Mathematics

Mathematics is a subject of great intrinsic power and beauty. It is the universal language of science, and is essential for a clear and complete understanding of virtually all phenomena. Mathematical training prepares a student to express and analyze problems and relationships in a logical manner in a wide variety of disciplines including the physical, engineering, social, biological, and medical sciences, business, and pure mathematics itself. This is a principal reason behind the perpetual need and demand for mathematicians in education, research centers, government, and industry.

The department offers three major programs leading to the degrees of bachelor of arts with major in mathematics, bachelor of science in mathematics, and bachelor of science in statistics. It also offers several minor programs for undergraduates. Students can earn their bachelor and master of education (M.Ed.) degree in elementary education or secondary education plus Pennsylvania teacher certification in 5 years.

At the graduate level, the department offers programs leading to the degrees of master of science in mathematics, master of science in applied mathematics, master of science in statistics, doctor of philosophy in mathematics, and doctor of philosophy in applied mathematics. The department is a part of the interdisciplinary program in analytical finance.

CALCULUS SEQUENCES

Many degree programs throughout the university include a mathematics requirement consisting of a sequence in calculus. The Department of Mathematics offers four calculus sequences:

MATH 021 & MATH 022 & MATH 023	Calculus I and Calculus II and Calculus III	12
MATH 031 & MATH 032 & MATH 033	Honors Calculus I and Honors Calculus II and Honors Calculus III	12
MATH 051 & MATH 052	Survey of Calculus I and Survey of Calculus II	7
MATH 081 & MATH 082	Calculus with Business Applications I and Calculus with Business and Economics Applications II	8

The MATH 021, MATH 022, MATH 023 sequence is a systematic development of calculus. Most students of mathematics, science, and engineering, will take some or all of this sequence.

As an honors sequence, the MATH 031, MATH 032, MATH 033 sequence covers essentially the same material but in greater depth and with more attention to rigor and proof. This sequence should be considered by students who have demonstrated exceptional ability in mathematics.

The MATH 051, MATH 052 sequence is a survey of calculus. This sequence is not sufficient preparation for most subsequent mathematics courses. Students contemplating further study in mathematics should consider MATH 021, MATH 022 instead.

MATH 081, MATH 082 sequence is a survey with business applications. This sequence is not sufficient preparation for most subsequent mathematics courses. Students contemplating further study in mathematics should consider MATH 021, MATH 022 instead.

MATH 075, MATH 076 is a two-semester sequence that substitutes for MATH 021, covering the same material but at a slower pace.

The MATH 031, MATH 032, MATH 033 sequence will be accepted in place of MATH 021,MATH 022,MATH 023. MATH 021, MATH 022 will be accepted in place of MATH 051, MATH 052. MATH 021 will be accepted in place of MATH 081. Credit will be awarded for only one course in each of the following groups:

Group 1		
MATH 021	Calculus I	4
MATH 075 & MATH 076	Calculus I, Part A and Calculus I, Part B	4
MATH 031	Honors Calculus I	4
MATH 051	Survey of Calculus I	4
MATH 081	Calculus with Business Applications I	4
Group 2		
MATH 022	Calculus II	4
MATH 032	Honors Calculus II	4
MATH 052	Survey of Calculus II	3
MATH 082	Calculus with Business and Economics Applications II	4
Group 3		
MATH 023	Calculus III	4
MATH 033	Honors Calculus III	4

UNDERGRADUATE DEGREE PROGRAMS

The Department of Mathematics offers degree programs in Mathematics and Statistics. These programs have the flexibility and versatility needed to prepare students for a wide variety of careers in government, industry, research and education.

Students in the degree programs in mathematics must satisfy three types of requirements: Core Mathematics Requirements, Advanced Mathematics Electives and General Electives. The Core Mathematics Requirement ensures a common core of knowledge appropriate for students in each program. The Advanced Mathematics Electives consist of courses with specific mathematical or statistical content chosen by the student in consultation with the major advisor to complement the student's interest and career aspirations. With these further breadth and greater depth of knowledge are achieved. The General Electives consist of additional courses chosen from among those offered by the university faculty. Students can use these electives to pursue interests beyond the major, or may use these to expand upon the basic requirements of the degree program. Students are strongly encouraged to use some of these electives to earn a minor in another discipline.

Students in the degree programs in statistics must satisfy four types of requirements beyond those required by the college: Required Major Courses, Major Electives, Professional Electives and General Electives. The Required Major Courses form the backbone of the program and ensure a common core of knowledge appropriate for students in the programs. The Major Electives consist of courses with specific mathematical or statistical content chosen by the student in consultation with the major advisor to complement the student's interest. The Professional Electives are meant for the students to develop their knowledge in some disciplines of applications of statistics. These can be broadly chosen in consultation with an advisor in a way that is consistent with each student's career aspirations.

Each student is provided a faculty advisor to guide an individual program and supervise the selection of electives.

B.A. WITH A MAJOR IN MATHEMATICS

The B.A. program in mathematics emphasizes fundamental principles as well as the mastery of techniques required for the effective use of mathematics. The program provides a solid foundation for those who want to pursue a mathematically oriented career or advanced study in any mathematically oriented field.

Requirements

BA MATHEMATICS		
Calculus requirement:		**12**
MATH 021 & MATH 022 & MATH 023	Calculus I and Calculus II and Calculus III	
Core Requirements		**15**
MATH 163	Introduction to Mathematical Reasoning	
MATH 242	Linear Algebra	
MATH 243	Algebra	
MATH 301	Principles of Analysis I	
Advanced Mathematics Electives		**15-20**

At least five courses (minimum of 15 credits) from the approved list; at least one of these must be at the 300 level; at most one course may be taken outside the department; chosen in consultation with major advisor.	
Total Credits	**42-47**

A student must achieve an average of 2.0 or higher in major courses.

B.S. IN MATHEMATICS

The BS in Mathematics program provides a more extensive and intensive study of mathematics and its applications. This program is especially recommended for students intending to pursue advanced study in mathematics, applied mathematics, or closely related fields.

Requirements

BS MATHEMATICS

Calculus Requirement		**12**
MATH 021 & MATH 022 & MATH 023	Calculus I and Calculus II and Calculus III	
Core Requirements		**15**
MATH 163	Introduction to Mathematical Reasoning	
MATH 242	Linear Algebra	
MATH 243	Algebra	
MATH 301	Principles of Analysis I	
Advanced Mathematics Electives		**24-32**
At least eight courses (minimum of 24 credits) from the approved list; at least four of these must be at the 300 level; at most two courses may be taken outside the department; chosen in consultation with major advisor.		
Two approved(*) CSE courses. (*)Computer sciences courses must include a programming component. They are approved by the major advisor. The CSE requirement is waived for students with a minor in Computer Science.		5-6
Total Credits		**56-65**

A student must achieve an average of 2.0 or higher in major courses.

List of approved Advanced Mathematics electives:

The list of Advanced Mathematics electives (ADV List) consists of the following courses:

- MATH 208, MATH 229, MATH 230, MATH 234, MATH 252, MATH 263, MATH 264;
- All 300 level courses offered by the Mathematics Department except MATH 301 (required core course), MATH 371 (see below), MATH 381 (see below), and MATH 391 (see below);
- Notes:
  - Together, MATH 202 *and* MATH 203 (as a three credit combination), is accepted as *one* Advanced Mathematics elective;
  - With prior approval, *one* Advanced Mathematics elective (3 credits) may be replaced with three credits of (a combination of) MATH 271(Readings), MATH 371(Readings), MATH 291 or MATH 381 (Undergraduate Research), or MATH 391(Senior Thesis) completed over one or two semesters;
  - All 400 level courses are accepted as Advanced Mathematics electives. (Note. To enroll in a 400 level course, an undergraduate must successfully petition the appropriate university committee.)

