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. This decision may be based on career goals, planned graduate studies, and/or other student interests. Before a student declares a double major, it is important to meet with the appropriate academic departments for advisement. 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.

Per college policy, each additional major requires a minimum of 15 credits that do not apply to the student’s first or subsequent major. Some double major combinations can be completed within the minimum 120 credit hour degree requirement, but in other cases additional coursework may be required. 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.

Curriculum
An Ignatian Foundation
All undergraduate students must complete either the Canisius Core Curriculum (http://catalog.canisius.edu/undergraduate/academics/curricular-information/core-curriculum/) or the All-College Honors Curriculum (http://catalog.canisius.edu/undergraduate/academics/curricular-information/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 a bachelor’s degree 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 number of credits required for graduation. The number of credits required to complete a bachelor’s degree may vary depending on the student’s major(s) and minor(s).

Major Requirements
Option A (Mathematics Major)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</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>
<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>
</tr>
<tr>
<td>Select one of the following:</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>MAT 312</td>
<td>Topics in Algebra</td>
<td></td>
</tr>
<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>
</tr>
<tr>
<td>MAT 421</td>
<td>Complex Analysis</td>
<td></td>
</tr>
<tr>
<td>Select four courses from the following:</td>
<td>12-16</td>
<td></td>
</tr>
<tr>
<td>Any additional 300 or 400-level mathematics courses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHY 335</td>
<td>Mathematical Analysis for Physicists</td>
<td></td>
</tr>
<tr>
<td>PHY 446</td>
<td>Quantum Mechanics I</td>
<td></td>
</tr>
<tr>
<td>Choose one of the following two sequences:</td>
<td>6-8</td>
<td></td>
</tr>
<tr>
<td>General Physics for Physical Science Majors (PHY 223, PHY 223L, PHY 224, and PHY 224L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any two Economics (ECO) classes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Credits 55-61
Option B (Mathematics with a Concentration in Another Area)

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</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>
<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>
</tr>
</tbody>
</table>

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

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

Select one of the following (‘restricted elective’):

MAT elective

MAT 312

MAT elective

MAT 322

MAT 352 (MAT352 is typically offered in the fall semester.)

MAT 421

MAT elective

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

Junior

Fall

MAT 311

Spring

MAT 381

MAT 321

MAT elective

MAT 380

Senior

Fall

MAT 480

Select one of the following (‘restricted elective’):

MAT elective

MAT 312

MAT elective

MAT 322

MAT 352 (MAT352 is typically offered in the fall semester.)

MAT 421
Option C

Freshman

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 111</td>
<td>MAT 112</td>
</tr>
<tr>
<td>PHY 223 (or ECO course)</td>
<td>PHY 224 (or ECO course)</td>
</tr>
</tbody>
</table>

Sophomore

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 211</td>
<td>MAT 219</td>
</tr>
<tr>
<td>MAT 230</td>
<td>MAT 351</td>
</tr>
</tbody>
</table>

Junior

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 321</td>
<td>MAT 381</td>
</tr>
<tr>
<td>MAT 352</td>
<td>Select one of the following statistics electives:</td>
</tr>
<tr>
<td>MAT 380</td>
<td>MAT 353</td>
</tr>
<tr>
<td></td>
<td>MAT 354</td>
</tr>
<tr>
<td></td>
<td>MAT 222 (or MAT elective)</td>
</tr>
</tbody>
</table>

Senior

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 480</td>
<td>Select one of the following statistics electives:</td>
</tr>
<tr>
<td></td>
<td>MAT elective</td>
</tr>
<tr>
<td></td>
<td>MAT 353</td>
</tr>
<tr>
<td></td>
<td>MAT 354</td>
</tr>
<tr>
<td></td>
<td>Select one of the following ('restricted elective'):</td>
</tr>
<tr>
<td></td>
<td>MAT 311 (MAT 311 is typically offered in the fall semester.)</td>
</tr>
<tr>
<td></td>
<td>MAT 322</td>
</tr>
<tr>
<td></td>
<td>MAT 421</td>
</tr>
</tbody>
</table>

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>
<th>Credits</th>
</tr>
</thead>
<tbody>
<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>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>MAT 230</td>
<td>Logic, Set Theory, and Proofs</td>
<td>4</td>
</tr>
</tbody>
</table>

Restricted Electives
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

**Applied Mathematics:**
- MAT 222 Differential Equations
- MAT 341 Numerical Analysis
- MAT 342 Graph Theory
- MAT 345 Climate and Sustainability
- PHY 335 Mathematical Analysis for Physicists

**Theoretical Mathematics:**
- MAT 311 Abstract Algebra
- MAT 312 Topics in Algebra
- MAT 321 Real Analysis
- MAT 322 Topics in Analysis
- MAT 421 Complex Analysis
MAT 110 Calculus for Business  
Calculus 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: fall & spring.

