MATHEMATICS

Why study mathematics? Many of the new wonders that we take for granted in our modern technological society have mathematical ideas and applications as their basis, though this role is often hidden from view. Complex economic and planning decisions, scientific discoveries that improve our lives, and new technologies and products are often possible only after mathematical or statistical analysis, or a computer visualization, simulation, design and implementation based on mathematics. Therefore, mathematicians, as well as mathematically educated scientists, engineers and economists, make important daily contributions in the understanding and advancement of science, the improvement and discovery of new technology, and decision-making and planning in business, industry and government. Students interested in using their mathematical skills in solving real world problems are well prepared, by majoring or minoring in mathematics, for careers such as in the insurance industry, software design, data and systems analysis, scientific computing, combustion research, the animated movie industry, and cryptanalysis to name a few, or a graduate degree in a related technical field. Those students with a very strong interest in mathematics itself can pursue graduate study in mathematics in preparation for careers as university or college mathematics teachers and in the development of new mathematical and statistical concepts and methods as researchers in academia, government and industry.

The curriculum of the program in the Department of Mathematics is designed to provide a broad education in both theoretical and applied mathematics. It also develops the scientific knowledge and the problem solving, computing, and communications skills that are critical to a successful mathematically based career. This preparation is greatly enhanced by taking advantage of the wide variety of science and engineering courses available to students and developing good communications skills, both through technical courses and the strong humanities program. The program offers a solid grounding in the foundational areas of calculus, differential equations, linear algebra, discrete and combinatorial algebra, and probability and statistics. These basic courses are complemented by a varied selection of upper division courses for further elective study in areas such as numerical analysis, operations research, advanced statistics, mathematical modeling, optimization, and other advanced topics in mathematics. Students are encouraged to develop a strong background in an area of science or engineering through election of courses leading to a minor or double major. By appropriate course selection students may complete a double major in mathematics and another field such as computer science, physics, chemistry, applied biology, or economics.

Degree Requirements

Major Concentrations: Mathematics majors choose to complete their program in one of four concentrations: Mathematics, Continuous Applied Mathematics, Discrete Applied Mathematics, or Statistics and Operations Research. The Mathematics concentration provides the foundational mathematical depth of a traditional mathematics major and is intended for students planning on graduate study in an area of mathematics. In applied mathematics there are two areas: the Continuous Applied Mathematics concentration and the Discrete Applied Mathematics concentration. Students selecting these concentrations may tailor their programs to interface with another major or to enhance industrial employment or graduate school opportunities. The Statistics and Operations Research concentration is recommended for students pursuing careers in actuarial science, graduate study in statistics, or employment in government or industry in a statistical capacity. It is strongly recommended that students considering graduate education in mathematics include MA 376 Abstract Algebra among their elective mathematics courses. Upon graduation a student may request the Head of the Mathematics Department to issue a letter attesting to the fact that the requirements in the chosen concentration have been completed.

Mathematics Coursework Requirements

All mathematics majors must complete a common core consisting of 39 credit hours of mathematics coursework, which provides breadth across the main areas of mathematics. A mathematics major must also complete an additional 12 credit hours of mathematics coursework specified for the selected major concentration plus an additional 12 credit hours earned in free elective mathematics or biomathematics courses. A mathematics major must additionally complete an 8-credit hour capstone experience. A total of 71 credit hours of mathematics courses is required for the major. None of the credits in the 71 hours above may be taken from the courses MA 190 Contemporary Mathematical Problems, MA351-MA356, MA 450 Mathematics Seminar or MA 223 Engineering Statistics (unless approved by the department head). These courses (except MA 190 Contemporary Mathematical Problems) may be taken as free electives. Finally, a student taking a degree program in which mathematics is the primary major must also take MA 190 Contemporary Mathematical Problems. A student whose second major is mathematics is not required to take MA 190, but is strongly encouraged to do so.

