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 University 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 and Dorothy Anderson, is awarded to one or more graduate students with outstanding teaching records
- The Jack and Peggy Borsting Award for Scholastic Achievement in Graduate Mathematics is awarded to a finishing graduate student based on outstanding academic work
- The Charles W. and Elizabeth H. Curtis Scholarship is awarded to a sophomore or junior to continue their studies in mathematics
- The DeCou Prize, which honors a former long-time department head, E. E. DeCou, and his son, E. J. DeCou, is awarded to an outstanding graduating senior
- 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 Marion Walter Future Teachers Award, which honors Professor Emerita Marion Walter, is awarded to an outstanding senior graduating with a precollege-teaching option
- The Civin Graduate Award, endowed by the family of Paul and Harriet Civin, is awarded for the purpose of attracting and retaining promising graduate students and encouraging underrepresented students in mathematics
- The Harrison Memory Award, endowed by Ann Hill Harrison in honor of former mathematics professor David K. Harrison, is awarded to outstanding students in mathematics

Faculty

Nicolas Addington, associate professor (algebraic geometry). BS, 2004, Washington (Seattle); PhD, 2009, Wisconsin, Madison. (2015)

Shabnam Akhtari, associate 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)

Tricia H. Bevans, senior instructor. BA, 1995, MS, 1998, Oregon. (2013)

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

Ellen E. Eischen, associate professor (number theory). BA, 2003, Princeton; PhD, 2009, Michigan, Ann Arbor. (2015)

Ben Elias, associate professor (representation theory, categorification). BA, 2005, Princeton; PhD, 2011, Columbia. (2014)

Cassandra Fisher, senior instructor. BS, 2010, George Fox; MS, 2012, Texas Tech. (2012)

Laura Fredrickson (geometric analysis and complex geometry). BS, 2010, California, Irvine; PhD, 2016, Texas, Austin. (2019)

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

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

Kristen Henderson, instructor. BA, 2001, California, Berkeley; MS, 2003, Nevada, Reno. (2015)

Patricia Hersh, professor (combinatorics). BA, 1995, Harvard; PhD, 1999, Massachusetts Institute of Technology. (2019)

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

Elina Kleshcheva, instructor, BS, 1987, MS, 1988, Moscow State. (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)

Robert Lipshitz, professor (differential topology). AB, 2002, Princeton; PhD, 2006, Stanford. (2015)

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)

Luca Mazzucato, assistant professor (computational neuroscience). Laurea, 2001, Padua; PhD, 2005, ISAS, Trieste. (2017)

Eric Merchant, instructor. BA, 1996, MS, 2000, PhD, 2005, Oregon. (2010)

James Murray, assistant professor (computational neuroscience). BS, Montana State; PhD, Johns Hopkins, 2013. (2020)

Maria Nemirovskaya, instructor. MS, 1996, Brigham Young; PhD, 2002, Massachusetts Institute of Technology. (2017)

Tammy Nezol, senior instructor. BA, 2004, BS, 2006, MS, 2008, Oregon. (2008)

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

Liliana Pazdan-Siudeja, instructor. MS, 2010, Illinois, Urbana-Champaign. (2013)

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 II; assistant department head. BS, 2003, MS, 2005, Oregon. (2005)

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

Peter Ralph, associate professor (populations and evolution with genomic data). AB, 2002, PhD, 2009, California, Berkeley. (2016)

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

Bijan Shahir, instructor. MS, 1979, PhD, 1987, Oregon; MSEE, 1999, Washington (Seattle). (2011)

Yefeng Shen, assistant professor (algebraic geometry). BS, 2006, Zhejiang University; MS, 2009, Peking University; PhD, 2013, University of Michigan. (2017)

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)

David C Steinberg, senior instructor. BSc, 2004, Alberta; MA, 2006, State University of New York, Binghamton; PhD, 2012, British Columbia. (2013)

Jennifer Thorenson, senior instructor. BS, 2003, North Dakota State; MS, 2005, PhD, 2013, Montana State. (2013)

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)

Kai Shyang Wang, instructor. MA, 1985, California, Berkeley. (2009)

Micah Warren, associate 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, associate professor (combinatorics). BS, 2001, MS, 2002, Carleton; PhD, 2008, British Columbia. (2012)

Emeriti

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

Bruce A. Barnes, professor emeritus. BA, 1960, Dartmouth College; 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)

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

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

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)

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)

