Mathematics

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Courses offered by the Department of Mathematics are designed to satisfy the needs of majors and nonmajors interested in mathematics primarily as part of a broad liberal education. They provide basic mathematical and statistical training for students in the social, biological, and physical sciences and in the professional schools; prepare teachers of mathematics; and provide advanced and graduate work for students specializing in the field.

Facilities

The department office and the Mathematics Library are housed in Fenton Hall. A reading and study area is located in the Moursund Reading Room of the Mathematics Library. The Hilbert Space, an undergraduate mathematics center, is in Deady Hall.

Awards and Prizes

- The William Lowell Putnam examination, a competitive, nationally administered mathematics examination, is given early each December. It contains twelve very challenging problems, and prizes are awarded to the top finishers in the nation. Interested students should consult the chair of the undergraduate affairs committee at the beginning of fall term
- The Anderson Award, endowed by Frank W. Anderson, honors an advanced graduate student with the department's most outstanding teaching record
- The Jack and Peggy Borsting Award for Scholastic Achievement in Graduate Mathematics is awarded to either a graduating or continuing graduate student
- The Curtis Scholarship, endowed by Charles W. and Elizabeth H. Curtis, honors a continuing undergraduate student who has shown outstanding achievement in mathematics
- The DeCou Prize, which honors a former long-time department head, E. E. DeCou, and his son, E. J. DeCou, is awarded annually to the outstanding graduating senior with a mathematics major
- The Juilfs Scholarship, in honor of Erwin and Gertrude Juilfs, is awarded to one or more students who show exceptional promise for achievement as evidenced by GPA, originality of research, or other applicable criteria
- The Stevenson Prize, funded by Donald W. and Jean Stevenson, is awarded annually to the outstanding senior graduating with a precollege-teaching option

Faculty

Shabnam Akhtari, assistant professor (number theory). BA, 2002, Sharif University of Technology; PhD, 2008, British Columbia. (2012)

Arkadiy D. Berenstein, professor (quantum groups, representation theory). MS, 1988, Moscow Transport Institute; PhD, 1996, Northeastern. (2000)

Boris Botvinnik, professor (algebraic topology). MS, 1978, Novosibirsk State; PhD, 1984, USSR Academy of Sciences, Novosibirsk. (1993)

Marcin Bownik, professor (harmonic analysis, wavelets). Magister, 1995, Warsaw, Poland; MA, 1997, PhD, 2000, Washington (St. Louis). (2003)

Jonathan Brundan, professor (Lie theory, representation theory). BA, 1992, Queens College, Cambridge; PhD, 1996, University of London. (1997)

Daniel K. Dugger, associate professor (algebraic topology and geometry, K-theory, commutative algebra). BA, 1994, Michigan, Ann Arbor; PhD, 1999, Massachusetts Institute of Technology. (2004)

Peter B. Gilkey, professor (global analysis, differential geometry). BS, MA, 1967, Yale; PhD, 1972, Harvard. (1981)

Hayden Harker, instructor. BA, 1995, Oberlin College; MS, 2000, PhD, 2005, Oregon. (2011)

Weiyong He, assistant professor (differential geometry, geometric analysis and partial differential equations). MS, 2004, Science and Technology of China; PhD, 2007, Wisconsin, Madison. (2009)

Fred Hervert, senior instructor. BA, 1983, MS, 1987, Northeastern Illinois. (1999)

James A. Isenberg, professor (mathematical physics, differential geometry, nonlinear partial differential equations). AB, 1973, Princeton; PhD, 1979, Maryland. (1982)

Alexander S. Kleshchev, professor (algebra, representation theory). BS, MS, 1988, Moscow State; PhD, 1993, Institute of Mathematics, Academy of Sciences of Belarus, Minsk. (1995)

David A. Levin, associate professor (probability theory and stochastic processes). BS, 1993, Chicago; MA, 1995, PhD, 1999, California, Berkeley. (2006)

Huaxin Lin, professor (functional analysis). BA, 1980, East China Normal, Shanghai; MS, 1984, PhD, 1986, Purdue. (1995)

Peng Lu, professor (differential geometry, geometric analysis). BSc, 1985, Nanjing; MSc, 1988, Nanki Mathematics Institute; PhD, 1996, State University of New York, Stony Brook. (2002)

Jean B. Nganou, instructor (finite dimensional division algebras). MS, 2001, Yaoundé I; PhD, 2009, New Mexico State. (2009)

Victor V. Ostrik, professor (representation theory). MS, 1995, PhD, 1999, Moscow State. (2003)

N. Christopher Phillips, professor (functional analysis). AB, 1978, MA, 1980, PhD, 1984, California, Berkeley. (1990)

Alexander Polishchuk, professor (algebraic geometry). MS, 1993, Moscow State; PhD, 1996, Harvard. (2003)

Michael R. Price, senior instructor; assistant department head. BS, 2003, MS, 2005, Oregon. (2006)

Nicholas J. Proudfoot, associate professor (algebraic geometry, combinatorics, topological groups). AB, 2000, Harvard; PhD, 2004, California, Berkeley. (2007)

Hal Sadofsky, associate professor (algebraic topology, homotopy theory). BS, 1984, Rochester; PhD, 1990, Massachusetts Institute of Technology. (1995)

Brad S. Shelton, professor (Lie groups, harmonic analysis, representations). BA, 1976, Arizona; MS, PhD, 1982, Washington (Seattle). (1985)

Christopher D. Sinclair, associate professor (random matrix theory, number theory). BS, 1997, Arizona; PhD, 2005, Texas, Austin. (2009)

Dev P. Sinha, associate professor (algebraic and differential topology). BS, 1993, Massachusetts Institute of Technology; PhD, 1997, Stanford. (2001)

Bartlomiej A. Siudeja, assistant professor (probability, differential equations). MS, 2003, Wroclaw University of Technology; PhD, 2008, Purdue, West Lafayette. (2011)

Craig Tingey, senior instructor. BA, BS, 1989, MS, 1991, Utah. (2001)

Arkady Vaintrob, associate professor (algebraic geometry, Lie theory and representation theory, mathematical physics). BA, 1976, Moscow Institute of Railway Engineering; MS, 1979, PhD, 1987, Moscow State. (2000)

Vadim Vologodski, associate professor (algebraic geometry, number theory). MS, 1996, Independent University of Moscow; PhD, 2001, Harvard. (2009)

Hao Wang, associate professor (mathematics of finance, probability, statistics). BS, 1980, MS, 1985, Wuhan (China); PhD, 1995, Carleton (Canada). (2000)

Micah Warren, assistant professor (geometric analysis). BS, 2000, Pacific Lutheran; MS, 2006, PhD, 2008, Washington (Seattle). (2012)

Yuan Xu, professor (numerical analysis). BS, 1982, Northwestern (China); MS, 1984, Beijing Institute of Aeronautics and Astronautics; PhD, 1988, Temple. (1992)

Benjamin Young, assistant professor (combinatorics). BS, 2001, MS, 2002, Carleton; PhD, 2008, British Columbia. (2012)

Sergey Yuzvinsky, professor (representation theory, combinatorics, multiplication of forms). MA, 1963, PhD, 1966, Leningrad. (1980)

Courtesy

Robert M. Solovay, courtesy professor (quantum computation, logic). MS, 1960, PhD, 1964, Chicago. (1990)

Emeriti

Frank W. Anderson, professor emeritus. BA, 1951, MS, 1952, PhD, 1954, Iowa. (1957)

Fred C. Andrews, professor emeritus. BS, 1946, MS, 1948, Washington (Seattle); PhD, 1953, California, Berkeley. (1957)

Bruce A. Barnes, professor emeritus. BA, 1960, Dartmouth; PhD, 1964, Cornell. (1966)

Richard B. Barrar, professor emeritus. BS, 1947, MS, 1948, PhD, 1952, Michigan. (1967)