Common Required Core

Code	Title	Hours
MA 111	Calculus I	5
MA 112	Calculus II	5
MA 113	Calculus III	5
MA 221	Matrix Algebra & Differential Equations I	4
MA 222	Matrix Algebra & Differential Equations II	4
MA 276	Introduction to Proofs	4
MA 366	Introduction to Real Analysis	4
MA 371	Linear Algebra I	4
MA 381	Introduction to Probability with Applications to Statistics	4
Total Hours		**39**

Mathematics Concentration Core

Code	Title	Hours
MA 367	Functions of a Complex Variable	4
MA 376	Abstract Algebra	4
Select one of the following:		4
MA 433	Numerical Analysis	
MA 436	Introduction to Partial Differential Equations	
MA 446	Combinatorial Optimization	
MA 481	Mathematical Statistics	
Total Hours		**12**

Continuous Applied Mathematics Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Continuous Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

Code	Title	Hours
MA 330	Vector Calculus	4
MA 336	Boundary Value Problems	4
MA 433	Numerical Analysis	4
Total Hours		**12**

Discrete Applied Mathematics Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Discrete Applied Mathematics Concentration are strongly urged to complete mathematics coursework in statistics as elective coursework.

Code	Title	Hours
MA 374	Combinatorics	4
MA 444	Deterministic Models in Operations Research	4
Select one of the following:		4
MA 376	Abstract Algebra	
MA 475	Topics in Discrete Mathematics	
MA 476	Algebraic Codes	
MA 477	Graph Theory	
Total Hours		**12**

Statistics and Operations Research Concentration Core 12 hrs.

Three courses selected per the list below. Students completing the Statistics and Operations Research Concentration are strongly urged to complete mathematics coursework in applied mathematics as elective coursework.

Code	Title	Hours
MA 382	Introduction to Statistics with Probability	4
MA 444	Deterministic Models in Operations Research	4
Select one of the following:		4
MA 445	Stochastic Models in Operations Research	
MA 446	Combinatorial Optimization	
MA 481	Mathematical Statistics	
MA 485	Applied Linear Regression	
MA 487	Design of Experiments	
Total Hours		**12**

It is strongly suggested that the student take as many of the above courses as possible.

Free Mathematics Electives—12 hrs.

Additional mathematics and biomathematics coursework in courses numbered 300 or above (MA 351- MA 356, MA 450 Mathematics Seminar, BMTH496-498 not allowed).

MA 190 Contemporary Mathematical Problems **(2 hrs.)** A student taking a degree program in which mathematics is the primary major must also take MA 190 Contemporary Mathematical Problems. A student whose second major is mathematics is not required to take MA 190 Contemporary Mathematical Problems, but is strongly encouraged to do so.

- **Senior Capstone (8 hrs.)** A student must complete an 8-credit hour Senior Capstone by completing MA 496 Senior Capstone I (4 hrs.), MA 497 Senior Capstone II (2 hrs.), and MA 498 Senior Capstone III (2 hrs.). Note that MA 491 Introduction to Mathematical Modeling may replace 2 hours of MA 496 Senior Capstone I and that MA 497 Senior Capstone II and MA 498 Senior Capstone III must be taken in separate terms. The capstone is an important experience for the mathematics major, representing a sustained effort to solve a complex problem in the mathematical sciences. The Senior Capstone must involve significant individual work, and it must culminate with both a written report and an oral presentation. Both the report and the presentation must be submitted to the department.
  Students double majoring in mathematics and another program who complete the senior project courses for that program must also complete MA 491 Introduction to Mathematical Modeling for the senior project to satisfy the Senior Capstone requirement within the mathematics major. Students double majoring in mathematics and another program who complete the senior thesis courses for that program can directly use those courses to satisfy the Senior Capstone requirement within the mathematics major. The Mathematics Capstone does not constitute a culminating major engineering design experience for students also majoring in an ABET accredited program.

Requirements

Summary of Requirements

Code	Title	Hours
Mathematics Coursework - core, concentration and electives [1]		63
Mathematics Senior Capstone		8
MA 190	Contemporary Mathematical Problems (primary major only)	2
Physical and Life Sciences [2]		24
Computer Science [3]		8
Humanities, Social Sciences, and the Arts (standard requirement, one course must be:)		36
ENGL H290	Technical & Professional Communication	
Technical Electives [4]		24
Free Electives		28
Miscellaneous [5]		2
Total Hours		**195**

1 MA351-MA356, MA 450 Mathematics Seminar, BMTH496-498 not allowed

2
- PH 111 Physics I, PH 112 Physics II, and PH 113 Physics III
- BIO 101 Essential Biology (or higher-level BIO course)
- CHEM 111 General Chemistry I
- 4 additional credit hours in Physical or Life Sciences 4 hrs.