Suggested Concentrations:

Applied Mathematical Modeling Concentration: This concentration should be considered by students interested in graduate study in applied mathematics or computational mathematics. The eight Advanced Mathematics electives are selected in consultation with a major advisor and must include the following:

- MATH 230
- MATH 319
- At least *two* courses selected from: MATH 320, MATH 322, MATH 323, MATH 341
- At least *two* additional courses selected from:
  - MATH 202/203, MATH 208, MATH 263, MATH 264, MATH 252
  - MATH 305, MATH 306, MATH 309, MATH 310, MATH 311, MATH 312, MATH 320, MATH 322, MATH 323, MATH 334, MATH 338, MATH 340, MATH 341, MATH 343
- At least *two* additional courses selected from the list of approved Advanced Mathematics Electives (see ADV List below)
- At least *four* of these courses must be at the 300 level.

Probability and Statistics Concentration: This concentration should be considered by students interested in actuarial science. The eight Advanced Mathematics electives are selected in consultation with a major advisor and must include the following:

- MATH 263
- MATH 264
- At least *two* courses selected from: MATH 310, MATH 312, MATH 334, MATH 338
- At least *two* additional courses selected from:
  - MATH 202/203, MATH 208, MATH 252,
  - MATH 305, MATH 306, MATH 309, MATH 310, MATH 311, MATH 312, MATH 320, MATH 322, MATH 323, MATH 334, MATH 338, MATH 340, MATH 341, MATH 343
- At least *two* additional courses selected from the list of approved Advanced Mathematics Electives (see ADV List below)
- At least *four* of these courses must be at the 300 level.

Theoretical Mathematics Concentration: This concentration should be considered by students interested in graduate study in mathematics or applied mathematics. The eight Advanced Mathematics electives are selected in consultation with a major advisor and must include the following:

- MATH 327
- MATH 302 or MATH 316
- At least *two* additional courses selected from: MATH 302, MATH 305, MATH 307, MATH 311, MATH 316, MATH 319, MATH 331, MATH 342
- At least *four* additional courses selected, in consultation with the major advisor, from the list of approved Advanced Mathematics Electives (see ADV List below)
- At least *four* of these courses must be at the 300 level.

Other concentration: Students, in consultation with the major advisor, may design their own concentration by selecting a coherent list of eight Advanced Mathematics electives from the list of approved courses (see ADV List above). For instance, this option should be considered by students with an interest in data science, computer science, or mathematical economics.

B.A. WITH A MAJOR IN STATISTICS

The B.A. program in statistics emphasizes fundamental principles for designing the process of data collection, for summarizing and interpreting data, and for drawing valid conclusions from data. The B.A. program provides a sufficient foundation for those who want to pursue a career in a field of applications of statistics and is flexible enough to be combined as a double major.

BA STATISTICS and DATA SCIENCE

Required Major course		
MATH 021	Calculus I	4
or MATH 051	Survey of Calculus I	
or MATH 081	Calculus with Business Applications I	
MATH 022	Calculus II	3-4
or MATH 052	Survey of Calculus II	
or MATH 082	Calculus with Business and Economics Applications II	
MATH 264	Introduction to Statistical Reasoning and Methods	4

Select one of the following: [1]		4
MATH 205	Linear Methods	
MATH 241	Applied Linear Algebra	
MATH 242	Linear Algebra	
MATH 263	Introduction to the Theory of Probability	3
or MATH 309	Probability with Applications and Simulations	
Advanced Statistics Electives		
Select three (3) of the following:		9-12
MATH 310	Random Processes and Applications	
MATH 312	Statistical Computing and Applications	
MATH 334	Mathematical Statistics	
MATH 338	Statistical Models in Data Science	
MATH 339	Time Series and Forecasting	
MATH 365	Statistical Machine Learning	
MATH 374	Statistical Project	3
Two approved CSE courses. [2]		5-7
Professional Electives		
Courses selected from a field of application of statistics and probability with the approval of the faculty advisor		6
Total Credits		**41-47**

1

MATH 241 is recommended. For students who may need more preparation, MATH 205 can be used as a major elective.

2

Computer sciences courses must include a programming component. They are approved by the major advisor.

B.S. IN STATISTICS

Statistics provides a body of principles for designing the process of data collection, for summarizing and interpreting data, and for drawing valid conclusions from data. It thus forms a fundamental tool in the natural and social sciences as well as business, medicine, and other areas of research. Mathematical principles, especially probability theory, underlie all statistical analyses. The B.S. program in Statistics provides students with a comprehensive study of the field of statistics. The standard track covers both the mathematical foundations of the discipline, as well as its applied aspect and its practical use. The applied track focuses on the latter. This program is especially recommended for students intending to pursue a career as a statistician, advanced studies in statistics, data science, or related fields.

The BS in Statistics and Data Science program offers two tracks: the standard track and the applied track.

STANDARD TRACK

BS STATISTICS and DATA SCIENCE, STANDARD TRACK

Required Major courses		
MATH 021	Calculus I	4
or MATH 051	Survey of Calculus I	
or MATH 081	Calculus with Business Applications I	
MATH 022	Calculus II	3-4
or MATH 052	Survey of Calculus II	
or MATH 082	Calculus with Business and Economics Applications II	
MATH 264	Introduction to Statistical Reasoning and Methods	4
Select one of the following: [1]		3-4
MATH 205	Linear Methods	
MATH 241/ STAT 342	Applied Linear Algebra	
MATH 242	Linear Algebra	
MATH 263	Introduction to the Theory of Probability	3
or MATH 309	Probability with Applications and Simulations	
MATH 310	Random Processes and Applications	3-4
MATH 312	Statistical Computing and Applications	3-4
MATH 334	Mathematical Statistics	3-4
MATH 338	Statistical Models in Data Science	3-4
MATH 365	Statistical Machine Learning	3-4
MATH 374	Statistical Project	3
Two approved CSE courses. [2]		5-7
Major Electives		
At least two courses with specific mathematical or statistical content chosen with the approval of the faculty advisor		8
Professional Electives		
Courses selected from two or three fields of application of statistics and probability with the approval of the faculty advisor		15
Total Credits		**63-72**

1

MATH 241 is recommended. For students who may need more preparation, MATH 205 can be used as a major elective.

2

Computer sciences courses must include a programming component. They are approved by the major advisor. The CSE requirement is waived for students with a minor in Computer Science.

APPLIED TRACK

BS STATISTICS and DATA SCIENCE, APPLIED TRACK

Required Major courses		
MATH 021	Calculus I	4
or MATH 051	Survey of Calculus I	
or MATH 081	Calculus with Business Applications I	
MATH 022	Calculus II	3-4
or MATH 052	Survey of Calculus II	
or MATH 082	Calculus with Business and Economics Applications II	
MATH 264	Introduction to Statistical Reasoning and Methods	4
Select one of the following: [1]		3-4
MATH 205	Linear Methods	
MATH 241/ STAT 342	Applied Linear Algebra	
MATH 242	Linear Algebra	
MATH 309	Probability with Applications and Simulations	3
MATH 312	Statistical Computing and Applications	3-4
MATH 334	Mathematical Statistics	3-4
MATH 339	Time Series and Forecasting	3-4
MATH 365	Statistical Machine Learning	3-4
MATH 374	Statistical Project	3
Two approved CSE courses. [2]		5-7
Major Electives		
At least three courses with specific mathematical or statistical content chosen with the approval of the faculty advisor		12
Professional Electives		
Courses selected from two or three fields of application of statistics and probability with the approval of the faculty advisor		15
Total Credits		**64-72**

1

MATH 241 is recommended. For students who may need more preparation, MATH 205 can be used as a major elective.