Glenn T. Beelman, senior instructor emeritus. BS, 1938, South Dakota State; AM, 1962, George Washington. (1966)

Charles W. Curtis, professor emeritus. BA, 1947, Bowdoin; MA, 1948, PhD, 1951, Yale. (1963)

Micheal N. Dyer, professor emeritus. BA, 1960, Rice; PhD, 1965, California, Los Angeles. (1967)

Robert S. Freeman, associate professor emeritus. BAE., 1947, New York University; PhD, 1958, California, Berkeley. (1967)

William M. Kantor, professor emeritus. BS, 1964, Brooklyn; MA, 1965, PhD, 1968, Wisconsin, Madison. (1971)

Richard M. Koch, professor emeritus. BA, 1961, Harvard; PhD, 1964, Princeton. (1966)

John V. Leahy, professor emeritus. PhD, 1965, Pennsylvania. (1966)

Shlomo Libeskind, professor emeritus. BS, 1962, MS, 1965, Technion-Israel Institute of Technology; PhD, 1971, Wisconsin, Madison. (1986)

Theodore W. Palmer, professor emeritus. BA, 1958, MA, 1958, Johns Hopkins; AM, 1959, PhD, 1966, Harvard. (1970)

Kenneth A. Ross, professor emeritus. BS, 1956, Utah; MS, 1958, PhD, 1960, Washington (Seattle). (1964)

Gary M. Seitz, professor emeritus. AB, 1964, MA, 1965, California, Berkeley; PhD, 1968, Oregon. (1970)

Allan J. Sieradski, professor emeritus. BS, 1962, Dayton; MS, 1964, PhD, 1967, Michigan. (1967)

Stuart Thomas, senior instructor emeritus. AB, 1965, California State, Long Beach; MA, 1967, California, Berkeley. (1990)

Donald R. Truax, professor emeritus. BS, 1951, MS, 1953, Washington (Seattle); PhD, 1955, Stanford. (1959)

Marie A. Vitulli, professor emerita. BA, 1971, Rochester; MA, 1973, PhD, 1976, Pennsylvania. (1976)

Marion I. Walter, professor emerita. BA, 1950, Hunter; MS, 1954, New York University; DEd, 1967, Harvard. (1977)

Lewis E. Ward Jr., professor emeritus. AB, 1949, California, Berkeley; MS, 1951, PhD, 1953, Tulane. (1959)

Jerry M. Wolfe, associate professor emeritus. BS, 1966, Oregon State; MA, 1969, PhD, 1972, Washington (Seattle). (1970)

Charles R. B. Wright, professor emeritus. BA, 1956, MA, 1957, Nebraska; PhD, 1959, Wisconsin, Madison. (1961)

The date in parentheses at the end of each entry is the first year on the University of Oregon faculty.

- **Bachelor of Arts: Applied Mathematics**
- **Bachelor of Arts: Pure Mathematics**
- **Bachelor of Arts: Secondary Teaching**
- **Bachelor of Arts: Design-Your-Own**
- **Bachelor of Science: Applied Mathematics**
- **Bachelor of Science: Pure Mathematics**
- **Bachelor of Science: Secondary Teaching**
- **Bachelor of Science: Design-Your-Own**
- **Minor**

Undergraduate Studies

Students planning to major in mathematics at the university should take four years of high school mathematics including a year of mathematics as a senior. Courses in algebra, geometry, trigonometry, and more advanced topics should be included whether offered as separate courses or as a unit.

College transfer students who have completed a year of calculus should be able to satisfy the major requirements in mathematics at the University of Oregon in two years.

Science Group Requirement

The department offers courses that satisfy the science group requirement:

MATH 105–107	University Mathematics I-III	12
MATH 211–213	Fundamentals of Elementary Mathematics I-III	12
MATH 231–233	Elements of Discrete Mathematics I-III	12
MATH 241–242 & MATH 243	Calculus for Business and Social Science I-II and Introduction to Methods of Probability and Statistics	12
MATH 246–247	Calculus for the Biological Sciences I-II	8
MATH 251–253	Calculus I-III	12
MATH 261–263	Calculus with Theory I-III	12
MATH 307	Introduction to Proof	4

The 100-level courses present important mathematical ideas in an elementary setting, stressing concepts more than computation. They do not provide preparation for other mathematics courses but are compatible with further study in mathematics.

Enrollment in Courses

Beginning and transfer students must take a placement examination before enrolling in their first UO mathematics course; the examination is given during each registration period. Students who transfer credit for calculus to the university are excused from the examination.

To enroll in courses that have prerequisites, students must complete the prerequisite courses with grades of C– or better or P.

Students cannot receive credit for a course that is a prerequisite to a course they have already taken. For example, a student with credit in Calculus for Business and Social Science I (MATH 241) cannot later receive credit for College Algebra (MATH 111). For more information about credit restrictions, contact a mathematics advisor.

Bridge Requirement

Most upper-division courses include mathematical proof as a significant element. To prepare for this, students must satisfy the bridge requirement as a prerequisite to taking any 300- or 400-level course other than Elementary Linear Algebra (MATH 341–342), Statistical Methods I-II (MATH 425–426), or Partial Differential Equations: Fourier Analysis I-II (MATH 421–422).

The bridge requirement is one of the following.

MATH 307	Introduction to Proof	4
MATH 231–232	Elements of Discrete Mathematics I-II	8
MATH 261–262	Calculus with Theory I-II	8

Note that this affects all majors because the bridge requirement must be satisfied before taking Elementary Analysis (MATH 315).

Calculus Sequences

The department offers four calculus sequences. Students need to consult an advisor in mathematics or in their major field about which sequence to take.

Sequence	Description
MATH 251–253	• Standard sequence recommended to most students in the physical sciences and mathematics • For students interested in more advanced mathematics courses
MATH 261–263	• Same material as the standard sequence but includes theoretical background material and is for strong students with an interest in mathematics • For students interested in more advanced mathematics courses
MATH 246–247, MATH 253	• Covers comparable material as Calculus I,II but with an emphasis on modeling and applications to the life sciences. • For students interested in more advanced mathematics courses
MATH 241–242, MATH 243	• Serves the mathematical needs of students in the business, managerial, and social sciences • For students **not** interested in more advanced mathematical courses

The first three sequences are equivalent as far as department requirements for majors or minors and as far as prerequisites for more advanced courses.

Program Plan Example

First Year		Credits
Select one of the following:		12
MATH 251–253	Calculus I-III	12
MATH 261–263	Calculus with Theory I-III	12
Select one of the following:		4-8
MATH 231–232	Elements of Discrete Mathematics I-II	8
MATH 261–262	Calculus with Theory I-II	8

MATH 307	Introduction to Proof	4
Second Year		
MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis	4
MATH 341–342	Elementary Linear Algebra	8
Third Year		
Upper-division mathematics course		4
Complete second-year sequence, as necessary		4
Fourth Year		
Three upper-division mathematics courses		12
	Total Credits:	36-40

1 Students interested in a physical science typically take the Introduction to Differential Equations (MATH 256) sequence.

2 Students interested in pure mathematics or computer and information science typically take the Elementary Analysis (MATH 315) sequence.

3 The sequences can be taken simultaneously, but it is possible to graduate in four years without taking both at once.

Students who are considering graduate school in mathematics should take at least one or two of the pure math sequences, Introduction to Analysis I-III (MATH 413–415), Introduction to Abstract Algebra I-III (MATH 444–446), or Introduction to Topology (MATH 431–432) and Introduction to Differential Geometry (MATH 433). The choice merits discussion with an advisor.

Bachelors Degree Requirements

The department offers undergraduate preparation for positions in government, business, and industry and for graduate work in mathematics and statistics. Each student's major program is individually constructed in consultation with an advisor.

Upper-division courses used to satisfy major requirements must be taken for letter grades, and only one D grade (D+ or D or D–) may be counted toward the upper-division requirement. At least 12 credits in upper-division mathematics courses must be taken in residence at the university.