3
- CSSE 120 Introduction to Software Development
- CSSE 220 Object-Oriented Software Development
- MA 332 Introduction to Computational Science may be taken instead of CSSE 220 Object-Oriented Software Development but then MA 332 Introduction to Computational Science cannot be counted towards the 63 hours of mathematics coursework

4 200 level or above coursework, approved by the major advisor, in areas of science, engineering, or economics in which 12 credit hours constitute a coherent set of three courses representing a specific area of technical depth and 12 credit hours represent technical breadth. Coursework in mathematics and biomathematics is not allowed. 24 hrs.

[5]
- RHIT 100 Foundations for Rose-Hulman Success
- MA 200 Career Preparation (primary major only)

Suggested Schedule

The schedule (Course Sequence) on the right is a suggested schedule only. Scheduling of courses may be altered, subject to the approval of the advisor, in order to take advantage of advanced placement or to accommodate a second major, area minor or other special program. However, note that some courses are offered only at certain times during the year, and all prerequisites must be met. In the schedule an MA elective is either a concentration elective or free math elective, as described above, and a science elective is a physical or life science elective as defined on this page.

Alternate Science Schedule: The recommended science schedule of six science courses starts with PH 111 Physics I. If CHEM 111 General Chemistry I is required in the fall quarter because of a double major or minor, then the alternate science sequence may be completed by taking the second science course in each place where a choice is given. Two science courses are to be taken in the winter quarter of freshman year.

Plan of Study

Below is a sample plan of study that illustrates one way to achieve the program requirements. Any given student's plan of study may differ based on a variety of factors (e.g., advanced credit, placement exams, adding a minor). Enrolled students will work with their academic advisor; utilize the degree audit/planner to create a specific plan of study.

Course	Title	Hours
Freshman		
Fall		
MA 111	Calculus I	5
PH 111 or CHEM 111	Physics I or General Chemistry I	4
Select one of the following:		4
HUM H190	First-Year Writing Seminar	
HSSA Elective		
RHIT 100	Foundations for Rose-Hulman Success	1
CSSE 120	Introduction to Software Development	4
	Hours	**18**
Winter		
MA 112	Calculus II	5
PH 112 or PH 111	Physics II or Physics I	4
Select one of the following:		4
CHEM 111	General Chemistry I	
BIO 101	Essential Biology	
or higher level BIO course		
Select one of the following:		4
HSSA Elective		
HUM H190	First-Year Writing Seminar	
	Hours	**17**
Spring		
MA 113	Calculus III	5
PH 113 or PH 112	Physics III or Physics II	4
MA 190	Contemporary Mathematical Problems	2
HSSA Elective		4
	Hours	**15**
Sophomore		
Fall		
MA 221	Matrix Algebra & Differential Equations I	4
MA 276	Introduction to Proofs	4
Select one of the following:		4
BIO 101	Essential Biology	
or higher level BIO course		
PH 113	Physics III	
CSSE 220	Object-Oriented Software Development [1]	4
	Hours	**16**
Winter		
MA 222	Matrix Algebra & Differential Equations II	4
Science Elective		4
Technical Elective		4
HSSA Elective		4
MA 200	Career Preparation [2]	1
	Hours	**17**
Spring		
MA 381	Introduction to Probability with Applications to Statistics	4
MA 371	Linear Algebra I	4
Technical Elective		4
HSSA Elective		4
	Hours	**16**
Junior		
Fall		
MA Elective		4
Technical Elective		4
Technical Elective		4
Select one of the following:		4
HSSA Elective		
ENGL H290	Technical & Professional Communication	
	Hours	**16**
Winter		
MA 366	Introduction to Real Analysis	4
MA Elective		4
Technical Elective		4
Select one of the following:		4
HSSA Elective		
ENGL H290	Technical & Professional Communication	
	Hours	**16**
Spring		
MA Elective		4
MA Elective		4
Technical Elective		4
Select one of the following:		4
HSSA Elective		
ENGL H290	Technical & Professional Communication	
	Hours	**16**
Senior		
Fall		
Select one of the following:		4
MA 496	Senior Capstone I	
MA 491 & MA 496	Introduction to Mathematical Modeling and Senior Capstone I	
Free Elective		4
Free Elective		4
HSSA Elective		4
	Hours	**16**
Winter		
MA 497	Senior Capstone II	2
MA Elective		4

