**MATHEMATICS (BA)**

Chair: Byung-Jay Kahng, PhD

**Introduction**

The Department of Mathematics and Statistics strives to transmit an understanding and appreciation of mathematics: its substance, its applicability, its literature, its current directions and problems, its historical development, its human worth and values; and to promote the development of skill in the practice of mathematics. For a more detailed description of the program, faculty, facilities, academic and co-curricular opportunities please go to the Mathematics and Statistics website (https://www.canisius.edu/academics/programs/mathematics).

**Qualifications**

Students must maintain a 2.0 GPA in their major and a 2.0 overall average to graduate with a degree in Mathematics and Statistics. Students must have a minimum grade of C- in all courses in the major.

**Advisement**

All students should have an advisor in the major and should contact the department directly to have an advisor assigned if they do not already have one. Meetings with academic advisors are required prior to students receiving their PIN for course registration each semester. All majors should work closely with their advisor in discussing career expectations, choosing their major electives, developing their entire academic program and planning their co-curricular or supplemental academic experiences.

**Double Majors**

Students who wish to expand their educational opportunities may decide to declare a double major. The decision may be based on career goals or planned graduate studies. Before a student declares a double major, it is important to meet with the appropriate academic departments for advisement. Some double major combinations can be completed within the minimum 120 credit hour degree requirement, but in some cases additional coursework may be required. In order to declare a double major, the student must complete the appropriate double major request form and get the signature of each department chairperson and the appropriate associate dean. Please note that students will receive only one degree, regardless of the number of majors they complete.

Popular double majors with mathematics are economics, computer science, education, and physics, but we have also had students double major in math and music, English, political science, philosophy, Spanish, psychology, pre-medicine, and other fields.

**Minors in Other Disciplines**

Minors provide students the opportunity to pursue additional interests but generally do not require as many courses as a major. Minors generally range from five to eight required courses. The minors page (http://catalog.canisius.edu/undergraduate/minors) provides a complete list of minors and provides links to each minor. Some majors and minors can be completed within the minimum 120 credit hour degree requirement, but in some cases additional coursework may be required. Students must complete the appropriate minor request form.

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**Curriculum**

**An Ignatian Foundation**

All undergraduate students must complete either the Canisius Core Curriculum (http://catalog.canisius.edu/undergraduate/academics/core-curriculum) or the All-College Honors Curriculum (http://catalog.canisius.edu/undergraduate/academics/core-curriculum/all-college-honors-program). Many schools refer to their college-wide undergraduate requirements as “general education” requirements. We believe that the core curriculum and the honors curriculum are more than a series of required classes; they provide the basis for a Jesuit education both with content and with required knowledge and skills attributes that are central to our mission.

**Free Electives**

Students may graduate with more but not less than 120 credit hours. Free electives are courses in addition to the Canisius Core Curriculum or All-College Honors Curriculum and major requirements sufficient to reach the minimum of 120 credit hours required for graduation.

**Major Requirements**

**Option A (Mathematics Major)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>MAT 111</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MAT 112</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MAT 219</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>MAT 222</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>or MAT 351</td>
<td>Probability &amp; Statistics I</td>
<td></td>
</tr>
<tr>
<td>MAT 230</td>
<td>Logic, Set Theory, and Proofs</td>
<td>4</td>
</tr>
<tr>
<td>MAT 311</td>
<td>Abstract Algebra</td>
<td>4</td>
</tr>
<tr>
<td>MAT 321</td>
<td>Real Analysis</td>
<td>4</td>
</tr>
<tr>
<td>MAT 380</td>
<td>Mathematics Seminar</td>
<td>1</td>
</tr>
<tr>
<td>MAT 381</td>
<td>Mathematics Seminar</td>
<td>1</td>
</tr>
<tr>
<td>MAT 480</td>
<td>Mathematics Seminar</td>
<td>1</td>
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</table>