Statistical Methods I (MATH 425) cannot be used to satisfy requirements for a mathematics major or minor.

To qualify for a bachelor's degree with a major in mathematics, a student must satisfy the requirements for one of four options: applied mathematics, pure mathematics, secondary teaching, or an option of your own design. In each option, most courses require calculus as a prerequisite, and in each option some of the courses require satisfying the bridge requirement.

Bachelor of Arts: Applied Mathematics

MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis [1]	4
MATH 341–342	Elementary Linear Algebra	8
Select four of the following:		16
MATH 343	Statistical Models and Methods	
MATH 351	Elementary Numerical Analysis I	
MATH 352	Elementary Numerical Analysis II	
MATH 411	Functions of a Complex Variable I	
MATH 412	Functions of a Complex Variable II	
MATH 420	Ordinary Differential Equations	
MATH 421	Partial Differential Equations: Fourier Analysis I	
MATH 422	Partial Differential Equations: Fourier Analysis II	
MATH 456	Networks and Combinatorics	
MATH 457	Discrete Dynamical Systems	
MATH 458	Introduction to Mathematical Cryptography	
MATH 461	Introduction to Mathematical Methods of Statistics I	
MATH 462	Introduction to Mathematical Methods of Statistics II	
MATH 463	Mathematical Methods of Regression Analysis and Analysis of Variance	
Total Credits		40

1 For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

Bachelor of Science: Applied Mathematics

MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis [1]	4
MATH 341–342	Elementary Linear Algebra	8
Select four of the following:		16
MATH 343	Statistical Models and Methods	
MATH 351	Elementary Numerical Analysis I	
MATH 352	Elementary Numerical Analysis II	
MATH 411	Functions of a Complex Variable I	
MATH 412	Functions of a Complex Variable II	
MATH 420	Ordinary Differential Equations	
MATH 421	Partial Differential Equations: Fourier Analysis I	
MATH 422	Partial Differential Equations: Fourier Analysis II	
MATH 456	Networks and Combinatorics	
MATH 457	Discrete Dynamical Systems	
MATH 458	Introduction to Mathematical Cryptography	
MATH 461	Introduction to Mathematical Methods of Statistics I	

MATH 462	Introduction to Mathematical Methods of Statistics II	
MATH 463	Mathematical Methods of Regression Analysis and Analysis of Variance	
Total Credits		40

[1] For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

Bachelor of Arts: Pure Mathematics

MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis [1]	4
MATH 341–342	Elementary Linear Algebra	8
Select four of the following:		16
MATH 391	Fundamentals of Abstract Algebra I	
MATH 392	Fundamentals of Abstract Algebra II	
MATH 393	Fundamentals of Abstract Algebra III	
MATH 394	Geometries from an Advanced Viewpoint I	
MATH 395	Geometries from an Advanced Viewpoint II	
MATH 413	Introduction to Analysis I	
MATH 414	Introduction to Analysis II	
MATH 415	Introduction to Analysis III	
MATH 431	Introduction to Topology	
MATH 432	Introduction to Topology	
MATH 433	Introduction to Differential Geometry	
MATH 441	Linear Algebra	
MATH 444	Introduction to Abstract Algebra I	
MATH 445	Introduction to Abstract Algebra II	
MATH 446	Introduction to Abstract Algebra III	
MATH 467	Stochastic Processes	
Total Credits		40

[1] For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

Bachelor of Science: Pure Mathematics

MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis [1]	4
MATH 341–342	Elementary Linear Algebra	8
Select four of the following:		16
MATH 391	Fundamentals of Abstract Algebra I	
MATH 392	Fundamentals of Abstract Algebra II	
MATH 393	Fundamentals of Abstract Algebra III	
MATH 394	Geometries from an Advanced Viewpoint I	
MATH 395	Geometries from an Advanced Viewpoint II	
MATH 413	Introduction to Analysis I	
MATH 414	Introduction to Analysis II	
MATH 415	Introduction to Analysis III	
MATH 431	Introduction to Topology	
MATH 432	Introduction to Topology	
MATH 433	Introduction to Differential Geometry	
MATH 441	Linear Algebra	
MATH 444	Introduction to Abstract Algebra I	
MATH 445	Introduction to Abstract Algebra II	
MATH 446	Introduction to Abstract Algebra III	
MATH 467	Stochastic Processes	
Total Credits		40

[1] For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

Bachelor of Arts: Secondary Teaching

MATH 315	Elementary Analysis [1]	4
MATH 341	Elementary Linear Algebra	4
MATH 343	Statistical Models and Methods	4
MATH 346	Number Theory	4
MATH 391–393	Fundamentals of Abstract Algebra I-III	12
MATH 394–395	Geometries from an Advanced Viewpoint I-II	8
CIS 122	Introduction to Programming and Problem Solving (or another programming course approved by advisor)	4
Total Credits		40

[1] For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

Bachelor of Science: Secondary Teaching

MATH 315	Elementary Analysis [1]	4
MATH 341	Elementary Linear Algebra	4
MATH 343	Statistical Models and Methods	4
MATH 346	Number Theory	4
MATH 391–393	Fundamentals of Abstract Algebra I-III	12
MATH 394–395	Geometries from an Advanced Viewpoint I-II	8
CIS 122	Introduction to Programming and Problem Solving (or another programming course approved by advisor)	4
Total Credits		40

[1] For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

Bachelor of Arts: Design-Your-Own

MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis [1]	4
MATH 341–342	Elementary Linear Algebra	8
Select four of the following: [2]		16
MATH 343	Statistical Models and Methods	

MATH 351	Elementary Numerical Analysis I
MATH 352	Elementary Numerical Analysis II
MATH 411	Functions of a Complex Variable I
MATH 412	Functions of a Complex Variable II
MATH 420	Ordinary Differential Equations
MATH 421	Partial Differential Equations: Fourier Analysis I
MATH 422	Partial Differential Equations: Fourier Analysis II
MATH 456	Networks and Combinatorics
MATH 457	Discrete Dynamical Systems
MATH 458	Introduction to Mathematical Cryptography
MATH 461	Introduction to Mathematical Methods of Statistics I
MATH 462	Introduction to Mathematical Methods of Statistics II
MATH 463	Mathematical Methods of Regression Analysis and Analysis of Variance
MATH 391	Fundamentals of Abstract Algebra I
MATH 392	Fundamentals of Abstract Algebra II
MATH 393	Fundamentals of Abstract Algebra III
MATH 394	Geometries from an Advanced Viewpoint I
MATH 395	Geometries from an Advanced Viewpoint II
MATH 413	Introduction to Analysis I
MATH 414	Introduction to Analysis II
MATH 415	Introduction to Analysis III
MATH 431	Introduction to Topology
MATH 432	Introduction to Topology
MATH 433	Introduction to Differential Geometry
MATH 441	Linear Algebra
MATH 444	Introduction to Abstract Algebra I
MATH 445	Introduction to Abstract Algebra II
MATH 446	Introduction to Abstract Algebra III
MATH 467	Stochastic Processes
Total Credits	40

1 For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

2 Select courses in consultation with advisor. It is important to get approval in advance; the four elective courses cannot be chosen arbitrarily. In some cases, upper-division courses can be substituted for the lower-division courses listed as requirements for this degree.

