletin.du.edu/search/?P=MATH%203162) Introduction to Real Analysis II, MATH 3110 (http://bulletin.du.edu/search/?P=MATH%203110) Topology, or the algebra sequence MATH 3170 (http://bulletin.du.edu/search/?P=MATH%203170) Introduction to Abstract Algebra, MATH 3166 (http://bulletin.du.edu/search/?P=MATH%203166) Group Theory, MATH 3176 (http://bulletin.du.edu/search/?P=MATH%203176) Rings and Fields.

Bachelor of Arts with Concentration in Finance

First Year

Fall	Credits	Winter	Credits	Spring	Credits
FSEM 1111	4	WRIT 1122	4	WRIT 1133	4
MATH 1951	4	MATH 1952	4	MATH 1953	4
SI: Natural	4	SI: Natural	4	SI: Natural	4
AI: Society	4	SI: Society	4	AI: Society	4
	16		**16**		**16**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
MATH 2060	4	MATH 2070	0-4	MATH 2080	4
MATH 2200	4	SI: Society	4	MATH 3151[2]	4
Language sequence	4	Language sequence	4	Language sequence	4
Minor	4	Minor	4	Minor	4
		INTZ 2501[1]	1-2		
	16		**13-18**		**16**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
Study Abroad	16	MATH 3080	4	MATH 3161[2]	4
		ACTG 2200	4	FIN 2800	4
		Minor	4	Minor	4
		Elective	4	Elective	4
	16		**16**		**16**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits
MATH Elective	4	MATH Elective	4	FIN Elective	4
FIN Elective	4	FIN Elective	4	Elective	4
Elective	4	Elective	4	Elective	4
Elective	4	Elective	4	Elective	4
	16		**16**		**16**

Total Credits: 189-194

1 INTZ 2501 (http://bulletin.du.edu/search/?P=INTZ%202501) is required for any student who studies abroad, and may be taken in any quarter within the year prior to studying abroad.

2 Besides MATH 3080, MATH 3161 and MATH 3151 (or MATH 3170), an additional 8 MATH credits at the 3000-level are required

Bachelor of Science with a Concentration in Artificial Intelligence

First Year

Fall	Credits	Winter	Credits	Spring	Credits
FSEM 1111	4	WRIT 1122	4	WRIT 1133	4
MATH 1951	4	MATH 1952	4	MATH 1953	4
Language sequence	4	Language sequence	4	Language sequence	4
Minor 1	4	Minor 1	4	Minor 1	4
	16		**16**		**16**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
MATH 2060	4	MATH 2070	0-4	MATH 2080	4
MATH 2200	4	SI: Society	4	MATH 3151	4
Minor 1	4	Minor 1	4	SI: Society	4
AI: Society	4	AI: Society	4	Elective	4
	16		**12-16**		**16**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
Study Abroad	16	MATH 3170	4	MATH 3161	4
		MATH 3080	4	MATH 3600	4
		Minor 2	4	Minor 2	4
		Elective	4		
	16		**16**		**12**

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits
Minor 2	4	Math of AI	4	Elective	4
Minor 2	4	Advanced Seminar	4	Elective	4
Elective	4	Minor 2	4	Elective	4
Math of AI	4			Minor 2	4
	16		**12**		**16**

Total Credits: 180-184

MATH 1010 Elements of College Algebra (2,4 Credits)
This course is designed to review the required algebra skills to be successful in Business Calculus. The following topics are covered: review of basic algebra, solving equations and inequalities, rectangular coordinate systems and graphing, polynomial and rational functions, exponential and logarithmic functions, and solving exponential and logarithmic equations. Students who completed a MATH course numbered 1200 or higher may not take this course.

MATH 1070 College Algebra and Trigonometry (4 Credits)
Selected topics in algebra and analytic trigonometry intended to prepare students for the calculus sequence. Cannot be used to satisfy the Analytical Inquiry: The Natural and Physical World requirement. Students who completed a MATH course numbered 1951 or higher may not take this course.

MATH 1150 Foundations Seminar (4 Credits)
The seminars offer challenging and interesting mathematical topics that require only high school mathematics. Examples of seminars are Introduction to Cryptography, Patterns and Symmetry, Mathematical Art and Patterns of Voting. This course counts toward the Analytical Inquiry: The Natural and Physical World requirement.