Brad S. Shelton, professor emeritus. BA, 1976, Arizona; MS, PhD, 1982, Washington (Seattle). (1985)

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)

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

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

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)

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

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

- **Bachelor of Arts: Standard Track**
- **Bachelor of Arts: Pure Mathematics**
- **Bachelor of Arts: Secondary Teaching**
- **Bachelor of Science: Standard Track**
- **Bachelor of Science: Pure Mathematics**
- **Bachelor of Science: Secondary Teaching**
- **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 whdether 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

2The department offers courses that satisfy the science group requirement:

Code	Title	Credits
MATH 105–107	University Mathematics I-III	12
MATH 211–213	Fundamentals of Elementary Mathematics I-III	12
MATH 231–232	Elements of Discrete Mathematics I-II	8
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:

Code	Title	Credits
MATH 307 and four of MATH 201, MATH 202, MATH 203, MATH 204, MATH 205, and MATH 206		12
MATH 231, MATH 232, and two of MATH 201, MATH 202, MATH 203, MATH 204, MATH 205, and MATH 206		12
MATH 261, MATH 262, and two of MATH 201, MATH 202, MATH 203, MATH 204, MATH 205, and MATH 206		12

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	• 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 two of the following		4
MATH 201	Algebra Math Lab	2
MATH 202	Geometry Math Lab	2
MATH 203	Analysis and Number Theory Math Lab	2
Second Year		
Select two of the following		4
MATH 204	Probability and Statistics Math Lab	2
MATH 205	Foundations Math Lab	2
MATH 206	Combinatorics Math Lab	2
Select one of the following		8
MATH 281–282	Several-Variable Calculus I-II	8
MATH 341–342	Elementary Linear Algebra	8
Select one of the following		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
Third Year		
Complete second year sequence as necessary		
CIS 122	Introduction to Programming and Problem Solving	4
Select one of the following Fundamentals sequences		8
MATH 316–317	Fundamentals of Analysis I-II	8
MATH 347–348	Fundamentals of Number Theory I-II	8
MATH 391–392	Fundamentals of Abstract Algebra I-II	8
One upper division mathematics course		4
Fourth Year		
Three upper-division mathematics courses		12
	Total Credits:	**64**

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.

Bachelor's 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 three options: the standard track, pure mathematics, or secondary teaching. In each option, most courses require calculus as a prerequisite, and in each option some of the courses require satisfying the bridge requirement.

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:

Code	Title	Credits
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 231–232	Elements of Discrete Mathematics I-II	8
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 320	Theory of 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 (and ideally during the penultimate year of study). There are two requirements for receiving departmental honors:

1. Complete all upper division mathematics courses with a net GPA of 3.7 or greater.
2. Write a thesis covering advanced topics as assigned by the honors advisor.

The degree with departmental honors is awarded to students whose work is judged truly exceptional.

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.

Four-Year Degree Plan

The degree plan shown is only a sample of how students may complete their degrees in four years. There are alternative ways. Students should consult their advisor to determine the best path for them.

To enroll with courses that have prerequisites, students must complete the prerequisite course with grades of C– or better or P. All upper-division mathematics courses must be taken for letter grades to count toward a mathematics major or minor, and only one D grade (D+ or D or D–) may be counted toward the upper-division requirements for the major or minor.

- **Standard Track**
- Pure Mathematics **(**p. 8**)**
- Secondary Teaching **(**p. 10**)**

Bachelor of Arts in Mathematics: Standard Track

Course	Title	Credits Milestones
First Year		
Fall		
MATH 203	Analysis and Number Theory Math Lab	2
MATH 251	Calculus I	4
WR 121	College Composition I	4
First term of first-year second-language sequence		5
	Credits	**15**
Winter		
MATH 252	Calculus II	4
WR 122	College Composition II	4
MATH 201	Algebra Math Lab	2
Second term of first-year second-language sequence		5
	Credits	**15**
Spring		
MATH 253	Calculus III	4
Third term of first-year second-language sequence		5
Social science group-satisfying course		4
Science group group-satisfying course		4
	Credits	**17**
Second Year		
Fall		
MATH 281	Several-Variable Calculus I	4
MATH 341	Elementary Linear Algebra	4
Arts and letters group-satisfying course		4
First term of second-year second-language sequence		4
	Credits	**16**
Winter		
MATH 282	Several-Variable Calculus II	4