Bachelor of Science: Design-Your-Own

MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
MATH 315	Elementary Analysis [1]	4
MATH 341–342	Elementary Linear Algebra	8
Select four of the following: [2]		16
MATH 343	Statistical Models and Methods	
MATH 351	Elementary Numerical Analysis I	
MATH 352	Elementary Numerical Analysis II	
MATH 411	Functions of a Complex Variable I	
MATH 412	Functions of a Complex Variable II	
MATH 420	Ordinary Differential Equations	
MATH 421	Partial Differential Equations: Fourier Analysis I	
MATH 422	Partial Differential Equations: Fourier Analysis II	
MATH 456	Networks and Combinatorics	
MATH 457	Discrete Dynamical Systems	
MATH 458	Introduction to Mathematical Cryptography	
MATH 461	Introduction to Mathematical Methods of Statistics I	
MATH 462	Introduction to Mathematical Methods of Statistics II	
MATH 463	Mathematical Methods of Regression Analysis and Analysis of Variance	
MATH 391	Fundamentals of Abstract Algebra I	
MATH 392	Fundamentals of Abstract Algebra II	
MATH 393	Fundamentals of Abstract Algebra III	
MATH 394	Geometries from an Advanced Viewpoint I	
MATH 395	Geometries from an Advanced Viewpoint II	
MATH 413	Introduction to Analysis I	
MATH 414	Introduction to Analysis II	
MATH 415	Introduction to Analysis III	
MATH 431	Introduction to Topology	
MATH 432	Introduction to Topology	
MATH 433	Introduction to Differential Geometry	
MATH 441	Linear Algebra	
MATH 444	Introduction to Abstract Algebra I	
MATH 445	Introduction to Abstract Algebra II	
MATH 446	Introduction to Abstract Algebra III	
MATH 467	Stochastic Processes	
Total Credits		40

1 For students who have completed Calculus with Theory I-III (MATH 261–263) with a grade of mid-C or better, the department will waive the requirement for Elementary Analysis (MATH 315).

2 Select courses in consultation with advisor. It is important to get approval in advance; the four elective courses cannot be chosen arbitrarily. In some cases, upper-division courses can be substituted for the lower-division courses listed as requirements for this degree.

Students are encouraged to explore the design-your-own option with an advisor. For example, physics majors typically fulfill the applied option. But physics students interested in the modern theory of elementary particles should construct an individualized program that includes abstract algebra and group theory. Another example: economics majors typically take statistics and other courses in the applied option. But students who plan to do graduate study in economics should consider the analysis sequence (Introduction to Analysis I-III (MATH 413–415)) and construct an individualized program that contains it.

Mathematics and Computer Science

The Department of Mathematics and the Department of Computer and Information Science jointly offer an undergraduate major in mathematics and computer science, leading to a bachelor of arts or a bachelor of

science degree. This program is described in the **Mathematics and Computer Science** section of this catalog.

Recommended Mathematics Courses for Other Areas

Students with an undergraduate mathematics degree often change fields when enrolling in graduate school. Common choices for a graduate career include computer science, economics, engineering, law, medicine, and physics. It is not unusual for a mathematics major to complete a second major as well. The following mathematics courses are recommended for students interested in other areas:

Actuarial Science		
MATH 351–352	Elementary Numerical Analysis I-II	8
MATH 461–462	Introduction to Mathematical Methods of Statistics I-II	8
MATH 463	Mathematical Methods of Regression Analysis and Analysis of Variance [1]	4
Biological Sciences		
MATH 461–462	Introduction to Mathematical Methods of Statistics I-II	8
Computer and Information Science		
MATH 231–233	Elements of Discrete Mathematics I-III	12
MATH 351–352	Elementary Numerical Analysis I-II	8
or MATH 461–462	Introduction to Mathematical Methods of Statistics I-II	
MATH 456	Networks and Combinatorics	4
Economics, Business, and Social Science		
MATH 461–462	Introduction to Mathematical Methods of Statistics I-II [2]	8
Physical Sciences and Engineering		
MATH 351–352	Elementary Numerical Analysis I-II	8
MATH 411–412	Functions of a Complex Variable I-II	8
MATH 420	Ordinary Differential Equations	4
MATH 421–422	Partial Differential Equations: Fourier Analysis I-II	8

1. Courses in computer science, accounting, and economics are also recommended. It is possible to take the first few actuarial examinations (on calculus, statistics, and numerical analysis) as an undergraduate student.
2. Students who want to take upper-division mathematics courses should take Calculus I-II (MATH 251–252) in place of Calculus for Business and Social Science I-II (MATH 241–242).

Honors Program

Students preparing to graduate with honors in mathematics should notify the department's honors advisor no later than the first term of their senior year.

They must complete two of the following four sets of courses with at least a mid-B average (3.00 grade point average):

Select two of the following:		8
MATH 413–414	Introduction to Analysis I-II	
MATH 431–432	Introduction to Topology	
MATH 444–445	Introduction to Abstract Algebra I-II	
MATH 461 & MATH 467	Introduction to Mathematical Methods of Statistics I and Stochastic Processes	

They must also write a thesis covering advanced topics assigned by their advisor. The degree with departmental honors is awarded to students whose work is judged truly exceptional.

Minor Requirements

To earn a minor in mathematics, a student must complete at least 30 credits in mathematics at the 200 level or higher, with at least 15 upper-division mathematics credits; Statistical Methods I (MATH 425) cannot be used toward the upper-division requirement. A minimum of 15 credits must be taken at the University of Oregon.

Only one D grade (D+ or D or D–) may be counted toward fulfilling the upper-division requirement. All upper-division courses must be taken for letter grades. The flexibility of the mathematics minor program allows each student, in consultation with a mathematics advisor, to tailor the program to his or her needs.

The minor is intended for any student, regardless of major, with a strong interest in mathematics. While students in such closely allied fields as computer and information science or physics often complete double majors, students with more distantly related majors such as psychology or history may find the minor useful.

Preparation for Kindergarten through Secondary School Teaching Careers

The College of Education offers a fifth-year program for middle-secondary licensure in mathematics and for elementary teaching. For more information, see the **College of Education** section of this catalog.

- **Master of Arts**
- **Master of Science**
- **Master of Arts: PrePhD**
- **Master of Science: PrePhD**
- **Doctor of Philosophy**

Graduate Studies

The university offers graduate study in mathematics leading to the master of arts (MA), master of science (MS), and doctor of philosophy (PhD) degrees.

Master's degree programs are available to suit the needs of students with various objectives. There are programs for students who intend to enter a doctoral program and for those who plan to conclude their formal study of pure or applied mathematics at the master's level.

Admission depends on the student's academic record—both overall academic quality and adequate mathematical background for the applicant's proposed degree program. Application forms for admission to the Graduate School may be obtained by writing to the head of the Department of Mathematics. Prospective applicants should note the

general university requirements for graduate admission that appear in the **Graduate School** section of this catalog.

Transcripts from all undergraduate and graduate institutions attended and copies of Graduate Record Examinations (GRE) scores in the verbal, quantitative, and mathematics tests should be submitted to the department.

In addition to general Graduate School requirements, the specific graduate program courses and conditions listed below must be fulfilled. More details can be found in the Department of Mathematics *Graduate Student Handbook*, available in the department office. All mathematics courses applied to degree requirements, including associated reading courses, must be taken for letter grades. A final written or oral examination or both is required for master's degrees except under the pre-PhD option outlined below. This examination is waived under circumstances outlined in the departmental *Graduate Student Handbook*.

Master's Degree Programs

Master of Arts: Pre-PhD Requirements

Two 600-level mathematics sequences [1]	24-45
Other 600-level courses [1, 2]	12-15
Total Credits	45

1. Students must complete two 600-level sequences acceptable for the qualifying examinations in the PhD program. In addition, they must complete one other 600-level sequence or a combination of three terms of 600-level courses approved by the master's degree subcommittee of the graduate affairs committee.
2. As many as 15 credits from graduate-level courses outside mathematics may be used toward the degree.

Master of Science: Pre-PhD Requirements

Two 600-level mathematics sequences [1]	24-45
Other 600-level courses [1, 2]	12-15
Total Credits	45

1. Students must complete two 600-level sequences acceptable for the qualifying examinations in the PhD program. In addition, they must complete one other 600-level sequence or a combination of three terms of 600-level courses approved by the master's degree subcommittee of the graduate affairs committee.
2. As many as 15 credits from graduate-level courses outside mathematics may be used toward the degree.