MATH 1200 Calculus for Business and Social Sciences (4 Credits)
This is a one-quarter course for students in business, social sciences, and liberal arts. It covers elementary differential calculus with emphasis on applications to business and the social sciences. Topics include functions, graphs, limits, continuity, differentiation, and mathematical models. Students are required to attend weekly labs. This course counts toward the Analytical Inquiry: The Natural and Physical World requirement.

MATH 1941 Calculus I Workshop (1 Credit)
This is a workshop that students can enroll in to accompany the course MATH 1951 Calculus I. Students will work in groups on challenging problems from Calculus to gain deeper understanding of the covered material. The workshop is not intended for remediation, tutoring, or working on homework assigned in the accompanying course. The workshop cannot be used toward math major/minor. Co-requisite: Students must be concurrently enrolled in MATH 1951 Calculus I.

MATH 1942 Calculus II Workshop (1 Credit)
This is a workshop that students can enroll in to accompany the course MATH 1952 Calculus II. Students will work in groups on challenging problems from Calculus to gain deeper understanding of the covered material. The workshop is not intended for remediation, tutoring, or working on homework assigned in the accompanying course. The course cannot be used toward math major/minor. Co-requisite: Students must be concurrently enrolled in MATH 1952 Calculus II.

MATH 1943 Calculus III Workshop (1 Credit)
This is a workshop that students can enroll in to accompany the course MATH 1953 Calculus III. Students will work in groups on challenging problems from Calculus to gain deeper understanding of the covered material. The workshop is not intended for remediation, tutoring, or working on homework assigned in the accompanying course. The course cannot be used toward math major/minor. Co-requisite: Students must be concurrently enrolled in MATH 1953 Calculus III.

MATH 1951 Calculus I (4 Credits)
Limits, continuity, differentiation of functions of one variable, applications of the derivative. This course counts toward the Analytical Inquiry: The Natural and Physical World requirement. Prerequisite: MATH 1070 or equivalent.

MATH 1952 Calculus II (4 Credits)
Differentiation and integration of functions of one variable especially focusing on the theory, techniques and applications of integration. Prerequisite: MATH 1951.

MATH 1953 Calculus III (4 Credits)
Integration of functions of one variable, infinite sequences and series, polar coordinates, parametric equations. Prerequisite: MATH 1952 OR math 1962.

MATH 1962 Honors Calculus II (4 Credits)
Same topics as MATH 1952 treated rigorously and conceptually. Topics include differentiation and integration of functions of one variable especially focusing on the theory, techniques and applications of integration. Prerequisites: MATH 1951 and permission of instructor.

MATH 1963 Honors Calculus III (4 Credits)
Same topics as MATH 1953 treated rigorously and conceptually. Topics include integration of functions of one variable, infinite sequences and series, polar coordinates, parametric equations. Prerequisites: MATH 1952 or MATH 1962 and permission of instructor.

MATH 1988 Study Abroad Resident Credit (0-18 Credits)

MATH 2050 Symbolic Logic (4 Credits)
Modern propositional logic; symbolization and calculus of predicates, especially predicates of relation. This course counts toward the Analytical Inquiry: The Natural and Physical World requirement. Cross listed with PHIL 2160.

MATH 2060 Elements of Linear Algebra (4 Credits)
Matrices, systems of linear equations, vectors, eigenvalues and eigenvectors; idea of a vector space; applications in the physical, social, engineering and life sciences. Prerequisite: MATH 1200 or MATH 1951.

MATH 2070 Introduction to Differential Equations (0-4 Credits)
Solution of linear differential equations; special techniques for nonlinear problems; mathematical modeling of problems from physical and biological sciences. Prerequisite: MATH 1953 or MATH 1963.

MATH 2080 Calculus of Several Variables (4 Credits)
Multivariable processes encountered in all sciences; multiple integration, partial differentiation and applications; algebra of vectors in Euclidean three-space; differentiation of scalar and vector functions. Prerequisite: MATH 1953 or MATH 1963.

MATH 2200 Mathematical Reasoning & Proof (4 Credits)
Introduction to theory of sets; relations and functions; logic, truth tables and propositional calculus; proof techniques; introduction to combinatorial techniques.

MATH 2988 Study Abroad Resident Credit (0-18 Credits)

MATH 3000 The Real World Seminar (1 Credit)
Lectures by alumni and others on surviving culture shock when leaving the University and entering the job world. Open to all students regardless of major. Cross listed with COMP 3000.