Select one of the following: 3

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MAT 312</td>
<td>Topics in Algebra</td>
<td></td>
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<tr>
<td>MAT 322</td>
<td>Topics in Analysis</td>
<td></td>
</tr>
<tr>
<td>MAT 352</td>
<td>Probability &amp; Statistics II</td>
<td></td>
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<tr>
<td>MAT 421</td>
<td>Complex Analysis</td>
<td></td>
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</tbody>
</table>

Select four courses from the following: 12-16

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 411</td>
<td>Mathematical Analysis for Physicists</td>
</tr>
<tr>
<td>PHY 446</td>
<td>Quantum Mechanics I</td>
</tr>
</tbody>
</table>

Choose one of the following two sequences: 6-8

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>PHY 223, PHY 223L, Phy 224, and PHY 224L</td>
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</table>

Any two Economics (ECO) classes

<table>
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<tr>
<th>Code</th>
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<th>Credits</th>
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</table>

**Option B (Mathematics with a Concentration in Another Area)**

<table>
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</thead>
<tbody>
<tr>
<td>MAT 111</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MAT 112</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
</tbody>
</table>
MAT 219  Linear Algebra  4
MAT 222  Differential Equations  3
or MAT 351  Probability & Statistics I  4
MAT 230  Logic, Set Theory, and Proofs  4
MAT 311  Abstract Algebra  4
MAT 321  Real Analysis  4
MAT 380  Mathematics Seminar  1
MAT 381  Mathematics Seminar  1
MAT 480  Mathematics Seminar  1
Select one of the following:  3
   MAT 312  Topics in Algebra
   MAT 322  Topics in Analysis
   MAT 352  Probability & Statistics II
   MAT 421  Complex Analysis
Select two of the following:  6-8
   any additional 300 or 400-level mathematics courses
   PHY 335  Mathematical Analysis for Physicists
   PHY 446  Quantum Mechanics I
Choose one of the following two sequences:  6-8
   General Physics for Physical Science Majors (PHY 223, PHY 223L, Phy 224, and PHY 224L)
   Any two Economics (ECO) classes
Four courses in another area approved by the Department of Mathematics and Statistics  12
Total Credits  61-65

Option C (Statistics)

<table>
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<tr>
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<tbody>
<tr>
<td>MAT 111</td>
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<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MAT 219</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>MAT 222</td>
<td>Differential Equations (or 300 or 400-level mathematics course)</td>
<td>3</td>
</tr>
<tr>
<td>MAT 230</td>
<td>Logic, Set Theory, and Proofs</td>
<td>4</td>
</tr>
<tr>
<td>MAT 321</td>
<td>Real Analysis</td>
<td>4</td>
</tr>
</tbody>
</table>
Select one of the following:  3-4
   MAT 311  Abstract Algebra
   MAT 322  Topics in Analysis
   MAT 421  Complex Analysis
   MAT 351  Probability & Statistics I
   MAT 352  Probability & Statistics II
   MAT 353  Regression Analysis
   MAT 354  Experimental Design and Statistical Computing
   MAT 380  Mathematics Seminar
   MAT 381  Mathematics Seminar
   MAT 480  Mathematics Seminar
Select one additional upper-level MAT elective  3-4
Choose one of the following two sequences:  6-8
   General Physics for Physical Science Majors (PHY 223, PHY 223L, Phy 224, and PHY 224L)
   Any two Economics (ECO) classes
   MAT elective
   MAT elective
   MAT elective
   MAT elective
   MAT 312
   MAT 322
   MAT 352 (MAT 352 is typically offered in the fall semester.)
   MAT 421
   MAT elective

Any two Economics (ECO) classes  54-58

Additional Course Considerations

Option A is designed to prepare the student for positions in which mathematical competence is sought, as well as for advanced study in graduate school.

Option B allows the student to develop expertise in another area besides mathematics. Many students combine this option with a major or minor in another department. Students interested in education can get a dual major to give them a strong background in mathematics while fulfilling the requirements of the School of Education.