Master of Arts Degree Requirements

Option 1

One 600-level sequence [1]		12-15
Select two of the following:		24
MATH 513–515	Introduction to Analysis I-III	
MATH 531–532 & MATH 533	Introduction to Topology and Introduction to Differential Geometry	
MATH 544–546	Introduction to Abstract Algebra I-III	

Option 2

Two 600-level sequences [1]		24-30
Select one of the following:		12
MATH 513–515	Introduction to Analysis I-III	
MATH 531–532 & MATH 533	Introduction to Topology and Introduction to Differential Geometry	
MATH 544–546	Introduction to Abstract Algebra I-III	

1. Excluding Reading and Conference: [Topic] (MATH 605)

Of the required 45 credits, 15 may be in graduate-level courses other than mathematics. Students should also have taken a three-term upper-division or graduate sequence in statistics, numerical analysis, computing, or other applied mathematics.

Master of Science Degree Requirements

Option 1

One 600-level sequence [1]		12-15
Select two of the following:		24
MATH 513–515	Introduction to Analysis I-III	
MATH 531–532 & MATH 533	Introduction to Topology and Introduction to Differential Geometry	
MATH 544–546	Introduction to Abstract Algebra I-III	

Option 2

Two 600-level sequences [1]		24-30
Select one of the following:		12
MATH 513–515	Introduction to Analysis I-III	
MATH 531–532 & MATH 533	Introduction to Topology and Introduction to Differential Geometry	
MATH 544–546	Introduction to Abstract Algebra I-III	

1. Excluding Reading and Conference: [Topic] (MATH 605)

Of the required 45 credits, 15 may be in graduate-level courses other than mathematics. Students should also have taken a three-term upper-division or graduate sequence in statistics, numerical analysis, computing, or other applied mathematics.

Doctor of Philosophy

The PhD is a degree of distinction not to be conferred in routine fashion after completion of a specific number of courses or after attendance in Graduate School for a given number of years.

The department offers programs leading to the PhD degree in the areas of algebra, analysis, applied mathematics, combinatorics, geometry, mathematical physics, numerical analysis, probability, statistics, and topology. Advanced graduate courses in these areas are typically

offered in Seminar: [Topic] (MATH 607). Each student, upon entering the graduate degree program in mathematics, reviews previous studies and objectives with the graduate advising committee. Based on this consultation, conditional admission to the master's degree program or the pre-PhD program is granted. A student in the pre-PhD program may also be a candidate for the master's degree.

Pre-PhD Program

To be admitted to the pre-PhD program, an entering graduate student must have completed a course of study equivalent to the graduate preparatory bachelor's degree program described above. Other students are placed in the master's degree program and may apply for admission to the pre-PhD program following a year of graduate study. Students in the pre-PhD program must take the qualifying examination at the beginning of their second year during the week before classes begin fall term. It consists of examinations on two basic 600-level graduate courses, one each from two of the following three categories:

1. algebra
2. analysis
3. numerical analysis, probability, statistics, topology, or geometry

PhD Program

Admission to the PhD program is based on the following criteria:

- satisfactory performance on the qualifying examination
- completion of three courses at a level commensurate with study toward a PhD
- satisfactory performance in seminars or other courses taken as a part of the pre-PhD or PhD program.

Students who are not admitted to the PhD program because of unsatisfactory performance on the fall-term qualifying examination may retake the examination at the beginning of winter term.

A student in the PhD program is advanced to candidacy after passing a language examination and the comprehensive examination. To complete the requirements for the PhD, candidates must submit a dissertation, have it read and approved by a dissertation committee, and defend it orally in a formal public meeting.

Language Requirement

The department expects PhD candidates to be able to read mathematical material in a second language selected from French, German, and Russian. Other languages are acceptable in certain fields. Language requirements may be fulfilled by any of the following:

1. passing a departmentally administered examination
2. satisfactorily completing a second-year college-level language course
3. passing an Educational Testing Service (ETS) examination

Comprehensive Examination

This oral examination emphasizes the basic material in the student's general area of interest. A student is expected to take this examination during the first three years in the combined pre-PhD and PhD programs. To be eligible to take this examination, a student must have completed the language examination and nearly all the course work needed for the PhD.

Dissertation

PhD candidates in mathematics must submit a dissertation containing substantial original work in mathematics. Requirements for final defense of the thesis are those of the Graduate School.

Courses

MATH 070. Elementary Algebra. 4 Credits.
Basics of algebra, including arithmetic of signed numbers, order of operations, arithmetic of polynomials, linear equations, word problems, factoring, graphing lines, exponents, radicals. Credit for enrollment (eligibility) but not for graduation; satisfies no university or college requirement. Additional fee.

MATH 095. Intermediate Algebra. 4 Credits.
Topics include problem solving, linear equations, systems of equations, polynomials and factoring techniques, rational expressions, radicals and exponents, quadratic equations. Credit for enrollment (eligibility) but not for graduation; satisfies no university or college requirement. Additional fee.
Prereq: MATH 70 or satisfactory placement test score.

MATH 105. University Mathematics I. 4 Credits.
Topics include logic, sets and counting, probability, and statistics. Instructors may include historical context of selected topics and applications to finance and biology.
Prereq: MATH 95 or satisfactory placement test score.

MATH 106. University Mathematics II. 4 Credits.
Topics include mathematics of finance, applied geometry, exponential growth and decay, and a nontechnical introduction to the concepts of calculus.
Prereq: MATH 95 or satisfactory placement test score.

MATH 107. University Mathematics III. 4 Credits.
Topics chosen from modular arithmetic and coding, tilings and symmetry, voting methods, apportionment, fair division, introductory graph theory, or scheduling.
Prereq: MATH 95 or satisfactory placement test score.

MATH 111. College Algebra. 4 Credits.
Algebra needed for calculus including graph sketching, algebra of functions, polynomial functions, rational functions, exponential and logarithmic functions, linear and nonlinear functions.
Prereq: MATH 95 or satisfactory placement test score.

MATH 112. Elementary Functions. 4 Credits.
Exponential, logarithmic, and trigonometric functions. Intended as preparation for MATH 251.
Prereq: Satisfactory placement test score.

MATH 199. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

MATH 211. Fundamentals of Elementary Mathematics I. 4 Credits.
Structure of the number system, logical thinking, topics in geometry, simple functions, and basic statistics and probability. Calculators, concrete materials, and problem solving are used when appropriate. Covers the mathematics needed to teach grades K–8. Sequence.
Prereq: MATH 111 or satisfactory placement test score.

MATH 212. Fundamentals of Elementary Mathematics II. 4 Credits.
Structure of the number system, logical thinking, topics in geometry, simple functions, and basic statistics and probability. Calculators, concrete materials, and problem solving are used when appropriate. Covers the mathematics needed to teach grades K–8. Sequence.
Prereq: MATH 211, C- or better.

MATH 213. Fundamentals of Elementary Mathematics III. 4 Credits.
Structure of the number system, logical thinking, topics in geometry, simple functions, and basic statistics and probability. Calculators, concrete materials, and problem solving are used when appropriate. Covers the mathematics needed to teach grades K–8. Sequence.
Prereq: MATH 212, C- or better.

MATH 231. Elements of Discrete Mathematics I. 4 Credits.
Sets, mathematical logic, induction, sequences, and functions. Sequence.
Prereq: MATH 112 or satisfactory placement test score.

MATH 232. Elements of Discrete Mathematics II. 4 Credits.
Relations, theory of graphs and trees with applications, permutations and combinations.
Prereq: MATH 231.

MATH 233. Elements of Discrete Mathematics III. 4 Credits.
Discrete probability, Boolean algebra, elementary theory of groups and rings with applications.
Prereq: MATH 232.

