

# Department of Mathematics

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The Department of Mathematics at Case Western Reserve University is an active center for mathematical research. Faculty members conduct research in algebra, analysis, applied mathematics, convexity, dynamical systems, geometry, imaging, inverse problems, life sciences applications, mathematical biology, modeling, numerical analysis, probability, scientific computing, stochastic systems, and other areas.

The department offers a variety of programs leading to both undergraduate and graduate degrees in traditional and applied mathematics. Undergraduate degrees are Bachelor of Arts or Bachelor of Science in mathematics and Bachelor of Science in applied mathematics. Graduate degrees are Master of Science and Doctor of Philosophy. The BS/MS program allows a student to earn a Bachelor of Science in either mathematics or applied mathematics and a master's degree from the mathematics department or another department in five years. The department, in cooperation with John Carroll University, offers a program for individuals interested in pre-college teaching. It also offers a specialized program with the Department of Physics.

Mathematics plays a central role in the physical, biological, economic, and social sciences. Because of this, employment prospects are always strong for individuals with degrees in mathematics, and there are excellent career opportunities. A bachelor's degree in mathematics or applied mathematics offers a strong background for graduate school in many areas (including computer science, medicine, and law, in addition to mathematics and science) or a position in the private sector. A master's degree (in mathematics or applied mathematics, or an undergraduate degree in applied mathematics combined with a master's in a different area) is an excellent basis for employment in the private sector in a technical field. A PhD degree is usually necessary for college teaching and research.

Students, both undergraduate and graduate, have opportunities to interact personally with faculty and other students, and research and other activities are available. In addition, undergraduates can obtain teaching experience via the department's supplemental instruction program.

Teacher Licensure | BS in Mathematics | BS in Applied Mathematics | BS in Mathematics and Physics | Integrated BS/MS | Minors

## Undergraduate Programs

### Majors

A Bachelor of Arts in mathematics, a Bachelor of Science in mathematics, a Bachelor of Science in mathematics and physics, and a Bachelor of Science in applied mathematics are available to students at Case Western Reserve University. All undergraduate mathematics degrees are based on a four-course sequence in calculus and differential equations and a five-course mathematics core in analysis and algebra.

### Bachelor of Arts in Mathematics

The BA degree requires at least 38 hours of mathematics courses, including:

The following four courses: *		14
MATH 121	Calculus for Science and Engineering I	
MATH 122	Calculus for Science and Engineering II	
MATH 223	Calculus for Science and Engineering III	
MATH 224	Elementary Differential Equations	
MATH 307	Introduction to Abstract Algebra I	3
MATH 308	Introduction to Abstract Algebra II	3
MATH 321	Fundamentals of Analysis I	3
MATH 322	Fundamentals of Analysis II	3
MATH 324	Introduction to Complex Analysis	3
or MATH 425	Complex Analysis I	
Three approved technical electives: **		9
ENGR 131	Elementary Computer Programming ***	3
Total Units		41

\* Or an equivalent sequence.

\*\* No more than one can be from outside the department.

\*\*\* Or other approved computer science course.

### Teacher Licensure

Students interested in teaching mathematics at the high school level can prepare for teacher licensure

through a joint program with John Carroll University. The requirements are:

(a) Completion of the BA program in mathematics, including the following as the three approved technical electives.:

MATH 150	Mathematics from a Mathematician's Perspective	3
MATH 304	Discrete Mathematics	3
STAT 312	Basic Statistics for Engineering and Science	3

(b) The completion of a second major in teacher education. Students interested in this option should consult the description of the Teacher Licensure Program elsewhere in this bulletin or contact the director of teacher education.

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## Bachelor of Science in Mathematics

The BS degree in mathematics requires at least 50 hours of mathematics courses.