Option C prepares the student for advanced work or graduate study and the many careers which utilize statistical thinking. This option, together with appropriate courses in business, constitutes a good preparation for a career in actuarial science.

Roadmap

Recommended Semester Schedule for Major Courses

Option A

Freshman
Fall
MAT 111
Spring
MAT 112
PHY 223 (or ECO course)
PHY 224 (or ECO course)

Sophomore
Fall
MAT 211
Spring
MAT 219
MAT 230
MAT 222 or 351

Junior
Fall
MAT 311
Spring
MAT 381
MAT 321
MAT elective
MAT 380

Senior
Fall
MAT 480
Spring
Select one of the following (‘restricted elective’):

<table>
<thead>
<tr>
<th>Code</th>
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<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MAT elective</td>
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<td></td>
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<tr>
<td>MAT 312</td>
<td></td>
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<tr>
<td>MAT 322</td>
<td></td>
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<tr>
<td>MAT 352 (MAT 352 is typically offered in the fall semester.)</td>
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<tr>
<td>MAT 421</td>
<td></td>
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<tr>
<td>MAT elective</td>
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</tbody>
</table>

Option B

Freshman
Fall
MAT 111
Spring
MAT 112
PHY 223 (or ECO course)
PHY 224 (or ECO course)

Sophomore
Fall
MAT 211
Spring
MAT 219
MAT 230
MAT 222 or 351
Mathematics (BA)

Junior

Fall
- MAT 311
- MAT 321
- MAT 380

Spring
- MAT 381
- MAT elective

Senior

Fall
- MAT 480
- Select one of the following ("restricted elective"):
  - MAT elective
  - MAT 312
  - MAT 322
  - MAT 352 (MAT352 is typically offered in the fall semester.)
  - MAT 421

Spring
- MAT elective

Option C

Freshman

Fall
- MAT 111
- PHY 223 (or ECO course)

Spring
- MAT 112
- PHY 224 (or ECO course)

Sophomore

Fall
- MAT 211
- MAT 230

Spring
- MAT 219
- MAT 351

Junior

Fall
- MAT 321
- MAT 352
- Select one of the following statistics electives:
  - MAT 380
  - MAT 353
  - MAT 354

Spring
- MAT 381

Senior

Fall
- MAT 480
- Select one of the following statistics electives:
  - MAT elective
  - MAT 353
  - MAT 354

Spring
- MAT 352 (MAT311 is typically offered in the fall semester.)

- MAT 421

Learning Goals & Objectives

Student Learning Goal 1:
Mathematics majors will perform tasks requiring logical reasoning.
Students will:
- Objective A: Understand the different types of mathematical statements and how they are used, including definitions, axioms, hypotheses, conclusions, theorems, corollaries, lemmata, and conjectures;
- Objective B: Understand methods of proof.

Student Learning Goal 2
Mathematics majors will know the content of the fundamental fields of mathematics and can perform tasks requiring complex reasoning.
Students will:
- Objective A: Use basic skills to manipulate expressions;
- Objective B: Know the basic definitions and theorems of mathematics;
- Objective C: Be able to perform tasks requiring complex reasoning.

Student Learning Goal 3
Mathematics majors will advance their understanding and knowledge of mathematics and their ability to convey mathematical concepts through currently available technology.
Students will:
- Objective A (Information Literacy): Use the internet and/or library resources to obtain relevant information concerning historical information or mathematical content in regards to current course or project. Students will be expected to both look up sources and learn to search for their own sources;
- Objective B (Computation): Use computers or graphing calculators to perform labor-intensive calculations and/or create graphical displays. Programs include, but are not limited to, Excel, Minitab (or other statistical software), and Mathematica (or other software);
- Objective C (Presentation): Use technology for the purpose of elegantly presenting mathematical ideas, theories or results. Technologies include PowerPoint, Prezzi, Jing, Beamer, Latex, Word, and graphical tools.

Student Learning Goal 4
Mathematics majors will communicate mathematical ideas with precision and clarity.
Students will:
- Objective A: Present mathematical material in writing;
- Objective B: Present mathematical material orally.