MATH 241. Calculus for Business and Social Science I. 4 Credits.
Introduction to topics in differential and integral calculus including some aspects of the calculus of several variables. Sequence. Students cannot receive credit for both MATH 241 and 251.
Prereq: MATH 111 or satisfactory placement test score; a programmable calculator capable of displaying function graphs.

MATH 242. Calculus for Business and Social Science II. 4 Credits.
Introduction to topics in differential and integral calculus including some aspects of the calculus of several variables. Students cannot receive credit for both MATH 242 and 252.
Prereq: MATH 241.

MATH 243. Introduction to Methods of Probability and Statistics. 4 Credits.
Discrete and continuous probability, data description and analysis, sampling distributions, emphasizes confidence intervals and hypothesis testing. Students cannot receive credit for both MATH 243 and 425.
Prereq: MATH 95 or satisfactory placement test score; MATH 111 recommended; a programmable calculator capable of displaying function graphs.

MATH 246. Calculus for the Biological Sciences I. 4 Credits.
For students in biological science and related fields. Emphasizes modeling and applications to biology. Differential calculus and applications. Sequence. Students cannot receive credit for more than one of MATH 241, 246, 251.
Prereq: MATH 112 or satisfactory placement test score.

MATH 247. Calculus for the Biological Sciences II. 4 Credits.
For students in biological science and related fields. Emphasizes modeling and applications to biology. Integral calculus and applications. Students cannot receive credit for more than one of MATH 242, 247, 252.
Prereq: MATH 246.

MATH 251. Calculus I. 4 Credits.
Standard sequence for students of physical and social sciences and of mathematics. Differential calculus and applications. Sequence. Students cannot receive credit for more than one of MATH 241, 246, 251.
Prereq: MATH 112 or satisfactory placement test score.

MATH 252. Calculus II. 4 Credits.
Standard sequence for students of physical and social sciences and of mathematics. Integral calculus. Sequence. Students cannot receive credit for more than one of MATH 242, 247, 252.
Prereq: MATH 251.

MATH 253. Calculus III. 4 Credits.
Standard sequence for students of physical and social sciences and of mathematics. Introduction to improper integrals, infinite sequences and series, Taylor series, and differential equations. Sequence. Students cannot receive credit for more than one of MATH 253, 263.
Prereq: MATH 252.

MATH 256. Introduction to Differential Equations. 4 Credits.
Introduction to differential equations and applications. Linear algebra is introduced as needed.
Prereq: MATH 253.

MATH 261. Calculus with Theory I. 4 Credits.
Covers both applications of calculus and its theoretical background. Axiomatic treatment of the real numbers, limits, and the least upper bound property.

MATH 262. Calculus with Theory II. 4 Credits.
Covers both applications of calculus and its theoretical background. Differential and integral calculus.
Prereq: MATH 261.

MATH 263. Calculus with Theory III. 4 Credits.
Covers both applications of calculus and its theoretical background. Sequences and series, Taylor's theorem.
Prereq: MATH 262.

MATH 281. Several-Variable Calculus I. 4 Credits.
Introduction to calculus of functions of several variables including partial differentiation; gradient, divergence, and curl; line and surface integrals; Green's and Stokes's theorems. Linear algebra introduced as needed. Sequence.
Prereq: MATH 253.

MATH 282. Several-Variable Calculus II. 4 Credits.
Introduction to calculus of functions of several variables including partial differentiation; gradient, divergence, and curl; line and surface integrals; Green's and Stokes's theorems. Linear algebra introduced as needed.
Prereq: MATH 281.

MATH 307. Introduction to Proof. 4 Credits.
Proof is how mathematics establishes truth and communicates ideas. Introduces students to proof in the context of interesting mathematical problems.
Prereq: MATH 247 or 252 or 262.

MATH 315. Elementary Analysis. 4 Credits.
Rigorous treatment of certain topics introduced in calculus including continuity, differentiation and integration, power series, sequences and series, uniform convergence and continuity.
Prereq: MATH 253 or equivalent; one from MATH 232, 262, 307.

MATH 341. Elementary Linear Algebra. 4 Credits.
Vector and matrix algebra; n-dimensional vector spaces; systems of linear equations; linear independence and dimension; linear transformations; rank and nullity; determinants; eigenvalues; inner product spaces; theory of a single linear transformation. Sequence.
Prereq: MATH 252. MATH 253 is recommended.

MATH 342. Elementary Linear Algebra. 4 Credits.
Vector and matrix algebra; n-dimensional vector spaces; systems of linear equations; linear independence and dimension; linear transformations; rank and nullity; determinants; eigenvalues; inner product spaces; theory of a single linear transformation.
Prereq: MATH 341.

MATH 343. Statistical Models and Methods. 4 Credits.
Review of theory and applications of mathematical statistics including estimation and hypothesis testing.
Prereq: MATH 252.

MATH 346. Number Theory. 4 Credits.
Topics include congruences, Chinese remainder theorem, Gaussian reciprocity, basic properties of prime numbers.
Prereq: MATH 253 or equivalent; one from MATH 232, 262, 307.

MATH 351. Elementary Numerical Analysis I. 4 Credits.
Basic techniques of numerical analysis and their use on computers. Topics include root approximation, linear systems, interpolation, integration, and differential equations. Sequence.
Prereq: MATH 253 or equivalent; one from MATH 232, 262, 307.

MATH 352. Elementary Numerical Analysis II. 4 Credits.
Basic techniques of numerical analysis and their use on computers. Topics include root approximation, linear systems, interpolation, integration, and differential equations.
Prereq: MATH 351.

MATH 391. Fundamentals of Abstract Algebra I. 4 Credits.
Introduction to algebraic structures including groups, rings, fields, and polynomial rings. Sequence.
Prereq: MATH 341; one from MATH 232, 262, 307.

MATH 392. Fundamentals of Abstract Algebra II. 4 Credits.
Introduction to algebraic structures including groups, rings, fields, and polynomial rings.
Prereq: MATH 391.

MATH 393. Fundamentals of Abstract Algebra III. 4 Credits.
Introduction to algebraic structures including groups, rings, fields, and polynomial rings.
Prereq: MATH 392.

MATH 394. Geometries from an Advanced Viewpoint I. 4 Credits.
Topics in Euclidean geometry in two and three dimensions including constructions. Emphasizes investigations, proofs, and challenging problems. For prospective secondary and middle school teachers.
Prereq: MATH 253 or equivalent; one from MATH 232, 262, 307.

MATH 395. Geometries from an Advanced Viewpoint II. 4 Credits.
Analysis of problems in Euclidean geometry using coordinates, vectors, and the synthetic approach. Transformations in the plane and space and their groups. Introduction to non-Euclidean geometries. For prospective secondary teachers.
Prereq: grade of C- or better in MATH 394.

MATH 399. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

MATH 401. Research: [Topic]. 1-21 Credits.
Repeatable.

MATH 403. Thesis. 1-4 Credits.
Repeatable.

MATH 405. Reading and Conference: [Topic]. 1-4 Credits.
Repeatable.

MATH 407. Seminar: [Topic]. 1-4 Credits.
Repeatable.

MATH 410. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

MATH 411. Functions of a Complex Variable I. 4 Credits.
Complex numbers, linear fractional transformations, Cauchy-Riemann equations, Cauchy's theorem and applications, power series, residue theorem, harmonic functions, contour integration, conformal mapping, infinite products. Sequence.
Prereq: MATH 281; one from MATH 232, 262, 307.

MATH 412. Functions of a Complex Variable II. 4 Credits.
Complex numbers, linear fractional transformations, Cauchy-Riemann equations, Cauchy's theorem and applications, power series, residue theorem, harmonic functions, contour integration, conformal mapping, infinite products.
Prereq: MATH 411.

MATH 413. Introduction to Analysis I. 4 Credits.
Differentiation and integration on the real line and in a dimensional Euclidean space; normed linear spaces and metric spaces; vector field theory and differential forms. Sequence.
Prereq: MATH 282, 315.