2

Computer sciences courses must include a programming component. They are approved by the major advisor. The CSE requirement is waived for students with a minor in Computer Science.

CONCENTRATION IN ACTUARIAL SCIENCE

Major Electives must include:

MATH 202	Actuarial Exam I	1
MATH 203	Actuarial Exam II - Financial Mathematics	2

Professional Electives (15 credit hours) must include at least three of these courses:

ACCT 151	Introduction to Financial Accounting	3
ECO 119	Intermediate Macroeconomic Analysis	3
ECO 146	Intermediate Microeconomic Analysis	3
FIN 125	Introduction to Finance	3

DEPARTMENTAL HONORS

Students may earn departmental honors by writing a thesis during their senior year. Students are accepted into the program during their junior year by the department chairperson. This acceptance is based upon the student's grades and a thesis proposal, which the student must prepare in conjunction with a thesis advisor selected by the student. An oral presentation as well as a written thesis are required for completion of the program.

MINOR PROGRAMS

The department offers minor programs in different branches of the mathematical sciences. The requirement consists of a Calculus course (MATH 023 or MATH 033 or MATH 052 or MATH 082 depending on the minor) and four additional courses shown below for each of the programs. At most one of the five courses in the minor program may also be required in the major program or another minor. For substitutions, the student should consult the chairperson.

Minor in Pure Mathematics

MINOR IN PURE MATHEMATICS

Required Courses		**16**
MATH 023	Calculus III	
MATH 242	Linear Algebra	
MATH 243	Algebra	
MATH 301	Principles of Analysis I	
Select one of the following:		**3-4**
MATH 307	General Topology I	
MATH 316	Complex Analysis	
MATH 319	Introduction to Differential Equations	
MATH 320	Ordinary Differential Equations	
MATH 327	Groups and Rings	
MATH 331	Differential Geometry of Curves and Surfaces	
MATH 342	Number Theory	
Total Credits		**19-20**

Minor in Applied Mathematics

MINOR IN APPLIED MATHEMATICS

MATH 023	Calculus III	4
MATH 341	Mathematical Models and Their Formulation	3
Select three of the following:		9-10
MATH 205	Linear Methods	
MATH 208	Complex Variables	
MATH 230	Numerical Methods	
MATH 231	Probability and Statistics	
MATH 241	Applied Linear Algebra	
MATH 242	Linear Algebra	
MATH 263	Introduction to the Theory of Probability	
MATH 264	Introduction to Statistical Reasoning and Methods	
MATH 319	Introduction to Differential Equations	
MATH 320	Ordinary Differential Equations	
MATH 322	Methods of Applied Analysis I	
MATH 323	Methods of Applied Analysis II	
Total Credits		**16-17**

Minor in Probability and Statistics

MINOR IN PROBABILITY AND STATISTICS

MATH 023	Calculus III	4
or MATH 052	Survey of Calculus II	
or MATH 082	Calculus with Business and Economics Applications II	
MATH 263	Introduction to the Theory of Probability	3
or MATH 309	Probability with Applications and Simulations	
Select one of the following:		3-4
MATH 012	Basic Statistics and Data Science	
MATH 231	Probability and Statistics	
MATH 264	Introduction to Statistical Reasoning and Methods	
Select two of the following:		6-8
MATH 310	Random Processes and Applications	
MATH 312	Statistical Computing and Applications	
MATH 334	Mathematical Statistics	
MATH 338	Statistical Models in Data Science	
MATH 339	Time Series and Forecasting	
MATH 365	Statistical Machine Learning	
Total Credits		**16-19**

Minor in Actuarial Science

MINOR IN ACTUARIAL SCIENCE

MATH 023	Calculus III	3-4
or MATH 052	Survey of Calculus II	
or MATH 082	Calculus with Business and Economics Applications II	
MATH 263	Introduction to the Theory of Probability	3
or MATH 309	Probability with Applications and Simulations	
MATH 310	Random Processes and Applications	3-4
MATH 202	Actuarial Exam I	1
MATH 203	Actuarial Exam II - Financial Mathematics	2
Select one of the following:		3
ACCT 108	Fundamentals of Accounting	
ACCT 151	Introduction to Financial Accounting	
ECO 119	Intermediate Macroeconomic Analysis	
ECO 146	Intermediate Microeconomic Analysis	
Total Credits		**15-17**

For information on examinations of actuarial societies, students may consult their minor advisor.

GRADUATE PROGRAMS IN MATHEMATICS

The department offers graduate programs leading to the degrees of master of science in mathematics, applied mathematics, or statistics, and the doctor of philosophy in mathematics or applied mathematics.

The Department does not offer a doctorate in statistics. However, students may choose statistics or mathematical statistics as a concentration in the doctor of philosophy programs in mathematics and applied mathematics. The Department is a part of the

interdisciplinary program in Financial Engineering. For details on the Master of Science in Financial Engineering, see the Interdisciplinary Graduate Study and Research, Financial Engineering section.

To begin graduate work in mathematics a student must present evidence of adequate undergraduate preparation. The undergraduate program should have included a year of advanced calculus, a semester of linear algebra, and a semester of abstract algebra.

M.S. in Mathematics or Applied Mathematics

The master's program requires 30 credit hours of graduate courses with at least 18 credit hours at the 400 level. With the permission of the chairperson, up to six credit hours of these courses can be replaced by a thesis. All students in the master's program must also pass a comprehensive examination. The M.S. degree can serve both as a final degree in mathematics or as an appropriate background for the Ph.D. degree.

M.S. in Statistics

This program requires 30 credit hours of graduate courses with at least 18 hours of 400-level STAT or MATH courses. The choice of courses must be approved by the graduate advisor, and up to six hours of coursework may be replaced with a thesis.

The M.S. program in statistics has two tracks:

statistics track

The statistics track has recommended courses:

MATH 309	Probability with Applications and Simulations	3
MATH 312	Statistical Computing and Applications	3-4
STAT 342	Applied Linear Algebra	3
STAT 410	Random Processes and Applications	3
STAT 434	Mathematical Statistics	3
STAT 438	Statistical Models in Data Science	3
STAT 471	Topics in Statistical Learning and Computing	3
Electives		
STAT 412	Advanced Applied Statistics	3
Select two other possible electives:		6
STAT 408	Seminar in Statistics and Probability	
STAT 409	Seminar in Statistics and Probability	
STAT 439	Time Series and Forecasting	
STAT 461	Topics In Mathematical Statistics	
STAT 465	Statistical Machine Learning	
STAT 474	Statistical Practice	
MATH 462	Modern Nonparametric Methods in Statistics	
ISE 332	Product Quality	
ISE 409	Time Series Analysis	
ISE 410	Design of Experiments	
ECO 460	Time Series Analysis	
ECO 463	Topics in Game Theory	
CSE 326	Fundamentals of Machine Learning	
or ISE 364	Introduction to Machine Learning	
CSE 347	Data Mining	
or ISE 365	Applied Data Mining	
Total Credits		**30-31**

stochastic modeling track

The stochastic modeling track has recommended courses:

MATH 309	Probability with Applications and Simulations	3
MATH 401	Real Analysis I	3
STAT 342	Applied Linear Algebra	3
STAT 410	Random Processes and Applications	3
STAT 463	Advanced Probability	3
Electives		
MATH 341	Mathematical Models and Their Formulation	3
STAT 434	Mathematical Statistics	3
STAT 438	Statistical Models in Data Science	3
STAT 464	Advanced Stochastic Processes	3
Select one other possible electives:		3
STAT 408	Seminar in Statistics and Probability	
STAT 409	Seminar in Statistics and Probability	
STAT 439	Time Series and Forecasting	
STAT 465	Statistical Machine Learning	
STAT 471	Topics in Statistical Learning and Computing	
STAT 474	Statistical Practice	
MATH 402	Real Analysis II	
MATH 430	Numerical Analysis	
MATH 467	Stochastic Calculus	
MATH 468	Financial Stochastic Analysis	
ECO 463	Topics in Game Theory	
CSE 411	Advanced Programming Techniques	
ISE 339	Stochastic Models and Applications	
ISE 409	Time Series Analysis	
ISE 416	Dynamic Programming	
ISE 439	Stochastic Models and Applications	
Total Credits		**30**

Ph.D. in Mathematics

The plan of work toward the doctor of philosophy degree will include a qualifying examination and an advanced topic examination. A language exam may be required at the discretion of the doctoral committee. The qualifying examination tests the student's command of algebra and real analysis. The content of the advanced topic examination is determined by a department committee. A general examination, the doctoral dissertation and its defense complete the work for the Ph.D. degree.