Minor
Mathematics Minor
(7 courses)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>Required Courses</td>
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</tr>
<tr>
<td>MAT 111</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>or MAT 115</td>
<td>Calculus for Business</td>
<td></td>
</tr>
<tr>
<td>MAT 112</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MAT 219</td>
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</tr>
<tr>
<td>MAT 230</td>
<td>Logic, Set Theory, and Proofs</td>
<td>4</td>
</tr>
</tbody>
</table>

Select one of the following tracks and take two of the courses in that track: 6-8

- Probability and Statistics:
  - MAT 351 Probability & Statistics I
  - MAT 352 Probability & Statistics II
Offered:

MAT 222  Differential Equations
MAT 341  Numerical Analysis
MAT 342  Graph Theory
MAT 345  Climate and Sustainability
PHY 335  Mathematical Analysis for Physicists

Prerequisite:

already has credit for MAT 111 or MAT 115.

Continuation of MAT 109. Differentiation, related rates, optimization problems, anti-differentiation, definite integral. Credit not allowed if student already has credit for MAT 111 or MAT 115.

Prerequisite: MAT 109

Offered: spring.

MAT 111 Calculus I

For science and mathematics majors. Calculus of functions of single variable. Functions, limits, differentiation, continuity, graphing, logarithm, exponential and inverse trigonometric functions, related rates, optimization problems, mean value theorem, l'Hospital's rule, anti-differentiation, definite integral. Credit not allowed if student already has credit for MAT 109 and MAT 110 or for MAT 115.

Fulfills College Core: Field 7 (Mathematical Sciences)

Offered: fall & spring.

MAT 112 Calculus II

Applications of integration, integration techniques, improper integrals, sequences, series, convergence tests, Taylor's series, applications; parametric and polar curves.

Prerequisite: minimum grade of C- in one of the following MAT 109 & MAT 110, MAT 111 or MAT 115.

Offered: fall & spring.

MAT 115 Calculus for Business

Credit for business students. Differentiation and integration of functions of one variable. Applications, concepts, examples and problems in economics and business. Credit not allowed if student already has credit for either MAT 109 and MAT 110 or for MAT 111.

Prerequisite: 3 1/2 years of high school mathematics.

Fulfills College Core: Field 7 (Mathematical Sciences)

Offered: every fall & spring.

MAT 109 Calculus with Review I

For science and mathematics majors. Calculus, with topics from pre-calculus. Logarithmic and exponential functions, trigonometric functions, limits, differentiation. Credit not allowed if student already has credit for MAT 111 or MAT 115.

Fulfills College Core: Field 7 (Mathematical Sciences)

Offered: fall.

MAT 110 Calculus with Review II

Continuation of MAT 109. Differentiation, related rates, optimization problems, anti-differentiation, definite integral. Credit not allowed if student already has credit for MAT 111 or MAT 115.

Prerequisite: MAT 109

Offered: spring.

MAT 110 Calculus with Review II

Continuation of MAT 109. Differentiation, related rates, optimization problems, anti-differentiation, definite integral. Credit not allowed if student already has credit for MAT 111 or MAT 115.

Prerequisite: MAT 109

Offered: spring.

MAT 109 Calculus with Review I

For science and mathematics majors. Calculus, with topics from pre-calculus. Logarithmic and exponential functions, trigonometric functions, limits, differentiation. Credit not allowed if student already has credit for MAT 111 or MAT 115.

Fulfills College Core: Field 7 (Mathematical Sciences)

Offered: fall.

MAT 110 Calculus with Review II

Continuation of MAT 109. Differentiation, related rates, optimization problems, anti-differentiation, definite integral. Credit not allowed if student already has credit for MAT 111 or MAT 115.