MATH 414. Introduction to Analysis II. 4 Credits.
Differentiation and integration on the real line and in a dimensional Euclidean space; normed linear spaces and metric spaces; vector field theory and differential forms.
Prereq: MATH 413.

MATH 415. Introduction to Analysis III. 4 Credits.
Differentiation and integration on the real line and in a dimensional Euclidean space; normed linear spaces and metric spaces; vector field theory and differential forms. Sequence.
Prereq: MATH 414.

MATH 420. Ordinary Differential Equations. 4 Credits.
Ordinary differential equations. General and initial value problems. Explicit, numerical, graphical solutions; phase portraits. Existence, uniqueness, stability. Power series methods. Gradient flow; periodic solutions.
Prereq: MATH 263 or 315.

MATH 421. Partial Differential Equations: Fourier Analysis I. 4 Credits.
Introduction to PDEs; wave and heat equations. Classical Fourier series on the circle; applications of Fourier series. Generalized Fourier series, Bessel and Legendre series.
Prereq: MATH 281 and either MATH 256 or 420.

MATH 422. Partial Differential Equations: Fourier Analysis II. 4 Credits.
General theory of PDEs; the Fourier transform. Laplace and Poisson equations; Green's functions and application. Mean value theorem and max-min principle.
Prereq: MATH 421.

MATH 425. Statistical Methods I. 4 Credits.
Statistical methods for upper-division and graduate students anticipating research in nonmathematical disciplines. Presentation of data, sampling distributions, tests of significance, confidence intervals, linear regression, analysis of variance, correlation, statistical software. Sequence. Only nonmajors may receive upper-division credit. Students cannot receive credit for both MATH 243 and 425.
Prereq: MATH 111 or satisfactory placement test score.

MATH 431. Introduction to Topology. 4 Credits.
Elementary point-set topology with an introduction to combinatorial topology and homotopy. Sequence.
Prereq: MATH 315.

MATH 432. Introduction to Topology. 4 Credits.
Elementary point-set topology with an introduction to combinatorial topology and homotopy. Sequence.
Prereq: MATH 431.

MATH 433. Introduction to Differential Geometry. 4 Credits.
Plane and space curves, Frenet-Serret formula surfaces. Local differential geometry, Gauss-Bonnet formula, introduction to manifolds.
Prereq: MATH 282, 342; one from MATH 232, 262, 307.

MATH 441. Linear Algebra. 4 Credits.
Theory of vector spaces over arbitrary fields, theory of a single linear transformation, minimal polynomials, Jordan and rational canonical forms, quadratic forms, quotient spaces.
Prereq: MATH 342; one from MATH 232, 262, 307.

MATH 444. Introduction to Abstract Algebra I. 4 Credits.
Theory of groups, rings, and fields. Polynomial rings, unique factorization, and Galois theory. Sequence.
Prereq: MATH 342; one from MATH 232, 262, 307.

MATH 445. Introduction to Abstract Algebra II. 4 Credits.
Theory of groups, rings, and fields. Polynomial rings, unique factorization, and Galois theory.
Prereq: MATH 444.

MATH 446. Introduction to Abstract Algebra III. 4 Credits.
Theory of groups, rings, and fields. Polynomial rings, unique factorization, and Galois theory.
Prereq: MATH 445.

MATH 456. Networks and Combinatorics. 4 Credits.
Fundamentals of modern combinatorics; graph theory; networks; trees; enumeration, generating functions, recursion, inclusion and exclusion; ordered sets, lattices, Boolean algebras.
Prereq: MATH 231 or 346; one from MATH 232, 262, 307.

MATH 457. Discrete Dynamical Systems. 4 Credits.
Linear and nonlinear first-order dynamical systems; equilibrium, cobwebs, Newton's method. Bifurcation and chaos. Introduction to higher-order systems. Applications to economics, genetics, ecology.
Prereq: MATH 256; one from MATH 232, 262, 307.

MATH 458. Introduction to Mathematical Cryptography. 4 Credits.
Mathematical theory of public key cryptography. Finite field arithmetic, RSA and Diffie-Hellman algorithms, elliptic curves, generation of primes, factorization techniques. Offered alternate years.
Prereq: MATH 341.

MATH 461. Introduction to Mathematical Methods of Statistics I. 4 Credits.
Discrete and continuous probability models; useful distributions; applications of moment-generating functions; sample theory with applications to tests of hypotheses, point and confidence interval estimates. Sequence.
Prereq: MATH 253 or 263; one from MATH 232, 262, 307.

MATH 462. Introduction to Mathematical Methods of Statistics II. 4 Credits.
Discrete and continuous probability models; useful distributions; applications of moment-generating functions; sample theory with applications to tests of hypotheses, point and confidence interval estimates.
Prereq: MATH 461.

MATH 463. Mathematical Methods of Regression Analysis and Analysis of Variance. 4 Credits.
Multinomial distribution and chi-square tests of fit, simple and multiple linear regression, analysis of variance and covariance, methods of model selection and evaluation, use of statistical software.
Prereq: MATH 342, MATH 462.

MATH 467. Stochastic Processes. 4 Credits.
Basics of stochastic processes including Markov chains, martingales, Poisson processes, Brownian motion and their applications.
Prereq: MATH 341, MATH 461.

MATH 503. Thesis. 1-12 Credits.
Repeatable.

MATH 507. Seminar: [Topic]. 1-4 Credits.
Repeatable.

MATH 510. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

MATH 511. Functions of a Complex Variable I. 4 Credits.
Complex numbers, linear fractional transformations, Cauchy-Riemann equations, Cauchy's theorem and applications, power series, residue theorem, harmonic functions, contour integration, conformal mapping, infinite products. Sequence.

MATH 512. Functions of a Complex Variable II. 4 Credits.
Complex numbers, linear fractional transformations, Cauchy-Riemann equations, Cauchy's theorem and applications, power series, residue theorem, harmonic functions, contour integration, conformal mapping, infinite products.
Prereq: MATH 411/511.

MATH 513. Introduction to Analysis I. 4 Credits.
Differentiation and integration on the real line and in a dimensional Euclidean space; normed linear spaces and metric spaces; vector field theory and differential forms. Sequence.

MATH 514. Introduction to Analysis II. 4 Credits.
Differentiation and integration on the real line and in a dimensional Euclidean space; normed linear spaces and metric spaces; vector field theory and differential forms. Sequence.
Prereq: MATH 413/513.

MATH 515. Introduction to Analysis III. 4 Credits.
Differentiation and integration on the real line and in a dimensional Euclidean space; normed linear spaces and metric spaces; vector field theory and differential forms. Sequence.
Prereq: MATH 414/514.

MATH 520. Ordinary Differential Equations. 4 Credits.
Ordinary differential equations. General and initial value problems. Explicit, numerical, graphical solutions; phase portraits. Existence, uniqueness, stability. Power series methods. Gradient flow; periodic solutions.

MATH 521. Partial Differential Equations: Fourier Analysis I. 4 Credits.
Introduction to PDEs; wave and heat equations. Classical Fourier series on the circle; applications of Fourier series. Generalized Fourier series, Bessel and Legendre series.
Prereq: MATH 420/520.

MATH 522. Partial Differential Equations: Fourier Analysis II. 4 Credits.
General theory of PDEs; the Fourier transform. Laplace and Poisson equations; Green's functions and application. Mean value theorem and max-min principle.
Prereq: MATH 421/521.

MATH 525. Statistical Methods I. 4 Credits.
Statistical methods for upper-division and graduate students anticipating research in nonmathematical disciplines. Presentation of data, sampling distributions, tests of significance, confidence intervals, linear regression, analysis of variance, correlation, statistical software. Sequence. Only nonmajors may receive graduate credit.

MATH 531. Introduction to Topology. 4 Credits.
Elementary point-set topology with an introduction to combinatorial topology and homotopy. Sequence.