Each candidate's plan of work must be approved by a special committee of the department. A Ph.D. student is required to have 18 credits of approved graduate level course work beyond the master's level. Successful completion of MATH 316 and MATH 307 is required of all students. After completion of 18 credits a student is required to take at least one course per academic year other than MATH 409 and MATH 499.

Mathematics, PhD

MATH 307	General Topology I
MATH 316	Complex Analysis
MATH 400-499 [1, 2, 3]	

1

A Ph.D. student is required to have 18 credits of approved graduate level course work beyond the master's level.

2

After completion of 18 credits a student is required to take at least one course per academic year other than MATH 409 and MATH 499

3

Each candidate's plan of work must be approved by a special committee of the department.

Ph.D. in Applied Mathematics

The plan of work toward the doctor of philosophy degree will include a qualifying examination and an advanced topic examination. A language examination may be required at the discretion of the doctoral committee. The *Ph.D. in Applied Mathematics* qualifying examination tests the student's command of *Statistics and Applied Probability* or of *Real Analysis and Differential Equations*. The content of the advanced topic examination is determined by a department committee. A general examination, the doctoral dissertation and its defense complete the work for the Ph.D. degree.

Each candidate's plan of work must be approved by a special committee of the department. A Ph.D. student is required to have 18 credits of approved graduate level course work beyond the master's level. After completion of 18 credits a student is required to take at least one course per academic year other than MATH 409 and MATH 499.

MATH Coursework [1, 2, 3]

1

A Ph.D. student is required to have 18 credits of approved graduate level course work beyond the master's level.

2

After completion of 18 credits a student is required to take at least one course per academic year other than MATH 409 and MATH 499.

3

Each candidate's plan of work must be approved by a special committee of the department.

Mathematics Courses

MATH 000 Preparation for Calculus 0,2 Credits
Intensive review of fundamental concepts in mathematics utilized in calculus, including functions and graphs, exponentials and logarithms, and trigonometry. This course is for students who need to take MATH 51, 81, or 21, but who require additional preparation in precalculus. The credits for this course do not count toward graduation, but do count toward GPA and current credit count. Consent of department.
Attribute/Distribution: MA

MATH 005 Introduction to Mathematical Thought 0,3 Credits
Meaning, content, and methods of mathematical thought illustrated by topics that may be chosen from number theory, abstract algebra, combinatorics, finite or nonEuclidean geometries, game theory, mathematical logic, set theory, topology.
Attribute/Distribution: MA, Q

MATH 009 Introduction to Finite Mathematics 4 Credits
Systems of linear equations, matrices, introduction to linear programming. Sets, counting methods, probability, random variables, introduction to Markov chains.
Attribute/Distribution: MA, Q

MATH 012 Basic Statistics and Data Science 0,4 Credits
A first course in the basic concepts and methods of statistics with illustrations from the social, behavioral, and biological sciences. Descriptive statistics; frequency distributions, mean and standard deviation, two-way tables, correlation and regression; random sampling, rules of probability, probability distributions and parameters, parameter estimation, confidence intervals, hypothesis testing, statistical significance. Note: Mathematics and Statistics majors may not receive credit for both MATH 012 & ECO 045.
Attribute/Distribution: MA, Q

MATH 014 (PHIL 014) Symbolic Logic 4 Credits
This course is an introduction to logical theory. Our primary goal is to study the notions of logical consequence and provability. The central question that we will try to answer is this: What exactly does it mean to say that some conclusion is a logical consequence of or is provable from a certain collection of premises? To answer this question as clearly and rigorously as possible, we will develop three symbolic logical systems: Term Logic, Sentence Logic, and Predicate Logic.
Attribute/Distribution: MA, Q

MATH 021 Calculus I 0,4 Credits
Functions and graphs; limits and continuity; derivative, differential, and applications; indefinite and definite integrals; trigonometric, logarithmic, exponential, and hyperbolic functions. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Attribute/Distribution: MA, Q

MATH 022 Calculus II 0,4 Credits
Applications of integration; techniques of integration; separable differential equations; infinite sequences and series; Taylor's Theorem and other approximations; curves and vectors in the plane. Students may not obtain credit for more than one of Math022, Math032, Math052, Math082. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 021 or MATH 076
Attribute/Distribution: MA, Q

MATH 023 Calculus III 0,4 Credits
Vectors in space; partial derivatives; Lagrange multipliers; multiple integrals; vector analysis; line integrals; Green's Theorem, Gauss's Theorem. Students may not obtain credit for more than one of MATH 023, MATH 033. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 022
Attribute/Distribution: MA, Q

MATH 031 Honors Calculus I 4 Credits
Same topics as in MATH 021, but taught from a more thorough and rigorous point of view. Students may not obtain credit for more than one of MATH 021, MATH 031, MATH 051, (MATH 075 and MATH 076), MATH 081. However all graded courses will still be factored into the GPA.
Attribute/Distribution: MA, Q

MATH 032 Honors Calculus II 4 Credits
Same topics as in MATH 022, but taught from a more thorough and rigorous point of view. Students may not obtain credit for more than one of Math022, Math032, Math052, Math082. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 031 or MATH 021
Attribute/Distribution: MA, Q

MATH 033 Honors Calculus III 0,4 Credits
Same topics as in MATH 023, but taught from a more thorough and rigorous point of view. Students may not obtain credit for more than one of Math023, Math033. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 022 or MATH 032
Attribute/Distribution: MA, Q

MATH 043 Survey of Linear Algebra 3 Credits
Matrices, vectors, vector spaces and mathematical systems, special kinds of matrices, elementary matrix transformations, systems of linear equations, convex sets, introduction to linear programming.
Attribute/Distribution: MA, Q

MATH 051 Survey of Calculus I 0,4 Credits
Limits. The derivative and applications to extrema, approximation, and related rates. Exponential and logarithm functions, growth and decay. Integration. Trigonometric functions and related derivatives and integrals. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Attribute/Distribution: MA, Q

MATH 052 Survey of Calculus II 3 Credits
Techniques of integration. Differential equations. Probability and calculus. Partial derivatives and extrema. Multiple integrals and applications. Students may not obtain credit for more than one of Math022, Math032, Math052, Math082. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 051 or MATH 021 or MATH 031 or MATH 076 or MATH 081
Attribute/Distribution: MA, Q

MATH 061 Calculus with Business Applications I, Part A 2 Credits
Covers the same material as the first half of MATH 081. Meets three hours per week, allowing more class time for each topic than does MATH 081. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math061 and Math062), (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Attribute/Distribution: MA, Q