MATH 342	Elementary Linear Algebra		4
Second term of second-year second-language sequence			4
Social science group-satisfying course			4
	Credits		**16**
Spring			
MATH 202	Geometry Math Lab		2
MATH 205	Foundations Math Lab		2
MATH 307	Introduction to Proof	Mathematics major bridge requirement completed	4
Third term of second-year second-language sequence		BA language requirement completed	4
Science group-satisfying course			4
	Credits		**16**
Third Year			
Fall			
MATH 316	Fundamentals of Analysis I		4
Arts and letters group satisfying course			4
Science group-satisfying course		Science group requirement completed	4
Upper-division Elective			4
	Credits		**16**
Winter			
MATH 317	Fundamentals of Analysis II	Mathematics major fundamentals requirement completed	4
Social science group satisfying course			4
Arts and letters group satisfying course			4
Upper-division elective			4
	Credits		**16**
Spring			
MATH 458	Introduction to Mathematical Cryptography		4
CIS 122	Introduction to Programming and Problem Solving	Mathematics major CIS requirement completed	4
Social science group satisfying course		Social science group requirement completed	4
Arts and letters group satisfying course		Arts and letters group requirement completed	4
	Credits		**16**
Fourth Year			
Fall			
MATH 461	Introduction to Mathematical Methods of Statistics I		4
Upper-division elective			4
Upper-division elective		Completed the multicultural requirement	4
	Credits		**12**
Winter			
MATH 462	Introduction to Mathematical Methods of Statistics II	Upper-division mathematics sequence completed	4
Upper-division elective			4
Upper-division elective		Need 26 upper-division credits beyond the mathematics major	4
	Credits		**12**
Spring			
MATH 397	History and Applications of Calculus	Mathematics major requirements completed	4
Upper-division elective			4
Elective			4
Elective		180 credits completed	4
	Credits		**16**
	Total Credits		**183**

Bachelor of Science in Mathematics: Standard Track

Course	Title	Credits	Milestones
First Year			
Fall			
MATH 251	Calculus I	BS mathematics requirement completed;	4
WR 121	College Composition I		4
Social science group-satisfying course			4

Science group-satisfying course			4
	Credits		**16**
Winter			
WR 122	College Composition II		4
Arts and letters group-satisfying course			4
MATH 201	Algebra Math Lab		2
MATH 206	Combinatorics Math Lab		2
MATH 252	Calculus II		4
	Credits		**16**
Spring			
MATH 253	Calculus III		4
Arts and letters group-satisfying course			4
Social science group-satisfying course			4
Elective			4
	Credits		**16**
Second Year			
Fall			
MATH 202	Geometry Math Lab		2
MATH 205	Foundations Math Lab		2
MATH 281	Several-Variable Calculus I		4
Arts and letters group-satisfying course			4
Science group-satisfying course			4
	Credits		**16**
Winter			
MATH 282	Several-Variable Calculus II		4
MATH 341	Elementary Linear Algebra		4
Elective			4
Social science group-satisfying course			4
	Credits		**16**
Spring			
MATH 307	Introduction to Proof	Mathematics major bridge requirement completed	4
MATH 342	Elementary Linear Algebra		4
Arts and letters group-satisfying course		Arts and letters group requirement completed	4
Science group-satisfying course			4
	Credits		**16**
Third Year			
Fall			
CIS 210	Computer Science I	Mathematics major CIS requirement completed	4
MATH 391	Fundamentals of Abstract Algebra I		4
Social science group-satisfying course		Social science group requirement completed	4
Upper-division Elective			4
	Credits		**16**
Winter			
MATH 392	Fundamentals of Abstract Algebra II	Mathematics major fundament requiremer completed	4
Upper-division elective			4
Elective			4
Elective			4
	Credits		**16**
Spring			
MATH 397	History and Applications of Calculus		4
Upper-division elective			4
Upper-division elective			4
Elective			4
	Credits		**16**
Fourth Year			
Fall			
MATH 444	Introduction to Abstract Algebra I		4
Upper-division elective			4
Elective		Completed multicultura requiremer	4
	Credits		**12**
Winter			
MATH 445	Introduction to Abstract Algebra II	Mathematics major upper-division sequence requiremer completed	4
Upper-division elective			4
Upper-division elective			4
	Credits		**12**
Spring			
MATH 458	Introduction to Mathematical Cryptography	Mathematics major completed	4
Elective			4
Elective		180 credits completed	4
	Credits		**12**
	Total Credits		**180**