MATH 532. Introduction to Topology. 4 Credits.
Elementary point-set topology with an introduction to combinatorial topology and homotopy. Sequence.
Prereq: MATH 431/531.

MATH 533. Introduction to Differential Geometry. 4 Credits.
Plane and space curves, Frenet-Serret formula surfaces. Local differential geometry, Gauss-Bonnet formula, introduction to manifolds.

MATH 541. Linear Algebra. 4 Credits.
Theory of vector spaces over arbitrary fields, theory of a single linear transformation, minimal polynomials, Jordan and rational canonical forms, quadratic forms, quotient spaces.

MATH 544. Introduction to Abstract Algebra I. 4 Credits.
Theory of groups, rings, and fields. Polynomial rings, unique factorization, and Galois theory. Sequence.

MATH 545. Introduction to Abstract Algebra II. 4 Credits.
Theory of groups, rings, and fields. Polynomial rings, unique factorization, and Galois theory.
Prereq: MATH 444/544.

MATH 546. Introduction to Abstract Algebra III. 4 Credits.
Theory of groups, rings, and fields. Polynomial rings, unique factorization, and Galois theory.
Prereq: MATH 445/545.

MATH 556. Networks and Combinatorics. 4 Credits.
Fundamentals of modern combinatorics; graph theory; networks; trees; enumeration, generating functions, recursion, inclusion and exclusion; ordered sets, lattices, Boolean algebras.

MATH 557. Discrete Dynamical Systems. 4 Credits.
Linear and nonlinear first-order dynamical systems; equilibrium, cobwebs, Newton's method. Bifurcation and chaos. Introduction to higher-order systems. Applications to economics, genetics, ecology.

MATH 561. Introduction to Mathematical Methods of Statistics I. 4 Credits.
Discrete and continuous probability models; useful distributions; applications of moment-generating functions; sample theory with applications to tests of hypotheses, point and confidence interval estimates. Sequence.

MATH 562. Introduction to Mathematical Methods of Statistics II. 4 Credits.
Discrete and continuous probability models; useful distributions; applications of moment-generating functions; sample theory with applications to tests of hypotheses, point and confidence interval estimates.
Prereq: MATH 461/561.

MATH 563. Mathematical Methods of Regression Analysis and Analysis of Variance. 4 Credits.
Multinomial distribution and chi-square tests of fit, simple and multiple linear regression, analysis of variance and covariance, methods of model selection and evaluation, use of statistical software.
Prereq: MATH 462/562.

MATH 567. Stochastic Processes. 4 Credits.
Basics of stochastic processes including Markov chains, martingales, Poisson processes, Brownian motion and their applications.
Prereq: MATH 561.

MATH 601. Research: [Topic]. 1-9 Credits.
Repeatable.

MATH 602. Supervised College Teaching. 1-16 Credits.
Repeatable.

MATH 603. Dissertation. 1-16 Credits.
Repeatable.

MATH 605. Reading and Conference: [Topic]. 1-5 Credits.
Repeatable.

MATH 607. Seminar: [Topic]. 1-5 Credits.
Repeatable. Topics include Advanced Topics in Geometry, Ring Theory, Teaching Mathematics.

MATH 616. Real Analysis. 4-5 Credits.
Measure and integration theory, differentiation, and functional analysis with point-set topology as needed. Sequence.

MATH 617. Real Analysis. 4-5 Credits.
Measure and integration theory, differentiation, and functional analysis with point-set topology as needed. Sequence.
Prereq: MATH 616.

MATH 618. Real Analysis. 4-5 Credits.
Measure and integration theory, differentiation, and functional analysis with point-set topology as needed. Sequence.
Prereq: MATH 617.

MATH 619. Complex Analysis. 4-5 Credits.
The theory of Cauchy, power series, contour integration, entire functions, and related topics.

MATH 634. Algebraic Topology. 4-5 Credits.
Development of homotopy, homology, and cohomology with point-set topology as needed. Sequence.

MATH 635. Algebraic Topology. 4-5 Credits.
Development of homotopy, homology, and cohomology with point-set topology as needed. Sequence.
Prereq: MATH 634.

MATH 636. Algebraic Topology. 4-5 Credits.
Development of homotopy, homology, and cohomology with point-set topology as needed. Sequence.
Prereq: MATH 635.

MATH 637. Differential Geometry. 4-5 Credits.
Topics include curvature and torsion, Serret-Frenet formulas, theory of surfaces, differentiable manifolds, tensors, forms and integration. Sequence.

MATH 638. Differential Geometry. 4-5 Credits.
Topics include curvature and torsion, Serret-Frenet formulas, theory of surfaces, differentiable manifolds, tensors, forms and integration. Sequence.
Prereq: MATH 637.

MATH 639. Differential Geometry. 4-5 Credits.
Topics include curvature and torsion, Serret-Frenet formulas, theory of surfaces, differentiable manifolds, tensors, forms and integration. Sequence.

MATH 647. Abstract Algebra. 4-5 Credits.
Group theory, fields, Galois theory, algebraic numbers, matrices, rings, algebras. Sequence.

MATH 648. Abstract Algebra. 4-5 Credits.
Group theory, fields, Galois theory, algebraic numbers, matrices, rings, algebras. Sequence.
Prereq: MATH 647.

MATH 649. Abstract Algebra. 4-5 Credits.
Group theory, fields, Galois theory, algebraic numbers, matrices, rings, algebras. Sequence.
Prereq: MATH 648.

MATH 672. Theory of Probability. 4-5 Credits.
Measure and integration, probability spaces, laws of large numbers, central-limit theory, conditioning, martingales, random walks.
Prereq: MATH 671.

MATH 673. Theory of Probability. 4-5 Credits.
Measure and integration, probability spaces, laws of large numbers, central-limit theory, conditioning, martingales, random walks.
Prereq: MATH 672.

MATH 681. Advanced Algebra: [Topic]. 4-5 Credits.
Repeatable. Topics selected from theory of finite groups, representations of finite groups, Lie groups, Lie algebras, algebraic groups, ring theory, algebraic number theory.

MATH 682. Advanced Algebra: [Topic]. 4-5 Credits.
Repeatable. Topics selected from theory of finite groups, representations of finite groups, Lie groups, Lie algebras, algebraic groups, ring theory, algebraic number theory.

MATH 683. Advanced Algebra: [Topic]. 4-5 Credits.
Repeatable. Topics selected from theory of finite groups, representations of finite groups, Lie groups, Lie algebras, algebraic groups, ring theory, algebraic number theory.

MATH 684. Advanced Analysis: [Topic]. 4-5 Credits.
Repeatable. Topics selected from Banach algebras, operator theory, functional analysis, harmonic analysis on topological groups, theory of distributions.

MATH 685. Advanced Analysis: [Topic]. 4-5 Credits.
Repeatable. Topics selected from Banach algebras, operator theory, functional analysis, harmonic analysis on topological groups, theory of distributions.

MATH 686. Advanced Analysis: [Topic]. 4-5 Credits.
Repeatable. Topics selected from Banach algebras, operator theory, functional analysis, harmonic analysis on topological groups, theory of distributions.

MATH 690. Advanced Geometry and Topology: [Topic]. 4-5 Credits.
Repeatable. Topics selected from classical and local differential geometry; symmetric spaces; low-dimensional topology; differential topology; global analysis; homology, cohomology, and homotopy; differential analysis and singularity theory; knot theory.

MATH 691. Advanced Geometry and Topology: [Topic]. 4-5 Credits.
Repeatable. Topics selected from classical and local differential geometry; symmetric spaces; low-dimensional topology; differential topology; global analysis; homology, cohomology, and homotopy; differential analysis and singularity theory; knot theory.

MATH 692. Advanced Geometry and Topology: [Topic]. 4-5 Credits.
Repeatable. Topics selected from classical and local differential geometry; symmetric spaces; low-dimensional topology; differential topology; global analysis; homology, cohomology, and homotopy; differential analysis and singularity theory; knot theory.