MATH 062 Calculus with Business Applications I, Part B 2 Credits
Continuation of MATH 061, covering the second half of MATH 081. Meets three hours per week. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math061 and Math062), (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 061
Attribute/Distribution: MA, Q

MATH 075 Calculus I, Part A 2 Credits
Covers the same material as the first half of MATH 021. Meets three hours per week, allowing more class time for each topic than does MATH 021. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Attribute/Distribution: MA, Q

MATH 076 Calculus I, Part B 2 Credits
Continuation of MATH 075, covering the second half of MATH 021. Meets three hours per week. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 075
Attribute/Distribution: MA, Q

MATH 081 Calculus with Business Applications I 0,4 Credits
Limits and continuity; exponential, logarithmic and trigonometric functions; derivatives; extrema; approximations; indefinite and definite integrals. Applications with emphasis on business and economics. Students may not obtain credit for more than one of Math021, Math031, Math051, (Math075 and Math076), Math081. However all graded courses will still be factored into the GPA.
Attribute/Distribution: MA, Q

MATH 082 Calculus with Business and Economics Applications II 0,4 Credits
Integration by parts, partial fractions, Riemann sums; differential equations; series; Taylor series. Vectors, inner products and projections; functions of several variables, partial derivatives. Multiple integrals; vector-valued functions. Applications with emphasis on finance and economics. Students may not obtain credit for more than one of Math022, Math032, Math052, Math082. However all graded courses will still be factored into the GPA.
Prerequisites: MATH 081 or MATH 021 or MATH 031 or MATH 076 or MATH 051
Attribute/Distribution: MA, Q

MATH 091 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 114 (PHIL 114) Metalogic 4 Credits
This is a course on the metatheory of First-Order Predicate Logic. It offers expositions of some of the most important results of this metatheory, such as the Soundness and Completeness Theorems, Gödel's first and second Incompleteness Theorems, Tarski's Indefinability Theorem, and Church's Undecidability Theorem. It also offers introductory expositions of set theory, computability theory, and Second-Order Predicate Logic. The course is structured to serve the needs of a mixed audience, including students with no background in symbolic logic.
Attribute/Distribution: MA, Q

MATH 130 (BIOS 130) Biostatistics 0,4 Credits
Elements of statistics and probability with emphasis on biological applications. Statistical analysis of experimental and observational data.
Prerequisites: MATH 052 or MATH 022 or MATH 032
Attribute/Distribution: Q

MATH 163 Introduction to Mathematical Reasoning 3 Credits
An introduction to the discipline of mathematics for students considering a major in mathematics. Provides an introduction to rigorous mathematical reasoning, including basic proof techniques (e.g., basic propositional calculus, induction, contradiction) and key concepts which recur throughout mathematics (e.g., universal and existential quantifiers, equivalence classes, basic set theory). Students majoring in mathematics should complete this course before MATH 242, MATH 243 or MATH 301 and are encouraged to complete this course in the first or second year of study.
Prerequisites: MATH 021
Attribute/Distribution: Q

MATH 171 Readings 1-3 Credits
Study of a topic in mathematics under individual supervision. Intended for students with specific interests in areas not covered in the listed courses. Consent of department chair required.
Attribute/Distribution: MA

MATH 191 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 201 Problem Solving 1 Credit
Practice in solving challenging mathematics problems using a variety of techniques. Permission of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 202 Actuarial Exam I 1 Credit
Preparation for the first actuarial exam – probability. Problems in calculus and probability with insurance applications.
Prerequisites: (MATH 023 or MATH 052 or MATH 082) and (MATH 231 or MATH 263 or MATH 309)
Attribute/Distribution: Q

MATH 203 Actuarial Exam II - Financial Mathematics 2 Credits
Preparation for the second actuarial exam - financial mathematics. Mathematics of interest and investments, interest rate measurement, present value, annuities, loan repayment schemes, bond valuation, introduction to derivative securities. Practice in solving problems from past exams.
Prerequisites: MATH 022 or MATH 052 or MATH 082
Attribute/Distribution: MA, Q

MATH 205 Linear Methods 3 Credits
Linear differential equations and applications; matrices and systems of linear equations; vector spaces; eigenvalues and application to linear systems of differential equations.
Prerequisites: MATH 022 or MATH 082
Attribute/Distribution: Q

MATH 208 Complex Variables 3 Credits
Functions of a complex variable; calculus of residues; contour integration; applications to conformal mapping and Laplace transforms.
Prerequisites: MATH 023
Attribute/Distribution: Q

MATH 214 (PHIL 214) Topics in Philosophical Logic 4 Credits
Topics may include the many systems of non-classical logic, truth theory, the impact of incompleteness and undecidability results on philosophy, the foundational projects of various philosophers/mathematicians, or the work of an important figure in the history of philosophical logic. Student must have completed at least one Philosophy course at the 100-level.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 229 Geometry 3-4 Credits
Discussion of geometry as an axiomatic system. Euclid's postulates. History of and equivalent versions of Euclid's fifth postulate. Finite projective geometries. NonEuclidean geometries based upon negation of the fifth postulate: Geometry on the sphere; Hyperbolic and elliptic geometries. Examination of the concepts of “straight”, angle, parallel, symmetry and duality in each of these geometries. Applications of the different geometries will be considered.
Attribute/Distribution: MA, Q

MATH 230 Numerical Methods 3 Credits
Representation of numbers and rounding error; polynomial and spline interpolation; numerical differentiation and integration; numerical solution of nonlinear systems; numerical solution of initial and boundary value problems; Monte Carlo methods. Knowledge of MATLAB or PYTHON or C required.
Prerequisites: MATH 205 or MATH 241 or MATH 242
Attribute/Distribution: Q

MATH 231 Probability and Statistics 3 Credits
Probability and distribution of random variables; populations and random sampling; chi-square and t distributions; estimation and tests of hypotheses; correlation and regression theory of two variables. Not available for credit to students who have completed both MATH 263 and MATH 264.
Prerequisites: MATH 022 or MATH 052 or MATH 082
Attribute/Distribution: Q

MATH 234 Fractal Geometry 3 Credits
Metric spaces and iterated function systems; various types of fractal dimension; Julia and Mandelbrot sets. Other topics such as chaos may be included. Small amount of computer use.
Prerequisites: MATH 023
Attribute/Distribution: Q

MATH 241 Applied Linear Algebra 3,4 Credits
The theoretical basis for applying linear algebra in other fields, including statistics. Topics will include systems of equations, vector spaces, matrices, and linear transformations. Additional topics will include matrix factorizations (including LU, QR, eigen-decomposition, and SVD) and how they can be used in computer analysis of data sets. Not available for credit to students who have completed MATH 242 or STAT 342.
Prerequisites: MATH 022 or MATH 082
Attribute/Distribution: Q

MATH 242 Linear Algebra 3-4 Credits
An introduction to the study of vector spaces and linear transformations, with emphasis on mathematical rigor. Not available for credit to students who have completed MATH 241 / STAT 342.
Prerequisites: MATH 022 and MATH 163
Attribute/Distribution: Q

MATH 243 Algebra 3,4 Credits
Introduction to basic concepts of modern algebra: groups, rings, and fields.
Prerequisites: MATH 242
Attribute/Distribution: Q

MATH 252 Introduction to Combinatorics and Graph Theory 3 Credits
Topics in combinatorics and graph theory chosen to introduce the subjects and some of their common proof techniques. Sequences and recursive formulas; counting formulas; bijections; inclusion/exclusion; the Pigeonhole Principle; generating functions; equivalence relations. Graph theory topics include trees, connectivity, traversability, matching and coloring. Not available for credit to students who have completed MATH 305.
Prerequisites: MATH 022
Attribute/Distribution: Q