Free Elective		4
Free Elective		4
Free Elective		4
	Hours	**18**
Spring		
MA 498	Senior Capstone III	2
MA Elective		4
Free Elective		4
Free Elective		4
	Hours	**14**
	Total Hours	**195**

[1] MA 332 Introduction to Computational Science - may be taken instead of CSSE 220 Object-Oriented Software Development but then MA 332 Introduction to Computational Science cannot be counted towards the 63 hours of mathematics coursework

[2] MA 200 Career Preparation - may be taken in the winter quarter of the sophomore year

Notes and Definitions

- The suggested four year plan is a guideline.
- Close consultation with the advisor on electives is required, especially for electives after the freshman year, or if a double major or minor is planned.

The following definitions of electives are specific to the Mathematics Department.

- **Math Elective:** A course either required by the concentration or a true math elective.
- **Science Elective:** Any Physical or Life Sciences elective (not Computer Science) at any level.
- **Technical Elective:** Non-mathematics courses numbered 200 or above in Engineering, Science or Economics; coursework in mathematics and biomathematics is not allowed.
- **Free Elective:** Any course.

Program Objectives
Program Goals and Objectives

To provide a foundation for further learning as well as contributing to the general education of students, the programs at Rose-Hulman all have a heavy investment in mathematics and science in the first two years. The freshman and sophomore mathematics curriculum is designed to contribute to this foundation by ensuring that students are familiar with basic mathematical and statistical concepts, and mathematical and statistical reasoning and modeling. Students will also understand the use of mathematics in other disciplines as well as developing an appreciation of mathematics as a discipline in its own right. In addition, students will learn to be competent users of mathematics, especially in problem solving, and be able to effectively communicate mathematically. The curriculum makes strong use of computer methods to develop students' mathematical understanding and to enhance their ability to use the computer in modeling, computation and problem solving.

For students seeking a major in mathematics, the curriculum prepares them for a mathematically based career after graduation or further graduate study. The major builds upon the goals and objectives of the freshman and sophomore curriculum. In addition to a deeper and broader study of mathematics, majors will further develop their ability to formulate and solve problems from a mathematical perspective, become familiar with the use of mathematics in other fields, and develop competence at the application of mathematics to at least one other field. Graduates will also be able to use technology effectively in mathematics and the application of mathematics. To complement these technical skills graduates will learn the professional skills of effective communication with both technical and non-technical audiences and the ability to work cooperatively with others.

Mathematics Program Goals and Student Learning Outcomes

Mathematics majors should be able to meet the following Student Learning Outcomes

Goal 1: Students will learn the fundamental principles underlying the major areas of mathematics

- SLO 1.1. Perform calculations and prove statements about objects, morphisms, and structure theorems in vector spaces and abstract algebra.
- SLO 1.2. Write rigorous proofs and state key counterexamples in the areas of sequences, continuity, differentiability, and integrability.
- SLO 1.3. Select, and produce appropriate characterizations for, a model for a random process through functions of random variables (e.g., expectation or probability statements).

Goal 2: Students will have a well-rounded scientific and mathematical background

- SLO 2.1. Develop focused further knowledge of at least one of the fields of mathematical sciences.
- SLO 2.2. Synthesize new and previous knowledge in cooperation with a faculty member.
- SLO 2.3. Demonstrate basic literacy in a number of scientific areas

Goal 3: Students will be able to use technology in a mathematical setting.

- SLO 3.1. Describe and implement computational approaches to solving a mathematical model.
- SLO 3.2. Use mathematical technology to analyze mathematical problems in at least one area.

Goal 4: Students will develop and utilize effective written and oral communication skills in a mathematical setting

- SLO 4.1. Rigorously write and critique mathematical proofs.
- SLO 4.2. Speak about mathematics in an articulate, sound, and well-organized fashion.
- SLO 4.3. Write a formal mathematical thesis or report.

Goal 5: Students will develop a broad appreciation for mathematics both as a discipline and as a tool for solving real world problems.

- SLO 5.1. Construct, analyze, and interpret a mathematical model to explain and predict relationships for given deterministic systems and random systems from science or industry.
- SLO 5.2. Create, manipulate, and interpret discrete models and continuous models to illustrate dynamics of a system over time.
- SLO 5.3. Generalize properties of numbers and functions to other algebraic, analytic, topological, or geometric structures.