The following four courses: *		14
MATH 121	Calculus for Science and Engineering I	
MATH 122	Calculus for Science and Engineering II	
MATH 223	Calculus for Science and Engineering III	
MATH 224	Elementary Differential Equations	
MATH 307	Introduction to Abstract Algebra I	3
MATH 308	Introduction to Abstract Algebra II	3
MATH 321	Fundamentals of Analysis I	3
MATH 322	Fundamentals of Analysis II	3
MATH 324	Introduction to Complex Analysis	3
or MATH 425	Complex Analysis I	
MATH 330	Introduction of Scientific Computing	3
Six approved technical electives **		18
The following three courses: *		9
PHYS 121	General Physics I - Mechanics	
PHYS 122	General Physics II - Electricity and Magnetism	
PHYS 221	Introduction to Modern Physics	
One of the following sequences:		6
ASTR 201 & ASTR 202	The Sun and its Planets and Stars, Galaxies, and the Universe	
CHEM 105 & CHEM 106	Principles of Chemistry I and Principles of Chemistry II	
CHEM 111 & ENGR 145	Principles of Chemistry for Engineers and Chemistry of Materials	
GEOL 110 & GEOL 115	Physical Geology and Introduction to Oceanography	
GEOL 110 & GEOL 210	Physical Geology and Historical Geology/Paleontology	
<b>Total Units</b>		<b>65</b>

\* Or an equivalent sequence.

\*\* No more than 9 hours may be from outside the department.

\*\*\* Or other approved computer science course.

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## Bachelor of Science in Applied Mathematics

The BS degree in applied mathematics requires at least 50 hours of course work in mathematics and related subjects, in addition to a professional core that is specific to the area of application of interest to the student. A student in this degree program must design a program of study in consultation with his or her academic advisor. This program of study must explicitly list the mathematics electives and the professional core in the area of application.

Areas of research in applied mathematics well represented in the department include:

- Applied dynamical systems
- Applied probability and stochastic processes
- Imaging
- Life science
- Scientific computing

Study plans with emphasis on areas of application closely related to mathematics but centered in other departments will also be considered. Such areas might include engineering applications, biology, cognitive science, or economics.

The following four courses: *		14
MATH 121	Calculus for Science and Engineering I	
MATH 122	Calculus for Science and Engineering II	
MATH 223	Calculus for Science and Engineering III	
MATH 224	Elementary Differential Equations	
MATH 304	Discrete Mathematics	3
MATH 307	Introduction to Abstract Algebra I	3
MATH 321	Fundamentals of Analysis I	3
MATH 322	Fundamentals of Analysis II	3
MATH 330	Introduction of Scientific Computing	3
One of the following two courses:		3
MATH 324	Introduction to Complex Analysis	
MATH 425	Complex Analysis I	
Approved mathematics electives:		18
Four courses specific to the concentration area of interest to the student (12 units)		
Two MATH courses at the 300 level or higher (6 units)		

Professional Core requirement	12
12 approved credit hours specific to an area of application. This requirement is intended to promote scientific breadth and encourage application of mathematics to other fields.	
Non-mathematics requirements	
The following three courses: *	9
PHYS 121 General Physics I - Mechanics	
PHYS 122 General Physics II - Electricity and Magnetism	
PHYS 221 Introduction to Modern Physics	
One of the following sequences:	6-8
ASTR 201 The Sun and its Planets & ASTR 202 and Stars, Galaxies, and the Universe	
CHEM 105 Principles of Chemistry I & CHEM 106 and Principles of Chemistry II	
CHEM 111 Principles of Chemistry for Engineers & ENGR 145 and Chemistry of Materials	
GEOL 110 Physical Geology & GEOL 115 and Introduction to Oceanography	
or GEOL 210 Historical Geology/Paleontology	
Total Units	77-79

\* Or equivalent sequence

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## Bachelor of Science in Mathematics and Physics

In contrast to the BS in applied mathematics or the BS in physics with a mathematical physics concentration, this degree provides a synergistic, coherent, and parallel education in mathematics and physics. To a close approximation, the challenging course work corresponds to combining the mathematics and physics cores, with the Physics Laboratory cluster replaced by a single, fourth-year laboratory semester. A student in this new program may use either of two official advisors, one available from each department, who would also constitute a committee for the administration of the degree and the approval of curriculum petitions.