MATH 261 Discrete Structures 3 Credits
Topics in discrete mathematical structures chosen for their applicability to computer science and engineering. Sets, propositions, induction, recursion; combinatorics; binary relations and functions; ordering, lattices and Boolean algebra; graphs and trees; groups and homomorphisms.
Prerequisites: MATH 021 or MATH 076

MATH 263 Introduction to the Theory of Probability 3 Credits
An introduction to the basics of Calculus-based theory of Probability. Includes combinatorial techniques, events, independence, and conditional probability; discrete and continuous probability distributions, expectation and variance; joint distributions and covariance; moment generating functions; basic form of the Laws of Large Numbers and the Central Limit Theorem. Prior knowledge of Probability not required. Not available for credit to students who have completed (MATH 231 and MATH 264) or MATH 309. Cannot be taken concurrently to MATH 309.
Prerequisites: MATH 022 or MATH 032 or MATH 052 or MATH 082
Attribute/Distribution: Q

MATH 264 Introduction to Statistical Reasoning and Methods 0,4 Credits
Introduction to the basic concepts, logic and issues involved in statistical reasoning and statistical methods used to analyze data and evaluate studies. Topics include descriptive statistics and exploratory data analysis, and basic concepts of machine learning; elementary probability and statistical inference. Examples drawn from various areas of application. Use of computer software (e.g., Minitab, R) to facilitate understanding and to complete data analysis. Not available for credit to students who have completed both MATH 231 and MATH 263.
Prerequisites: MATH 021 or MATH 051 or MATH 081
Attribute/Distribution: Q

MATH 271 Readings 1-3 Credits
Study of a topic in mathematics under individual supervision. Intended for students with specific interests in areas not covered in the listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA

MATH 281 Undergraduate Research 1-4 Credits
Research in mathematics or statistics under the direction of a faculty member. Department permission required.
Repeat Status: Course may be repeated.

MATH 282 Internship 1-4 Credits
Professionally supervised practicum experience in an area related to Mathematics or Statistics.
Repeat Status: Course may be repeated.

MATH 291 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 300 Apprentice Teaching 1-4 Credits
Supervised participation in various aspects of the teaching of a course. Consent of instructor, department chairperson, and permission of the Dean required.
Repeat Status: Course may be repeated.

MATH 301 Principles of Analysis I 3-4 Credits
Existence of limits, continuity and uniform continuity; HeineBorel Theorem; existence of extreme values; mean value theorem and applications; conditions for the existence of the Riemann integral; absolute and uniform convergence; emphasis on theoretical material from the calculus of one variable.
Prerequisites: MATH 023
Attribute/Distribution: Q, W

MATH 305 Enumerative Combinatorics 3 Credits
An introduction to basic theoretical results and techniques of enumerative combinatorics such as combinatorial identities, generating functions, inclusion/exclusion, recurrence relations, bijective proofs and permutations. Additional topics will be covered as time permits.
Prerequisites: MATH 242
Attribute/Distribution: Q

MATH 307 General Topology I 3-4 Credits
An introductory study of topological spaces, including metric spaces, separation and countability axioms, connectedness, compactness, product spaces, quotient spaces, function spaces.
Prerequisites: MATH 301
Attribute/Distribution: MA, Q

MATH 309 Probability with Applications and Simulations 3 Credits
Foundations of Probability; Random Variables; Probability Models; Expectations and Moment Generating Functions; Joint and Conditional Distributions; Functions of Random Variables. Introduction to fundamental ideas and techniques of stochastic modeling, with an emphasis on the applications. The last part of the course is devoted to techniques and methods of Monte Carlo simulation. R or other software will be used in this course.
Prerequisites: MATH 022 or MATH 032 or MATH 052 or MATH 082
Attribute/Distribution: Q

MATH 310 Random Processes and Applications 3-4 Credits
Theory and applications of stochastic processes. Limit theorems, introduction to random walks, Markov chains, Poisson processes, birth and death processes, and Brownian motion. Applications to financial mathematics, biology, business and engineering.
Prerequisites: MATH 263 or MATH 309 or (MATH 231 and (MATH 205 or MATH 241),)
Attribute/Distribution: Q

MATH 311 Graph Theory 3 Credits
An introduction to basic theoretical results and techniques of graph theory such as trees, connectivity, matchings, coloring, planar graphs and Hamiltonicity. Additional topics will be covered as time permits.
Prerequisites: MATH 163 or MATH 252 or CSE 140
Attribute/Distribution: Q

MATH 312 Statistical Computing and Applications 3,4 Credits
Use of statistical computing packages; exploratory data analysis; Monte Carlo methods; randomization and resampling, application and interpretation of a variety of statistical methods in real world problems.
Prerequisites: (MATH 012 or MATH 231 or MATH 264 or ECO 045) and (MATH 021 or MATH 031 or MATH 051 or MATH 062 or MATH 076 or MATH 081)
Attribute/Distribution: Q

MATH 316 Complex Analysis 3-4 Credits
Concept of analytic function from the points of view of the CauchyRiemann equations, power series, complex integration, and conformal mapping.
Prerequisites: MATH 301
Attribute/Distribution: MA, Q

MATH 319 Introduction to Differential Equations 3 Credits
An introductory, yet rigorous treatment of topics in differential equations chosen to prepare students for advanced work in mathematics or applied mathematics. Homogeneous and non-homogeneous linear differential equations, existence and uniqueness theorems, Gronwall's inequality; systems of first order linear differential equations; autonomous first-order systems: critical points, stability, bifurcation; series and periodic solutions, Fourier series and their convergence; introduction to numerical simulation methods.
Prerequisites: MATH 242 or MATH 205 or MATH 241
Attribute/Distribution: Q

MATH 320 Ordinary Differential Equations 3-4 Credits
The analytical and geometric theory of ordinary differential equations, including such topics as linear systems, systems in the complex plane, oscillation theory, stability theory, geometric theory of nonlinear systems, finite difference methods, general dynamical systems.
Prerequisites: MATH 023 and (MATH 205 or MATH 319)
Attribute/Distribution: Q

MATH 321 Topics in Discrete Mathematics 3 Credits
Selected topics in areas of discrete mathematics. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 322 Methods of Applied Analysis I 3 Credits
Fourier series, eigenfunction expansions, SturmLiouville problems, Fourier integrals and their application to partial differential equations; special functions. Emphasis is on a wide variety of formal applications rather than logical development.
Prerequisites: MATH 205 or MATH 319
Attribute/Distribution: Q

MATH 323 Methods of Applied Analysis II 3 Credits
Green's functions; integral equations; variational methods; asymptotic expansions, method of saddle points; calculus of vector fields, exterior differential calculus.
Prerequisites: MATH 322
Attribute/Distribution: MA, Q

MATH 327 Groups and Rings 3-4 Credits
An intensive study of the concepts of group theory including the Sylow theorems, and of ring theory including unique factorization domains and polynomial rings.
Prerequisites: MATH 242 and MATH 243
Attribute/Distribution: MA, Q

MATH 331 Differential Geometry of Curves and Surfaces 3 Credits
Local and global differential geometry of curves and surfaces in Euclidean 3space. Frenet formulas for curves, isoperimetric inequality, 4vertex theorem; regular surfaces, first fundamental form, Gauss map, second fundamental form; curvatures for curves and surfaces and their relations; The GaussBonnet theorem.
Prerequisites: MATH 023 and (MATH 205 or MATH 242)
Attribute/Distribution: Q