Bachelor of Arts in Mathematics: Pure Mathematics

Course	Title	Credits	Milestones
First Year			
Fall			
MATH 203	Analysis and Number Theory Math Lab	2	
MATH 251	Calculus I	4	
WR 121	College Composition I	4	
First term of first-year second-language sequence		5	
	Credits	**15**	
Winter			
WR 122	College Composition II	4	
MATH 201	Algebra Math Lab	2	
MATH 252	Calculus II	4	
Second term of first-year second-language sequence		5	
	Credits	**15**	
Spring			
MATH 253	Calculus III	4	
Third term of first-year second-language sequence		5	
Social science group-satisfying course		4	
Science group group-satisfying course		4	
	Credits	**17**	
Second Year			
Fall			
MATH 281	Several-Variable Calculus I	4	
MATH 341	Elementary Linear Algebra	4	
Arts and letters group-satisfying course		4	
First term of second-year second-language sequence		4	
	Credits	**16**	
Winter			
MATH 282	Several-Variable Calculus II	4	
MATH 342	Elementary Linear Algebra	4	
Second term of second-year second-language sequence		4	
Social science group-satisfying course		4	
	Credits	**16**	
Spring			
MATH 202	Geometry Math Lab	2	
MATH 205	Foundations Math Lab	2	
MATH 307	Introduction to Proof	4	MATH major Bridge requiremer completed
Third term of second-year second-language sequence		4	BA language requirement completed
Science group-satisfying course		4	
	Credits	**16**	
Third Year			
Fall			
MATH 316	Fundamentals of Analysis I	4	
Arts and letters group satisfying course		4	
Science group-satisfying course		4	Science group requiremer completed
Upper-division Elective		4	
	Credits	**16**	
Winter			
MATH 317	Fundamentals of Analysis II	4	MATH major Analysis requirement completed
Social science group satisfying course		4	
Arts and letters group satisfying course		4	
Upper-division elective		4	
	Credits	**16**	
Spring			
CIS 122	Introduction to Programming and Problem Solving	4	MATH major CIS requiremer completed
MATH 433	Introduction to Differential Geometry	4	
Social science group satisfying course		4	Social science group requiremer completed
Arts and letters group satisfying course		4	Arts and letters group requirement completed
	Credits	**16**	
Fourth Year			
Fall			
MATH 444	Introduction to Abstract Algebra I	4	
Upper-division elective		4	
Upper-division elective		4	Complete the multi-cultural requirement by now
	Credits	**12**	
Winter			
MATH 445	Introduction to Abstract Algebra II	4	MATH major Abstract Algebra requirement completed
Upper-division elective		4	
Upper-division elective		4	
	Credits	**12**	

Spring			
MATH 320	Theory of Differential Equations (MATH major requirements completed)		4
Upper-division elective			4
Elective			4
Elective		180 credits completed	4
	Credits		**16**
	Total Credits		**183**

Bachelor of Science in Mathematics: Pure Mathematics

Course	Title	Credits	Milestones
First Year			
Fall			
WR 121	College Composition I		4
MATH 251	Calculus I (Only one MATH course can be counted toward science group requirement)	BS MATH requiremer completed	4
Social science group-satisfying course			4
Science group-satisfying course			4
	Credits		**16**
Winter			
WR 122	College Composition II		4
MATH 201	Algebra Math Lab		2
MATH 206	Combinatorics Math Lab		2
MATH 252	Calculus II		4
Arts and letters group-satisfying course			4
	Credits		**16**
Spring			
MATH 253	Calculus III		4
Arts and letters group-satisfying course			4
Social science group-satisfying course			4
Elective			4
	Credits		**16**
Second Year			
Fall			
MATH 202	Geometry Math Lab		2
MATH 205	Foundations Math Lab		2
MATH 281	Several-Variable Calculus I		4
Arts and letters group-satisfying course			4
Science group-satisfying course			4
	Credits		**16**
Winter			
MATH 282	Several-Variable Calculus II		4
MATH 341	Elementary Linear Algebra		4
Elective			4
Social science group-satisfying course			4
	Credits		**16**
Spring			
MATH 307	Introduction to Proof	MATH major Bridge requiremer completed	4
MATH 342	Elementary Linear Algebra		4
Arts and letters group-satisfying course		Arts and letters group requiremer completed	4
Science group-satisfying course			4
	Credits		**16**
Third Year			
Fall			
CIS 210	Computer Science I	MATH major CIS requirement completed	4
MATH 391	Fundamentals of Abstract Algebra I		4
Social science group-satisfying course		Social science group requirement completed	4
Upper-division Elective			4
	Credits		**16**
Winter			
MATH 392	Fundamentals of Abstract Algebra II	MATH major Abstract Algebra requiremer completed	4
Upper-division elective			4
Elective			4
Elective			4
	Credits		**16**
Spring			
MATH 320	Theory of Differential Equations		4
Upper-division elective			4
Upper-division elective			4
Elective			4
	Credits		**16**
Fourth Year			
Fall			
MATH 316	Fundamentals of Analysis I		4
Upper-division elective			4
Elective		Complete the multi-cultural requiremer by now	4
	Credits		**12**