The total number of required credits for the major is 126, with at least 35 in MATH, at least 38 in PHYS, 6-7 in senior project and departmental seminar, and 9-11 in other science. The remainder of the hours include SAGES requirements, CAS distribution requirements, and open electives.

### A. Mathematics requirements

MATH 121	Calculus for Science and Engineering I	4
MATH 122	Calculus for Science and Engineering II	4
or MATH 124	Calculus II	
MATH 223	Calculus for Science and Engineering III	3

or MATH 227	Calculus III	
MATH 224	Elementary Differential Equations	3
or MATH 228	Differential Equations	
MATH 307	Introduction to Abstract Algebra I	3
MATH 308	Introduction to Abstract Algebra II	3
or MATH 330	Introduction of Scientific Computing	
MATH 321	Fundamentals of Analysis I	3
MATH 322	Fundamentals of Analysis II	3
MATH 324	Introduction to Complex Analysis	3
Approved Mathematics electives *		6
--- (35 hours in Mathematics)		
B. Physics requirements		
PHYS 121	General Physics I - Mechanics	4
or PHYS 123	Physics and Frontiers I - Mechanics	
PHYS 122	General Physics II - Electricity and Magnetism	4
or PHYS 124	Physics and Frontiers II - Electricity and Magnetism	
PHYS 221	Introduction to Modern Physics	3
PHYS 310	Classical Mechanics	3
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 331	Introduction to Quantum Mechanics I	3
or PHYS 481	Quantum Mechanics I	
PHYS 332	Introduction to Quantum Mechanics II	3
or PHYS 482	Quantum Mechanics II	
One of the following:		3
PHYS 315	Introduction to Solid State Physics	
PHYS 316	Introduction to Nuclear and Particle Physics	
PHYS 326	Physical Optics	
PHYS 327	Quantum Electronics	
PHYS 328	Cosmology and the Structure of the Universe	
PHYS 336	Modern Cosmology	
PHYS 365	General Relativity	
PHYS 423	Classical Electromagnetism	3
PHYS 472	Graduate Physics Laboratory	3
Two of the following: **		6
PHYS 250	Computational Methods in Physics	
PHYS 349	Methods of Mathematical Physics I	
PHYS 350	Methods of Mathematical Physics II	
--- (38 hours in Physics)		
C. Senior project and seminar; one of two options: ***		6-7
C(i) Mathematics option		
MATH 351	Senior Project for the Mathematics and Physics Program ****	
SAGES departmental seminar in Mathematics		
C(ii) Physics option		
PHYS 303	Advanced Laboratory Physics Seminar	
PHYS 351	Senior Physics Project	
PHYS 352	Senior Physics Project Seminar	
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D. Other science requirements (9-11 hours)		
CHEM 105	Principles of Chemistry I	3-04
or CHEM 111	Principles of Chemistry for Engineers	
CHEM 106	Principles of Chemistry II	3-04
or ENGR 145	Chemistry of Materials	
ENGR 131	Elementary Computer Programming	3
Total Units		88-91

\* Subject to the approval of the advisory committee. These may be chosen from the general list of mathematics courses at the 300 level or higher. Subject to approval, students may substitute an appropriate course from outside the mathematics and physics departments.

\*\* Subject to the approval of the advisory committee, students may substitute an appropriate course from outside the mathematics and physics departments.

\*\*\* Either option satisfies the SAGES capstone and departmental seminar requirements.

\*\*\*\* MATH 351 Senior Project for the Mathematics and Physics Program is a year-long course, 2 credits per semester.

In addition to the major coursework listed, there are requirements of 10 hours of SAGES freshman and university seminars, 12 hours of CAS distribution requirements, and enough open electives to bring the total number of hours to at least 126.