Prerequisite: MAT 109

Offered: spring.
MAT 161 Mathematics for Elementary Teachers  3 Credits
Designed to provide a solid foundation for the mathematical topics encountered in elementary schools. The primary goal is to develop a deep understanding of mathematical concepts so future teachers can teach with knowledge and confidence. The main topics are: problem solving processes and strategies, elementary set theory, the theory behind basic arithmetic, number systems, basic probability and statistics, elementary geometry.
Prerequisite: 3 years of high school mathematics or equivalent.
Fulfills College Core: Field 7 (Mathematical Sciences)
Offered: occasionally.

MAT 191 Introduction to Discrete Mathematics  4 Credits
Fundamental topics with computer science applications. Sets and logic, propositional and predicate calculus, elements of combinatorics and counting, elementary discrete probability, functions and relations, and graphs.
Prerequisite: sophomore standing or instructor's permission.
Offered: fall.

MAT 211 Calculus III  4 Credits
Continuation of MAT 111 and MAT 112. Analytic geometry of 3-dimensional space and calculus of functions of several variables.
Prerequisite: minimum grade of C- in MAT 112.
Offered: fall & spring.

MAT 219 Linear Algebra  4 Credits
Prerequisite: MAT 112 or permission of instructor.
Offered: spring.

MAT 222 Differential Equations  3 Credits
Introduction to the theory and applications of ordinary differential equations.
Prerequisite: minimum grade of C- in MAT 211.
Offered: spring.

MAT 230 Logic, Set Theory, and Proofs  4 Credits
Transition from calculus to upper division courses: logic and methods of proof; set theory; relations, orders and functions; number systems; cardinality.
Prerequisite: minimum grade of C- in MAT 112 or permission of instructor.
Offered: fall.

MAT 301 History of Mathematics  3 Credits
Development and interrelations of major areas of mathematics, from ancient to modern times. Emphasis on both historical context and mathematical content. Mathematics as cultural heritage.
Prerequisite: MAT 111 & MAT 112.
Offered: occasionally.

MAT 311 Abstract Algebra  4 Credits
Introduction to the basic structures of abstract algebra: groups, rings, fields.
Prerequisite: minimum grade of C- in both MAT 219 and MAT 230.
Offered: fall.

MAT 312 Topics in Algebra  3 Credits
Continuation of MAT 311. Selected topics from groups, rings, integral domains, field extensions and Galois theory.
Prerequisite: MAT 311.
Offered: spring of odd-numbered years.

MAT 313 Number Theory  3 Credits
Divisibility, prime numbers, numerical functions, congruencies, quadratic reciprocity, Diophantine equations.
Prerequisite: MAT 311 or permission of instructor.
Offered: occasionally.

MAT 321 Real Analysis  4 Credits
Advanced study of limits, continuity, differentiation and integration of functions.
Prerequisite: minimum grade of C- in MAT 211, MAT 219 & MAT 230.
Offered: fall.

MAT 322 Topics in Analysis  3 Credits
Continuation of MAT 321. Selected topics from functions of one or several variables.
Prerequisite: minimum grade of C- in MAT 321.
Offered: occasionally.

MAT 331 Geometry  3 Credits
Prerequisite: MAT 230.
Offered: fall of even-numbered years.

MAT 341 Numerical Analysis  3 Credits
Prerequisite: MAT 219 & an elementary knowledge of computer programming.
Offered: occasionally.

MAT 342 Graph Theory  3 Credits
This course covers basic constructions on graphs. Complete graphs, bipartite graphs, trees, cycles, and more general graphs are studied along with their combinatorial properties. Euler circuits, Hamilton circuits, spanning trees. Applications of graphs to optimization problems such as the Traveling Salesperson Problem and Construction of the Minimal Spanning Trees.
Prerequisite: MAT 111 or MAT 115.
Offered: spring of even-numbered years.