MATH 3010 History of Mathematics (4 Credits)
This course surveys major mathematical developments beginning with ancient Egyptians and Greeks and tracing the development through Hindu-Indian mathematics, Arabic mathematics, and European mathematics up to the 18th century. Prerequisite: MATH 1953 or MATH 1963.

MATH 3040 Lattices and Order (4 Credits)
Ordered sets, lattices as relational and as algebraic structures, ideals and filters, complete lattices, distributive and modular lattices, Boolean algebras, duality for finite distributive lattices. Prerequisite: MATH 2200.

MATH 3050 Set Theory (4 Credits)
Zermelo-Fraenkel axioms, axiom of choice, Zorn's Lemma, ordinals, cardinals, cardinal arithmetic. Prerequisite: MATH 2200.

MATH 3060 Mathematical Logic (4 Credits)
Classical propositional calculus (deductive systems and truth-table semantics), first-order logic (axiomatization and completeness), elements of recursion theory, introduction to nonclassical logics. Prerequisite: MATH 2200.

MATH 3080 Introduction to Probability (4 Credits)
Basic probability models, combinatorial methods, random variables, independence, conditional probability, probability laws, applications to classical problems. Prerequisite: MATH 1953 or MATH 1963.

MATH 3090 Mathematical Probability (4 Credits)
Limit theorems for independent random variables, multivariate distributions, generating functions. Prerequisites: MATH 2080 and MATH 3080.

MATH 3110 Topology (4 Credits)
Point set topology including topological spaces, connectedness, compactness and separate axioms; preparation for advanced courses in analysis. Prerequisite: MATH 3161. Cross listed with MATH 4110.

MATH 3151 Advanced Linear Algebra (4 Credits)
Vector spaces, linear mappings, matrices, inner product spaces, eigenvalues and eigenvectors. Prerequisite: MATH 2060 and MATH 2200.

MATH 3161 Introduction to Real Analysis (4 Credits)
A theoretical introduction to the structure of real numbers, to convergence of sequences and series, and to the topology of the real line, including limits and continuity. Prerequisites: MATH 2080 and MATH 2200.

MATH 3162 Introduction to Real Analysis II (4 Credits)
A rigorous introduction to the analysis of functions of a real variable, including differentiation, Riemann integration, and the notions of pointwise and uniform convergence for sequences of functions. Prerequisite: MATH 3161.

MATH 3166 Group Theory (4 Credits)
Groups and homomorphisms, isomorphism theorems, symmetric groups and G-sets, the Sylow theorems, normal series, fundamental theorem of finitely generated abelian groups. Cross listed with MATH 4166. Prerequisite: MATH 3170.

MATH 3170 Introduction to Abstract Algebra (4 Credits)
Examples of groups, permutations, subgroups, cosets, Lagrange theorem, normal subgroups, factor groups, homomorphisms, isomorphisms, rings, integral domains, quaternions, rings of polynomials, Euclid algorithm, ideals, factor rings, maximal ideals, principal ideals, fields, construction of finite fields. Prerequisite: MATH 2060 and MATH 2200.

MATH 3176 Rings and Fields (4 Credits)
Rings, domains, fields; ideals, quotient rings, polynomials; PIDs, UFDs, Euclidean domains; maximal and prime ideals, chain conditions; extensions of fields, splitting fields, algebraic and transcendental extensions; brief introduction to Galois theory. Cross listed with MATH 4176. Prerequisite: MATH 3170 or equivalent.

MATH 3260 Metric Spaces (4 Credits)
Metric spaces and continuous functions; completeness and compactness; examples including norm spaces; pointwise and uniform convergence; Baire Category Theorem. Cross listed with MATH 4260. Prerequisite: MATH 3161 or equivalent.

MATH 3311 Linear Programming (4 Credits)
Linear optimization models, simplex algorithm, sensitivity analysis and duality, network models, dynamic programming, applications to physical, social and management sciences. Prerequisite: MATH 2060.

MATH 3312 Markov Chains (4 Credits)
Discrete-time and continuous Markov Chains, ergodic theorems, random processes, elementary queueing theory, applications. Prerequisite: MATH 2060 and MATH 3080.