First Year	Units	
	Fall	Spring
General Physics I - Mechanics (PHYS 121) or Physics and Frontiers I - Mechanics (PHYS 123)	4	
Calculus for Science and Engineering I (MATH 121)	4	
Elementary Computer Programming (ENGR 131)	3	
Principles of Chemistry I (CHEM 105)* or Principles of Chemistry for Engineers (CHEM 111)	3	
SAGES freshman seminar	4	
Principles of Chemistry Laboratory (CHEM 113)	2	
General Physics II - Electricity and Magnetism (PHYS 122) or Physics and Frontiers II - Electricity and Magnetism (PHYS 124)		4
Calculus for Science and Engineering II (MATH 122) or Calculus II (MATH 124)		4
Principles of Chemistry II (CHEM 106)* or Chemistry of Materials (ENGR 145)		3
Principles of Chemistry Laboratory (CHEM 113)		2
Other non-major course ***		3
Year Total:	20	16
Second Year	Units	
	Fall	Spring
Introduction to Modern Physics (PHYS 221)	3	
Calculus for Science and Engineering III (MATH 223) or Calculus III (MATH 227)	3	

Introduction to Abstract Algebra I (MATH 307)	3	
Non-major courses ***	9	
Classical Mechanics (PHYS 310)		3
MP Group I**		3
Elementary Differential Equations (MATH 224) or Differential Equations (MATH 228)		3
Introduction to Abstract Algebra II (MATH 308) or Introduction of Scientific Computing (MATH 330)		3
Year Total:	18	12
Third Year	Units	
	Fall	Spring
Thermodynamics and Statistical Mechanics (PHYS 313)	3	
Introduction to Quantum Mechanics I (PHYS 331) or Quantum Mechanics I (PHYS 481)	3	
Fundamentals of Analysis I (MATH 321)	3	
MP Group II**	3	
Non-major courses ***	9	
Introduction to Quantum Mechanics II (PHYS 332) or Quantum Mechanics II (PHYS 482)		3
Fundamentals of Analysis II (MATH 322)		3
Introduction to Complex Analysis (MATH 324)		3
MP Group III**		3
Year Total:	21	12
Fourth Year	Units	
	Fall	Spring
PHYS 3XX****	3	
Graduate Physics Laboratory (PHYS 472)	3	
MP Group IV**	3	
SAGES Department seminar *****	3	
Classical Electromagnetism (PHYS 423)		3
Senior Project *****		3-4
Non-major courses ***		12

Year Total:	12	18-19
Total Units in Sequence:		129-130

- \* If approved by the M&P committee, other science sequence courses may be substituted.
- \*\* The "M&P group" of four courses corresponds to two physics courses and two mathematics courses. The physics courses would be chosen from P250, P349, and P350. The mathematics courses are subject to approval by the advisory committee and are thereby referred to as 'approved electives.' They may be chosen from the general list of mathematics courses at the 300 level or higher. Also subject to approval, students may choose a course from outside the mathematics and physics departments as a substitute in the M&P group.
- \*\*\* The number of open electives will vary depending on whether students choose 3-credit or 4-credit courses to fulfill other requirements (chemistry, senior project)
- \*\*\*\* An advanced physics course to be selected from the following list: PHYS 315 Introduction to Solid State Physics, PHYS 316 Introduction to Nuclear and Particle Physics, PHYS 326 Physical Optics, PHYS 327 Quantum Electronics, PHYS 328 Cosmology and the Structure of the Universe, PHYS 336 Modern Cosmology, PHYS 365 General Relativity.
- \*\*\*\*\* The Senior Project and SAGES departmental seminar should either be the Mathematics option (MATH 351 Senior Project for the Mathematics and Physics Program and a Mathematics departmental seminar), or the Physics option (PHYS 303 Advanced Laboratory Physics Seminar, PHYS 351 Senior Physics Project, and PHYS 352 Senior Physics Project Seminar).