Winter			
MATH 317	Fundamentals of Analysis II	MATH major Analysis requiremer complete	4
Upper-division elective			4
Upper-division elective			4
	Credits		**12**
Spring			
MATH 458	Introduction to Mathematical Cryptography	MATH major completed	4
Elective			4
Elective		180 credits completed	4
	Credits		**12**
	Total Credits		**180**

Bachelor of Arts in Mathematics: Secondary Teaching

Course	Title	Credits	Milestones
First Year			
Fall			
WR 121	College Composition I	4	
MATH 203	Analysis and Number Theory Math Lab	2	
MATH 251	Calculus I (Only one MATH course can be counted toward science group requirement)	4	
First term of first-year second-language sequence		5	
	Credits	**15**	
Winter			
WR 122	College Composition II	4	
MATH 201	Algebra Math Lab	2	
MATH 252	Calculus II	4	
Second term of first-year second-language sequence		5	
	Credits	**15**	
Spring			
MATH 253	Calculus III	4	
Third term of first-year second-language sequence		5	
Social science group-satisfying course		4	
Science group-satisfying course		4	
	Credits	**17**	
Second Year			
Fall			
MATH 281	Several-Variable Calculus I	4	
MATH 341	Elementary Linear Algebra	4	
Arts and letters group-satisfying course		4	
First term of second-year second-language sequence		4	
	Credits	**16**	
Winter			
CIS 122	Introduction to Programming and Problem Solving	MATH major CIS requirement completed	4
MATH 307	Introduction to Proof		4
Second term of second-year second-language sequence			4
Social science group-satisfying course			4
	Credits		**16**
Spring			
MATH 202	Geometry Math Lab		2
MATH 205	Foundations Math Lab	MATH major Bridge requirement completed	2
MATH 343	Statistical Models and Methods		4
Third term of second-year second-language sequence		BA language requirement completed	4
Science group-satisfying course		Science group requiremer completed	4
	Credits		**16**
Third Year			
Fall			
MATH 391	Fundamentals of Abstract Algebra I		4
Science group-satisfying course		Science group requirement completed	4
Arts and letters group satisfying course			4
Upper-division Elective			4
	Credits		**16**
Winter			
MATH 392	Fundamentals of Abstract Algebra II		4
Upper-division elective			4
Social science group satisfying course			4
Arts and letters group satisfying course			4
	Credits		**16**
Spring			
MATH 397	History and Applications of Calculus		4
Social science group satisfying course		Social science group requirement completed	4
Arts and letters group satisfying course		Arts and letters group requiremer completed	4

Elective			4
	Credits		**16**
Fourth Year			
Fall			
MATH 394	Geometries from an Advanced Viewpoint I		4
Upper-division elective			4
Upper-division elective		Complete the multi-cultural requirement by now	4
	Credits		**12**
Winter			
MATH 347	Fundamentals of Number Theory I		4
MATH 395	Geometries from an Advanced Viewpoint II		4
Upper-division elective			4
Upper-division elective			4
	Credits		**16**
Spring			
MATH 348	Fundamentals of Number Theory II	MATH major completed	4
Upper-division elective			4
Elective		180 credits completed	4
	Credits		**12**
	Total Credits		**183**