MATH 3351 Introduction to Dynamical Systems (4 Credits)
Dynamical systems (one-parameter families such as circle rotations/tent maps, shift spaces); global properties (transitivity/mixing/sensitivity); behavior of trajectories (chaos, long-term averages, periodicity). Prerequisite: MATH 3161.

MATH 3400 Introduction to Geometry (4 Credits)
Specific geometrical systems including finite, Euclidean, non-Euclidean and projective geometries. Prerequisite: MATH 2200.

MATH 3451 Chaos, Dynamics & Fractals (4 Credits)
Introduction to one-dimensional dynamical systems, fractals; fixed and periodic points; sources and sinks; period doubling and tangent node bifurcations; chaotic dynamical systems; Sarkovskii's Theorem. Prerequisite: MATH 3161.

MATH 3550 Introduction to Theory of Numbers (4 Credits)
Concepts of nonanalytic number theory and its history; prime numbers, divisibility, continued fractions, modular arithmetic, Diophantine equations and unsolved conjectures. Prerequisites: MATH 2200.

MATH 3600 Numerical Analysis (4 Credits)
An introduction to numerical methods. Topics include: iterative methods, Banach fixed point method, Runge-Kutta and finite element methods for partial differential equations, numerical optimization and gradient descent algorithm, and back propagation in neural networks. Prerequisites: MATH 2200.

MATH 3605 Mathematics of Complex Networks (4 Credits)
An introduction to the study of complex networks, focusing on the modeling, classification and geometrical properties of complex systems. Topics include stochastic and non-stochastic models of complex networks, measures of centrality and clustering, influence propagation and geometric data (expansion, the small world phenomena and PageRank). Prerequisite: MATH 2200.

MATH 3610 Machine Learning: Linear Models and Regression (4 Credits)
An introduction to modern regression techniques, with an emphasis in theoretical foundations and applications in artificial intelligence and machine learning. Topics include multilinear regression, polynomial regression, logistic regression, and support vector machines, including kernels methods. Prerequisite: MATH 3151 & MATH 3080.

MATH 3615 Statistics and Stochastic Methods (4 Credits)
Statistical decision theory, estimation, testing, confidence intervals. Bayesian statistics, introduction to Markov chains, and hidden Markov chains with applications to artificial intelligence. Prerequisite: MATH 2200 & MATH 3080.

MATH 3651 Ordinary Differential Equations (4 Credits)
Modeling of phenomena by ordinary differential equations; techniques of analysis and solution of such equations; oscillation theory and boundary value problems, power series methods, special functions, Laplace transforms and difference equations. Prerequisites: MATH 2060 and MATH 2070.

MATH 3661 Partial Differential Equations (4 Credits)
First and second order linear equations, Fourier series, the wave equation, the Cauchy problem, the heat equation, maximum principles, Laplace's equation, Green's functions. Prerequisites: MATH 2070 and MATH 2080.

MATH 3701 Combinatorics (4 Credits)
The principle of inclusion and exclusion, elementary counting techniques, systems of distinct representatives, partitions, recursion and generating functions, Latin squares, designs and projective planes. Prerequisite: MATH 2200.

MATH 3705 Topics in Mathematics (4 Credits)
Varying selected advanced topics in mathematics, depending on student demand and instructor interest.

MATH 3710 Graph Theory (4 Credits)
Paths, cycles, trees, Euler tours and Hamilton cycles, bipartite graphs, matchings, basic connectivity theorems, planar graphs, Kuratowski's theorem, chromatic number, n-color theorems, introduction to Ramsey theory. Prerequisite: MATH 2200.

MATH 3720 Coding Theory (4 Credits)
Goals of coding theory and information theory, instantaneous and Huffman codes, Shannon theorems, block and linear codes, generating and parity-check matrices, Hamming codes, perfect codes, binary Golay code, Reed-Muller codes, cyclic codes, BCH codes, Reed-Solomon codes, ideas of convolutional and turbo codes. Prerequisite: MATH 3170.

MATH 3851 Functions Complex Variable (4 Credits)
Complex numbers, analytic functions, complex integration, series expansions, residue theory, conformal maps, advanced topics and applications. Prerequisites: MATH 2060 and MATH 2080 and MATH 2200.

MATH 3988 Study Abroad Resident Credit (0-18 Credits)

MATH 3991 Independent Study (1-10 Credits)
Cannot be arranged for any course that appears in regular course schedule for that particular year.

MATH 3995 Independent Research (1-10 Credits)