MAT 121 Mathematics through History  
3 Credits  
Liberal arts mathematics course. Tracing the development of mathematical ideas globally and through history, with emphasis on problem solving techniques, quantitative thinking, and deductive reasoning.  
Prerequisite: 3 years of high school mathematics or equivalent.  
Fulfills College Core: Field 7 (Mathematical Sciences)  
Offered: once a year.

MAT 131 Statistics for Social Sciences  
3 Credits  
A first course for majors in social or health sciences. Descriptive statistics, calculators, computer programs and introduction to inferential statistics. Credit not allowed if student already has credit for MAT 141 or MAT 351.  
Prerequisite: 3 years of high school mathematics or equivalent.  
Fulfills College Core: Field 7 (Mathematical Sciences)  
Offered: fall & spring.

MAT 141 Inferential Statistics and Computers for Science  
4 Credits  
Elementary probability theory, descriptive statistics, hypothesis testing, estimation, correlation and regression. The computer will be used with one of the standard statistical packages. Credit not allowed if student already has credit for MAT 131 or MAT 351.  
Prerequisite: 3 1/2 years of high school mathematics.  
Fulfills College Core: Field 7 (Mathematical Sciences)  
Offered: fall & spring.

MAT 150 Mathematics and Politics  
3 Credits  
Liberal arts course emphasizing applications of math in the social sciences. Covers topics such as voting theory, decisions made by groups, measurement of political power.  
Prerequisite: 3 years of high school mathematics or equivalent.  
Fulfills College Core: Field 7 (Mathematical Sciences), Justice  
Offered: once a year.

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.  
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.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Offered:</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 222</td>
<td>Differential Equations</td>
<td>3</td>
<td>Introduction to the theory and applications of ordinary differential equations.</td>
<td>Occasionally.</td>
</tr>
<tr>
<td>MAT 230</td>
<td>Logic, Set Theory, and Proofs</td>
<td>4</td>
<td>Transition from calculus to upper division courses: logic and methods of proof; set theory; relations; orders; functions; number systems; cardinality.</td>
<td>Fall.</td>
</tr>
<tr>
<td>MAT 301</td>
<td>History of Mathematics</td>
<td>3</td>
<td>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.</td>
<td>Occasionally.</td>
</tr>
<tr>
<td>MAT 310</td>
<td>Abstract Algebra</td>
<td>4</td>
<td>Introduction to the basic structures of abstract algebra; groups, rings, fields.</td>
<td>Fall.</td>
</tr>
<tr>
<td>MAT 311</td>
<td>Topics in Algebra</td>
<td>3</td>
<td>Continuation of MAT 311. Selected topics from groups, rings, integral domains, field extensions and Galois theory.</td>
<td>Fall.</td>
</tr>
<tr>
<td>MAT 321</td>
<td>Real Analysis</td>
<td>4</td>
<td>Advanced study of limits, continuity, differentiation, and integration of functions.</td>
<td>Fall.</td>
</tr>
<tr>
<td>MAT 322</td>
<td>Topics in Analysis</td>
<td>3</td>
<td>Continuation of MAT 321. Selected topics from functions of one or several variables.</td>
<td>Occasionally.</td>
</tr>
<tr>
<td>MAT 331</td>
<td>Geometry</td>
<td>3</td>
<td>Axioms for geometry and their consequences: independence of the parallel postulate. Rudiments of hyperbolic geometry. Geometric transformations.</td>
<td>Fall of even-numbered years.</td>
</tr>
<tr>
<td>MAT 342</td>
<td>Graph Theory</td>
<td>3</td>
<td>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.</td>
<td>Occasionally.</td>
</tr>
<tr>
<td>MAT 345</td>
<td>Climate and Sustainability</td>
<td>3</td>
<td>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.</td>
<td>Spring of even-numbered years.</td>
</tr>
<tr>
<td>MAT 347</td>
<td>Introduction to the mathematical aspects of modern probability theory and the theory of statistics.</td>
<td>3</td>
<td>Continuation of MAT 351. Introduction to the mathematical aspects of modern probability theory and the theory of statistics.</td>
<td>Fall.</td>
</tr>
<tr>
<td>MAT 351</td>
<td>Probability &amp; Statistics I</td>
<td>3</td>
<td>Introduction to the mathematical aspects of modern probability theory and the theory of statistics.</td>
<td>Fall.</td>
</tr>
<tr>
<td>MAT 352</td>
<td>Probability &amp; Statistics II</td>
<td>3</td>
<td>Continuation of MAT 351. Introduction to the mathematical aspects of modern probability theory and the theory of statistics.</td>
<td>Fall.</td>
</tr>
</tbody>
</table>

*Restriction: seniors only.*

Fulfills College Core: Core Capstone
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: spring of even-numbered years.

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.