MAT 345 Climate and Sustainability  3 Credits
This course, for majors from all the sciences, develops the use of conceptual models in understanding complicated situations, while illustrating the role of scientific arguments in societal debates about climate change and sustainability. Topics include: the Earth's energy balance, historical data for ocean and atmosphere and temperature and their circulation and oscillation patterns, the carbon cycle and biological systems, and handling large data. The increasingly sophisticated examples explored in the course will introduce the use of various areas of mathematics: linear models and networks, calculus-based dynamical systems, statistics and data assessment, and analysis of periodic phenomena. Students will learn about these topics by seeing simple examples of their use. The last part of the course will center on sustainability issues, and connections to global awareness, diversity, ethics, and justice.
Prerequisite: MAT 111 or equivalent. Restriction: seniors only.
Fulfills College Core: Core Capstone, (part of the Sustainability Core Pathway)
Offered: occasionally.

MAT 351 Probability & Statistics I  3 Credits
Introduction to the mathematical aspects of modern probability theory and the theory of statistics.
Prerequisite: MAT 211.
Offered: spring.
MAT 352 Probability & Statistics II 3 Credits
Continuation of MAT 351. Introduction to the mathematical aspects of modern probability theory and the theory of statistics.
Prerequisite: MAT 351.
Offered: fall.

MAT 353 Regression Analysis 3 Credits
Linear regression and correlation. Covariance, residual sum of squares, residual variance, correlation coefficient, tests of significance for correlation coefficient and for regression coefficients. Non-linear regression.
Prerequisite: MAT 351 & MAT 352, or permission of instructor.
Offered: spring of odd-numbered years.

MAT 354 Experimental Design and Statistical Computing 3 Credits
Analyzing data; one-way/two-way blocking; chi-square, goodness of fit. Statistical computing package; Monte-Carlo simulation-subset selection, central limit theorem; residual plots.
Prerequisite: MAT 351 & MAT 352, or permission of instructor.
Offered: spring of even-numbered years.

MAT 361 Probability for Actuaries 1 Credit
This course prepares students to take Exam P of the Society of Actuaries or Exam 1 from the Casualty Actuary Society. Key probability concepts are reviewed and students learn to apply these tools to problems encountered by actuaries. The course will develop a thorough command of calculus and probability topics. Additionally, a very basic knowledge of insurance and risk management is introduced.
Prerequisite: MAT 211 & MAT 351. Corequisite: MAT 352 or permission of instructor.
Offered: fall.

MAT 362 Financial Mathematics for Actuaries 1 Credit
This course prepares students to take Exam FM of the Society of Actuaries or Exam 2 from the Casualty Actuary Society. It covers interest theory (discrete and continuous) and an introduction to derivative securities.
Prerequisite: MAT 111 & MAT 112 or permission of instructor.
Offered: spring.

MAT 380 Mathematics Seminar 1 Credit
Mathematics seminar for majors. To be taken for three semesters.
Prerequisite: junior standing.
Offered: fall & spring.

MAT 381 Mathematics Seminar 1 Credit
Mathematics seminar for majors. To be taken for three semesters.
Prerequisite: junior standing.
Offered: fall & spring.

MAT 411 Topology 3 Credits
An introduction to topology, stressing concrete examples including surfaces. Point-set, geometric and algebraic topology with interconnections and applications.
Prerequisite: MAT 230.
Offered: occasionally.

MAT 421 Complex Analysis 3 Credits
Prerequisites: MAT 321 or PHY 335.
Offered: occasionally.

MAT 480 Mathematics Seminar 1 Credit
Mathematics seminar for majors. To be taken for three semesters.
Prerequisite: junior standing.
Fulfills College Core: Oral Communication
Offered: fall & spring.

MAT 498 Internship in Mathematics 1-3 Credits
Internship involving non-routine tasks linking academic concepts to practical experience. May be used for free elective credit only. Internships require an application and approval by the associate dean.
Prerequisite: permission of the chair & associate dean.
Offered: occasionally.

MAT 499 Independent Study 1-4 Credits
Study and work with a faculty supervisor. Project to be determined by faculty agreement. Independent studies require an application and approval by the associate dean.
Prerequisite: permission of the instructor, department chair, & associate dean.
Offered: occasionally.