MATH 334 Mathematical Statistics 3-4 Credits
Populations and random sampling; sampling distributions; theory of statistical estimation; criteria and methods of point and interval estimation; theory of testing statistical hypotheses.
Prerequisites: (MATH 263 or MATH 309) and (MATH 264 or MATH 231)
Attribute/Distribution: Q

MATH 338 Statistical Models in Data Science 3,4 Credits
Least square principles in multiple regression and their interpretations; estimation, hypotheses testing, confidence and prediction intervals, modeling, regression diagnostic, multicollinearity, model selection, analysis of variance and covariance; logistic regression. Introduction to topics in time series analysis such as ARMA, ARCH, and GARCH models. Applications to natural sciences, finance and economics. Use of computer packages.
Prerequisites: (MATH 012 or MATH 231 or MATH 264) and (MATH 043 or MATH 205 or MATH 241 or MATH 242 or STAT 342)
Attribute/Distribution: Q

MATH 339 Time Series and Forecasting 3,4 Credits
This course introduces the student to the statistical analysis of time series data and useful models: autocorrelation, stationarity, trend removal, and seasonal adjustment, basic time series models like AR, MA, ARMA; estimation, forecasting, and GARCH models; multivariate models, and factor models. The course emphasizes the main ideas and the most popular and widely used methods, and the use of a computer to practice the methods. Knowledge of scientific programming in a language such as R required.
Prerequisites: (MATH 264 or MATH 312) and (MATH 263 or MATH 309)
Attribute/Distribution: Q

MATH 340 (CSE 340) Design and Analysis of Algorithms 0,3 Credits
Algorithms for searching, sorting, manipulating graphs and trees, finding shortest paths and minimum spanning trees, scheduling tasks, etc.: proofs of their correctness and analysis of their asymptotic runtime and memory demands. Designing algorithms: recursion, divide-and-conquer, greediness, dynamic programming. Limits on algorithm efficiency using elementary NP-completeness theory.
Prerequisites: (MATH 021 or MATH 031 or MATH 076) and CSE 140 and CSE 017
Attribute/Distribution: Q

MATH 341 Mathematical Models and Their Formulation 3 Credits
Mathematical modeling of engineering and physical systems with examples drawn from diverse disciplines. Emphasis is on building models of real world problems and the analysis as well as numerical simulations of the models.
Prerequisites: MATH 205 or MATH 241 or MATH 242
Attribute/Distribution: Q

MATH 342 Number Theory 3-4 Credits
Basic concepts and results in number theory, including such topics as primes, the Euclidean algorithm, Diophantine equations, congruences, quadratic residues, quadratic reciprocity, primitive roots, number-theoretic functions, distribution of primes, Pell's equation, Fermat's theorem, partitions. Consent of instructor required.
Attribute/Distribution: MA, Q

MATH 343 Introduction To Cryptography 3,4 Credits
Classical elementary cryptography: Caesar cipher, other substitution ciphers, block ciphers, general linear ciphers. Fast random encryption (DES and AES: Advanced Encryption Standard). Public key systems (RSA and discrete logs). Congruences, modular arithmetic, fast exponentiation, polynomials, matrices. Distinction between polynomial time (primality), Subexponential time (factoring) and fully Exponential computation (elliptic curves). Introduction to sieving and distributed computation. Consent of instructor required.
Attribute/Distribution: MA, Q

MATH 365 Statistical Machine Learning 3,4 Credits
This course provides a broad introduction to concepts, methods, and practices of statistical machine learning: parametric and nonparametric regression, logistic regression, classification, and basic neural networks; kernel and nearest neighbor estimation, clustering, Bayesian and mixture models. In addition, we will explore selected topics like model selection, cross-validation; PCA, dimension reduction, regularized regression; trees, and ensemble learning. Knowledge of scientific programming in a language such as R required.
Prerequisites: (MATH 205 or MATH 241 or MATH 242) and (MATH 264 or MATH 312) and (MATH 263 or MATH 309)
Attribute/Distribution: Q

MATH 369 Mathematics of Actuarial Science 3 Credits
Introduces tools from actuarial and financial mathematics necessary for insurance applications both for property/casualty insurance as well as life insurance. It presents the basic mathematics of interest rates and investments, such as present value, annuity calculations, and bond valuation, as well as elements of actuarial premium calculation. An introduction to modeling claims with both frequency and severity distribution, as well as modeling with Poisson processes and possibly Markov Chains will be presented. Aspects of survival analysis, as used in life-insurance.
Prerequisites: MATH 309 or MATH 310

MATH 371 Readings 1-3 Credits
The study of a topic in mathematics under appropriate supervision, designed for the individual student who has studied extensively and whose interests lie in areas not covered in the listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 374 Statistical Project 3 Credits
Supervised field project or independent reading in statistics or probability. Consent of department chair required.
Attribute/Distribution: MA, Q, W

MATH 381 Undergraduate Research 1-4 Credits
Research in mathematics or statistics under the direction of a faculty member. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: Q

MATH 382 Internship 1-4 Credits
Professionally supervised practicum experience in an area related to Mathematics or Statistics.
Repeat Status: Course may be repeated.

MATH 383 Senior Honors Thesis 3 Credits
Independent research under faculty supervision, culminating in a thesis presented for departmental honor. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 391 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: MA, Q

MATH 401 Real Analysis I 3 Credits
Set theory, real numbers; introduction to measures, Lebesgue measure; integration, general convergence theorems; differentiation, functions of bounded variation, absolute continuity; Lp spaces.
Prerequisites: MATH 301

MATH 402 Real Analysis II 3 Credits
Metric spaces; introduction to Banach and Hilbert space theory; Fourier series and Fejer operators; general measure and integration theory, RadonNikodym and Riesz representation and theorems; LebesgueStieljtes integral.
Prerequisites: MATH 307 or MATH 401

MATH 405 Partial Differential Equations I 3 Credits
Classification of partial differential equations; methods of characteristics for first order equations; methods for representing solutions of the potential, heat, and wave equations, and properties of the solutions of these equations; maximum principles.
Prerequisites: MATH 319 or MATH 320

MATH 406 Partial Differential Equations II 3 Credits
Continuation of MATH 405. Emphasis on second order equations with variable coefficients and systems of first order partial differential equations.
Prerequisites: MATH 405

MATH 408 Algebraic Topology I 3 Credits
Polyhedra; fundamental groups; simplicial and singular homology.
Prerequisites: MATH 307 and (MATH 243 or MATH 327)

MATH 409 Mathematics Seminar 1-6 Credits
An intensive study of some field of mathematics not offered in another course. Consent of department chair required.

MATH 410 Independent study 1-4 Credits
The study of a topic in mathematics under appropriate supervision, designed for the individual student who has studied extensively and whose interests lie in areas not covered in the listed courses. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 416 Complex Function Theory 3 Credits
Continuation of MATH 316.
Prerequisites: MATH 316

MATH 423 Differential Geometry I 3 Credits
Differential manifolds, tangent vectors and differentials, submanifolds and the implicit function theorem. Lie groups and Lie algebras, homogeneous spaces. Tensor and exterior algebras, tensor fields and differential forms, de Rham cohomology, Stokes' theorem, the Hodge theorem. Must have completed the required course prerequisites or receive permission of instructor.
Prerequisites: MATH 243 and MATH 301 and MATH 307

MATH 424 Differential Geometry II 3 Credits
Curves and surfaces in Euclidean space; mean and Gaussian curvatures, covariant differentiation, parallelism, geodesics, GaussBonnet formula. Riemannian metrics, connections, sectional curvature, generalized GaussBonnet theorem. Further topics.
Prerequisites: MATH 423

MATH 428 Fields And Modules 3 Credits
Field theory, including an introduction to Galois theory; the theory of modules, including tensor products and classical algebras.
Prerequisites: MATH 327

MATH 430 Numerical Analysis 3 Credits
Multistep methods for ordinary differential equations; finite difference methods for partial differential equations; numerical approximation of functions. Use of computer required.
Prerequisites: MATH 230

MATH 435 Functional Analysis I 3 Credits
Banach spaces and linear operators; separation and extension theorems; open mapping and uniform boundedness principles; weak topologies; local convexity and duality; Banach algebras; spectral theory of operators; and compact operators.
Prerequisites: MATH 307 and MATH 401

MATH 444 Algebraic Topology II 3 Credits
Continuation of MATH 408. Cohomology theory, products, duality.
Prerequisites: MATH 408

MATH 445 Topcs in Algebraic Topology 3 Credits
Selected topics reflecting the interests of the professor and the students.
Prerequisites: MATH 444

MATH 449 Topics In Algebra 3 Credits
Intensive study of topics in algebra with emphasis on recent developments. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 455 Topics In Number Theory 3 Credits
Selected topics in algebraic and/or analytic number theory. Consent of instructor required.
Repeat Status: Course may be repeated.