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## **Integrated BS/MS Program in Mathematics and/or Applied Mathematics**

The integrated BS/MS program is intended for highly motivated candidates for the BS in mathematics and applied mathematics who wish to pursue an advanced degree. Application to the BS/MS program must be made after completion of 75 semester hours of course work and prior to

attaining senior status (completion of 90 semester hours). Generally, this means that a student will submit the application during his/her sixth semester of undergraduate course enrollment and will have no fewer than two semesters of remaining BS requirements to complete. Applicants should consult the dean of undergraduate studies.

A student admitted to the program may, in the senior year, take up to nine hours of graduate courses (400 level and above) that will count towards both BS and MS requirements. The courses to be doubled-counted must be specified at the time of application. Any undergraduate course work that is to be applied to the MS must be beyond that used to satisfy BS degree requirements and must conform to university, graduate school, and department rules. Students may petition to transfer graduate course work taken prior to application to the BS/MS program subject to the rules of the graduate school.

Students for whom the master's project or thesis is a continuation and development of the senior project should register for (or the appropriate project course) during the senior year and are expected to complete all other courses for the BS before enrolling in further MS course work and thesis (continuing the senior project). Students for whom the master's thesis or project is distinct from the senior project will be expected to complete the BS degree before taking further graduate courses for the master's degree.

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## **Integrated BS/MS in Applied Mathematics and Another Discipline**

There is the possibility of an integrated five-year study plan leading to a BS in applied mathematics and an MS in the area of application. In order to complete the requirements for the BS/MS in five years, students must choose an area outside mathematics that integrates well with mathematics, such as computing/information science, operations research, systems engineering, control theory, biology, or cognitive science. The general academic requirements for Integrated BS/MS programs must be followed. (Since the graduate courses required for the MS degree are determined by the respective department, each student in the dual-degree program should have a secondary advisor in that department, starting no later than the junior year, and consult with this advisor concerning requirements for the MS degree.)

## Minor

A minor in mathematics is available to all undergraduates. It consists of 17 credit hours of approved course work in mathematics. No more than two courses can be used to satisfy both minor requirements and the requirements of the student's major field (meaning departmental degree requirements, including departmental technical electives and common course requirements of the student's school). The 17 hours must be from among the following MATH courses:

MATH 121	Calculus for Science and Engineering I	4
or MATH 125	Math and Calculus Applications for Life, Managerial, and Social Sci I	
MATH 122	Calculus for Science and Engineering II	4
or MATH 124	Calculus II	
or MATH 126	Math and Calculus Applications for Life, Managerial, and Social Sci II	
MATH 223	Calculus for Science and Engineering III	3
or MATH 227	Calculus III	
MATH 224	Elementary Differential Equations	3
or MATH 228	Differential Equations	
MATH 150	Mathematics from a Mathematician's Perspective *	3
MATH 201	Introduction to Linear Algebra	3
or MATH 307	Introduction to Abstract Algebra I	
MATH 301	Undergraduate Reading Course	1-3
MATH 302	Departmental Seminar	3
MATH 303	Elementary Number Theory	3
MATH 304	Discrete Mathematics	3
MATH 308	Introduction to Abstract Algebra II	3
MATH 321	Fundamentals of Analysis I	3
MATH 322	Fundamentals of Analysis II	3
MATH 324	Introduction to Complex Analysis	3
MATH 327	Convexity and Optimization	3
MATH 330	Introduction of Scientific Computing	3
MATH 333	Mathematics and Brain	3
MATH 338	Introduction to Dynamical Systems	3
MATH 343	Theoretical Computer Science	3
MATH 363	Knot Theory	3
MATH 380	Introduction to Probability	3
Or any 400-level MATH course		

\* To count toward a minor in Mathematics, MATH 150 Mathematics from a Mathematician's Perspective must be taken in the first or second year.