Bachelor of Science in Mathematics: Secondary Teaching

Course	Title	Credits Milestones	
First Year			
Fall			
WR 121	College Composition I		4
MATH 251	Calculus I (Only one MATH course can be counted toward science group requirement)	BS MATH requiremer completed	4
Social science group-satisfying course			4
Science group-satisfying course			4
	Credits		**16**
Winter			
WR 122	College Composition II		4
MATH 201	Algebra Math Lab		2
MATH 206	Combinatorics Math Lab		2
MATH 252	Calculus II		4
Arts and letters group-satisfying course			4
	Credits		**16**
Spring			
MATH 253	Calculus III		4
Arts and letters group-satisfying course			4
Social science group-satisfying course			4
Elective			4
	Credits		**16**
Second Year			
Fall			
MATH 202	Geometry Math Lab		2
MATH 205	Foundations Math Lab		2
MATH 281	Several-Variable Calculus I		4
Arts and letters group-satisfying course			4
Science group-satisfying course			4
	Credits		**16**
Winter			
MATH 307	Introduction to Proof	MATH major Bridge requirement completed	4
MATH 341	Elementary Linear Algebra		4
Elective			4
Social science group-satisfying course			4
	Credits		**16**
Spring			
CIS 122	Introduction to Programming and Problem Solving	MATH major CIS requiremer completed	4
MATH 343	Statistical Models and Methods		4
Arts and letters group-satisfying course		Arts and letters group requiremer completed	4
Science group-satisfying course			4
	Credits		**16**
Third Year			
Fall			
MATH 391	Fundamentals of Abstract Algebra I		4
Social science group-satisfying course		Social science group requiremer completed	4
Elective			4
Upper-division elective			4
	Credits		**16**
Winter			
MATH 347	Fundamentals of Number Theory I		4
MATH 392	Fundamentals of Abstract Algebra II	MATH major Abstract Algebra requirement completed	4
Upper-division elective			4
Elective			4
	Credits		**16**

Spring			
MATH 348	Fundamentals of Number Theory II		4
Upper-division elective			4
Upper-division elective			4
Elective			4
	Credits		**16**
Fourth Year			
Fall			
MATH 394	Geometries from an Advanced Viewpoint I		4
Upper-division elective			4
Elective		Complete the multi-cultural requiremer by now	4
	Credits		**12**
Winter			
MATH 395	Geometries from an Advanced Viewpoint II		4
Upper-division elective			4
Upper-division elective			4
	Credits		**12**
Spring			
MATH 397	History and Applications of Calculus (MATH major requirements completed)		4
Elective			4
Elective		180 credits completed	4
	Credits		**12**
	Total Credits		**180**

- Accelerated Master's Program **(**http://catalog.uoregon.edu/archive/2021-2022/arts_sciences/mathematics/am/**)**
- **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. The application for admission is available online (http://math.uoregon.edu/graduate/apply-online/). Prospective applicants should note the general university requirements for graduate admission that appear in the **Graduate School** section of this catalog as well as requirements specific to the department at math.uoregon.edu/graduate/admissions (http://math.uoregon.edu/graduate/admissions/). (http://math.uoregon.edu/graduate/admissions/)

Transcripts from all undergraduate and graduate institutions attended and copies of Graduate Record Examinations (GRE) scores in the verbal, quantitative, and mathematics tests (general and subject GREs) 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 and online (http://math.uoregon.edu/graduate/handbook/). 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*.

Courses

MATH 099. Special Studies: [Topic]. 1-2 Credits.
Credit for enrollment (eligibility) but not for graduation; satisfies no university or college requirement. Repeatable.

MATH 101. Foundations of Algebra and Mathematical Modeling. 4 Credits.
Critical elements of pre-college algebra, topics including equation solving; rational, radical, and polynomial expression evaluation and simplification; lines, linear equations, and quadratic equations. Focus on mathematical modeling and preparation for additional college level mathematics.
Prereq: UO Math Placement Exam with a score of 35-48.

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 101 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 101 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 101 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 101 or satisfactory placement test score.

MATH 112. Elementary Functions. 4 Credits.
Exponential, logarithmic, and trigonometric functions. Intended as preparation for MATH 251.
Prereq: MATH 111 or satisfactory placement test score.

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

MATH 201. Algebra Math Lab. 2 Credits.
Exploratory course in mathematics. Course focuses on techniques of mathematical exploration and discovery, the language of mathematics, and foundational issues. Topics from algebra.

MATH 202. Geometry Math Lab. 2 Credits.
Exploratory course in mathematics. Course focuses on techniques of mathematical exploration and discovery, the language of mathematics, and foundational issues. Topics from geometry.