MATH 461 Topics In Mathematical Statistcs 3 Credits
An intensive study of one or more topics such as theory of statistical tests, statistical estimation, regression, analysis of variance, nonparametric methods, stochastic approximation, and decision theory.
Repeat Status: Course may be repeated.
Prerequisites: MATH 334 and MATH 401

MATH 462 Modern Nonparametric Methods in Statistics 3 Credits
Classical and modern methods of nonparametric statistics; order and rank statistics; tests based on runs, signs, ranks, and order statistics; distribution free statistical procedures for means, variances, correlations, and trends; relative efficiency; KolmogorovSmirnov statistics; statistical applications of Brownian process; modern techniques such as robust methods, nonparametric smoothing, and bootstrapping; additional topics such as nonparametric regression and dimension reduction.
Prerequisites: (MATH 334 or STAT 334) and (MATH 338 or STAT 338)

MATH 463 (STAT 463) Advanced Probability 3 Credits
Measure theoretic foundations; random variables, integration in a measure space, expectations; convergence of random variables and probability measures; conditional expectations; characteristic functions; sums of random variables, limit theorems.
Prerequisites: MATH 309 and MATH 401

MATH 464 Advanced Stochastic Process 3 Credits
Theory of stochastic processes; stopping times; martingales; Markov processes; Brownian motion; stochastic calculus; Brownian bridge, laws of suprema; Gaussian processes.
Prerequisites: MATH 309 and MATH 401

MATH 465 Topics in Probability 3 Credits
Selected topics in probability. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 467 Stochastic Calculus 3 Credits
Brownian Motion, Martingales. Introduction to the theory of Stochastic Calculus, Itô Formula, and Stochastic Differential Equations, Black-Scholes model. Development of the Martingale Representation Theorem and Girsanov's theorem for change of measure. Multidimensional Stochastic Calculus. Applications to different problems from finance, physics, biology, etc.
Prerequisites: MATH 231 or MATH 309

MATH 468 Financial Stochastic Analysis 3 Credits
Basic mathematical concepts behind pricing of derivative securities. Hedging and pricing by arbitrage in the setting of binary trees and Black-Scholes model. Application of Stochastic Calculus to the pricing of a variety of financial instruments: multiple stock models, American and exotic options, and foreign currency interest rate. Heath-Jarrow-Morton model for the term structure of interest rates and short rate models. Applications of the theory to a variety of interest rates contracts including swaps, caps, floors, swap options.
Prerequisites: MATH 467

MATH 470 Proseminar 1-3 Credits
Preparation for entering the mathematics profession. Topic of emphasis typically include methods of teaching mathematics, commonly available research tools and the publication process, the responsibilities of an academic position, and searching for a job. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 471 Homological Algebra 3 Credits
Modules, tensor products, categories and functors, homology functors, projective and injective modules.
Prerequisites: MATH 428

MATH 472 Group Representations 3 Credits
Linear representations and character theory with emphasis on the finite and compact cases.
Prerequisites: MATH 428

MATH 475 Topics in Geometry 3 Credits
Selected topics in geometry, such as geometric analysis, algebraic geometry, complex geometry, characteristic classes, geometric flows or geometric measure theory, with emphasis on recent developments. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 481 Research 1-4 Credits
Research in mathematics or statistics under the direction of a faculty member. Consent of department chair required.
Repeat Status: Course may be repeated.

MATH 490 Thesis 1-6 Credits

MATH 491 Special Topics 1-3 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.

MATH 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.

Statistics Courses

STAT 342 Applied Linear Algebra 3 Credits
The theoretical basis for applying linear algebra in other fields, including statistics. Topics will include systems of equations, vector spaces, matrices, and linear transformations. Additional topics will include matrix factorizations (including LU, QR, eigen-decomposition, and SVD) and how they can be used in computer analysis of data sets. Not available for credit to students who have completed MATH 241 or MATH 242.
Prerequisites: MATH 022 or MATH 032 or MATH 052 or MATH 082
Attribute/Distribution: Q

STAT 408 Seminar in Statistics and Probability 1-6 Credits
Intensive study of some field of statistics or probability not offered in another course. Consent of department required.

STAT 409 Seminar in Statistics and Probability 1-6 Credits
Intensive study of some field of statistics or probability not offered in another course. Consent of department required.

STAT 410 Random Processes and Applications 3 Credits
See MATH 310.

STAT 412 Advanced Applied Statistics 3 Credits
Selected advanced topics in applied statistics. Possible topics include nonparametric statistics, multivariate statistics, generalized linear model, survival analysis, time series analysis or other modern applied statistical methods with application to real world problems. Topics could vary from one semester to another depending on the interests of the faculty member and the students.
Repeat Status: Course may be repeated.

STAT 434 Mathematical Statistics 3 Credits
See MATH 334.
Prerequisites: (MATH 263 or MATH 309) and (MATH 264 or MATH 231)

STAT 438 Linear Models In Statistics with Applications 3 Credits
See MATH 338.

STAT 439 Time Series and Forecasting 3 Credits
See MATH 339.

STAT 461 Topics In Mathematical Statistics 3 Credits
See MATH 461.

STAT 462 Modern Nonparametric Methods in Statistics 3 Credits
See MATH 462.

STAT 463 (MATH 463) Advanced Probability 3 Credits
See MATH 463.
Prerequisites: MATH 309 and MATH 401

STAT 464 Advanced Stochastic Processes 3 Credits
See MATH 464.

STAT 465 Statistical Machine Learning 3 Credits
See MATH 365.

STAT 471 Topics in Statistical Learning and Computing 3 Credits
Selected advanced topics in statistical learning and computing. Possible topics include linear and nonlinear regression, applied spatial statistics, applied multivariate and longitudinal data analysis, functional data analysis, survival analysis, data analytics, statistical methods that use intensive-computing or simulations, data mining techniques, with application and interpretation of a variety of statistical methods in real world problems. Topics could vary from one semester to another depending on the interests of the faculty member and the students.
Repeat Status: Course may be repeated.

STAT 474 Statistical Practice 3 Credits
Outside university consulting practice that is led by faculty members and experienced members from companies in the region. The live consulting projects provide working examples from which students gain practical experience in statistical practice. Students use this experience to assemble a portfolio of materials that demonstrates the knowledge and skills they have gained during their time in the program. This also offers opportunities to interface with working professionals through the practical training experience. Permission of instructor required.
Repeat Status: Course may be repeated.
Prerequisites: MATH 312 and STAT 438 and STAT 434 and (STAT 465 or STAT 471)