MATH 203. Analysis and Number Theory Math Lab. 2 Credits.
Exploratory course in mathematics. Course focuses on techniques of mathematical exploration and discovery, the language of mathematics, and foundational issues. Topics from analysis and the theory of numbers.

MATH 204. Probability and Statistics Math Lab. 2 Credits.
Exploratory course in mathematics. Course focuses on techniques of mathematical exploration and discovery, the language of mathematics, and foundational issues. Topics from probability and statistics.

MATH 205. Foundations Math Lab. 2 Credits.
Exploratory course in mathematics. Course focuses on techniques of mathematical exploration and discovery, the language of mathematics, and foundational issues. Topics from the foundations of mathematics.

MATH 206. Combinatorics Math Lab. 2 Credits.
Exploratory course in mathematics. Course focuses on techniques of mathematical exploration and discovery, the language of mathematics, and foundational issues. Topics from combinatorics.

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 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 more than one of MATH 241, 246, 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 more than one of MATH 242, 247, 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 101 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.
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 316. Fundamentals of Analysis I. 4 Credits.
Rigorous treatment of topics introduced in calculus such as limits, sequences, series, the Cauchy condition, and continuity. Development of mathematical proof in these contexts. Sequence with MATH 317.
Prereq: MATH 253 or equivalent; one from MATH 232, MATH 262, MATH 307.

MATH 317. Fundamentals of Analysis II. 4 Credits.
Rigorous treatment of topics introduced in calculus such as continuity, uniform convergence, power series, differentiation, and integration. Development of mathematical proof in these contexts. Sequence with MATH 316.
Prereq: MATH 316.

MATH 320. Theory of Differential Equations. 4 Credits.
An introduction to differential equations for students with background in linear algebra, with a mixture of applications and theory. Topics include linear and nonlinear equations, systems of equations, and questions of existence and uniqueness.
Prereq: MATH 281, MATH 342; one from MATH 232, MATH 262, MATH 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. Students cannot get credit for both MATH 343 and DSCI 345M/MATH 345M.
Prereq: MATH 252.

MATH 345M. Probability and Statistics for Data Science. 4 Credits.
Introduction to probability and statistics, with an emphasis upon topics relevant for data science. Multilisted with DSCI 345M. Students cannot get credit for both MATH 343 and DSCI 345M/MATH 345M.
Prereq: MATH 342, CIS 211.

MATH 347. Fundamentals of Number Theory I. 4 Credits.
A study of congruences, the Chinese remainder theorem, the theory of prime numbers and divisors, Diophantine equations, and quadratic reciprocity. Development of mathematical proof in these contexts. Sequence with MATH 348.
Prereq: MATH 253 or equivalent; one from MATH 232, MATH 262, MATH 307.

MATH 348. Fundamentals of Number Theory II. 4 Credits.
Study of nonlinear Diophantine equations, sums of squares, the theory of partitions, geometric number theory, and the distribution of prime numbers. Development of mathematical proof in these contexts. Sequence with MATH 347.
Prereq: MATH 347.

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 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 397. History and Applications of Calculus. 4 Credits.
Historical applications of calculus. Topics may include volumes by the method of exhaustion, Archimedean spiral, Kepler problem, calculus of variations, brachistochrone problem, spread of infectious disease, analysis of savings.
Prereq: MATH 253; one from MATH 232, MATH 262, MATH 307.

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]. 1-5 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, MATH 317.

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 421M. Partial Differential Equations: Fourier Analysis I. 4 Credits.
Introduction to PDEs with a view towards applications in physics. Wave and heat equations, classical Fourier series on the circle, Bessel and Legendre series. Multilisted with PHYS 421M.
Prereq: MATH 253; one from MATH 256, MATH 281.

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 421M or PHYS 421M.

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 317.

MATH 432. Introduction to Topology. 4 Credits.
Introduction to smooth manifolds and differential topology. Sequence.
Prereq: MATH 281, MATH 341, 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: one from MATH 232, MATH 262, MATH 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]. 1-5 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 521M. Partial Differential Equations: Fourier Analysis I. 4 Credits.
Introduction to PDEs with a view towards applications in physics. Wave and heat equations, classical Fourier series on the circle, Bessel and Legendre series. Multilisted with PHYS 521M.

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 600M. Temporary Mulitlisted Course. 1-5 Credits.
Repeatable.

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 610. Experimental Course: [Topic]. 1-5 Credits.
Repeatable.

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.