

The **Mathematical Sciences Program** is designed to provide broad training in basic mathematics together with some specialization in an area of application of mathematics. Each student must select one of the eight Program Options as a special area.

Because of the somewhat more specific requirements of the Program Options, careful planning and frequent consultation with your advisor are essential to ensure timely completion of the program.

Students may choose from 8 different Program Options within the Mathematical Science Program:

- (a) **Discrete and Algorithmic Methods**
- (b) **Numerical and Applied Analysis**
- (c) **Operations Research and Modeling**
- (d) **Probabilistic Methods**
- (e) **Mathematical Economics**
- (f) **Control Systems**
- (g) **Mathematical Physics**
- (h) **Mathematical Biology**

The concentration program must include at least nine courses: four basic courses (II.), three courses from one of the Program Options (III.), and two additional courses (IV.) as described below. At least two of the five (optional and additional) courses must be MATH courses.

I. *Prerequisites\*\* (3-7 courses)* *{ must be completed with C- or better }*

Instructions	Course(s)	Student Elections (enter your course selections here)
<b>Accepted Transfer Credit</b>	AP Phys 139/239	1. _____
Select <b>one</b> of the following <b>course pairs</b> :	Math 215 & 217 Math 285 & 217 Math 285 & 286 Math 295 & 296	1. _____ 2. _____
<b>EECS 183 or working knowledge</b> of a high-level computer language (Fortran, C, or C++)	EECS 183 or working knowledge of a high-level computer language (Fortran, C, or C++)  <i>*Students are encouraged to take EECS 280 and EECS 281 as well.</i>	3. _____
All of these sequences are <b>strongly recommended</b> :	Physics 140 & Physics 141* Physics 240 & Physics 241* Bio 171 & Bio 172* EECS 280 & EECS 281  <i>*Phys 140, 141, 240 &amp; 242 are required for the Numerical &amp; Applied Analysis, &amp; Physics Options. *Bio 171 &amp; 172 are required for the Biology Option</i>	<b>(strongly recommended)</b> 4. _____ 5. _____ 6. _____ 7. _____

*Basic Courses\*\* (4 courses)*

*{must be completed with C- or better}*

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>one</b> of the following <b>Differential Equations</b> courses:	Math 286 Math 316	1. _____
Select <b>one</b> of the following <b>Discrete Math/Modern Algebra</b> courses:	Math 312 Math 412 Math 465 Math 493	2. _____
Select <b>one</b> the following <b>Analysis</b> courses:	Math 351 Math 354 Math 450 Math 451 Math 454	3. _____
Select <b>one</b> the following <b>Probability</b> courses:	Math 425 Math 525	4. _____

**\*\* More advanced students, such as those who have completed Math 396, may substitute higher level courses with the approval of a concentration advisor. All students are strongly encouraged to include in their program one of the more theoretical courses: Math 412, 451, 493, 494, or 525.**

*II. Program Options (# courses varies – see below)*

A student in the **Mathematical Sciences Program** must choose one of the eight Options (a-h) below and complete at least three of the courses listed under that option. This requirement is designed to provide focus and depth to the program and can only be waived by a departmental advisor in favor of a program which provides this depth in some equivalent way. An acceptable program must include some of the more difficult courses. Advice should be sought from a departmental advisor before selecting an option. As an initial guide, we give a brief description of the Options

*III. Advanced Courses\*\* (2 courses)*

To complete the major program each student should elect two additional advanced courses in mathematics or a related area. Every student must include, either here or elsewhere in his/her program, a cognate course numbered 300 or above taught outside the department which emphasizes the application of significant mathematical tools (at least at the level of Math 215) in another discipline. In all cases **approval of a departmental advisor is required**. This is a very flexible requirement designed to accommodate special interests and may be satisfied by a broad range of courses in other departments (generally numbered 300 or above) or by mathematics courses numbered 400 or above.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>two Advanced</b> courses:	<i>Selected with approval from a mathematical sciences advisor</i>	1. _____ 2. _____

*IV. Requirements*

At least two of the courses in III. and IV. must be MATH courses

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[lsa.umich.edu/math](http://lsa.umich.edu/math)

## Mathematical Sciences: Program Options

### (a) Discrete and Algorithmic Methods\*\* (3 courses)

Discrete and algorithmic methods are concerned with the analysis of finite structures such as graphs, networks, codes, incidence structures, and combinatorial structures. The rapid growth of this area has been driven largely by its role as the mathematical core of computer science. Typical problems of this field involve optimization, emulation, or probabilistic estimation.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 416 - Theory of Algorithms Math 420 - Adv Linear Algebra Math 465 - Intro to Combntrcs Math 475 - Elem Number Theory Math 481 - Intro to Math Logic Math 561 - Linear Prog I Math 565 - Comb & Graph Theory Math 566 - Combinatorial Thry Math 567 - Intro Coding Theory	Math 575 - Intro Theory of Numbers EECS 376 - Found. of Comp Sci. EECS 445 - Intro Machine Lrng EECS 477 - Intro to Algorithms EECS 550 - Information Theory EECS 574 - Comput Complexity EECS 586 - Design/Analysis. Algorithms EECS 587 - Parallel Computing IOE 614 - Integer Progrmng
		1. _____ 2. _____ 3. _____

**\*\*Students choosing this option are strongly encouraged to take EECS 280 and 281**

### (b) Numerical and Applied Analysis\*\* (3 courses)

As computers become more powerful, they are being used to solve increasingly complex problems in science and technology. Examples of such problems include developing high-temperature superconducting materials, determining the structure of a protein from its amino acid sequence, and creating methods to model global climate change. Industrial and government research laboratories require personnel who are trained in applying numerical and analytical techniques to solve such problems. Numerical techniques are algorithms for computer simulation, and analytical techniques may rely on series expansions such as the Taylor or Fourier series expansions. There is a close connection between numerical and analytical techniques. A new analytical technique often leads to more effective numerical algorithms; a good example is the development of wavelets and their applications in signal processing. Students wishing to enter this field must acquire a strong background in mathematics, science, and computing.

Students in the Numerical and Applied Analysis Program may choose to pursue a second major in Data Science. This combination is a powerful recommendation to a prospective employer that the student can think quantitatively about information; collect, manage, analyze, and visualize massive datasets; and that the student has both the computational tools and the rigorous analytical methods to reason about information.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 354 - Fourier Analy & Applications Math 404 - Intermediate Diff Equations Math 420 - Advanced Linear Algebra Math 423 - Math of Finance Math 451 - Advanced Calc I Math 452 - Advanced Calc II Math 454 - Bound Val. Prob for PDE Math 462 - Mathematical Models Math 463 - Math Modeling in Biology	Math 464 - Inverse Problems Math 471 - Intro to Numerical Methods Math 550 - Intro to Adaptive Systems Math 555 - Intro to Complex Variables AERO 225 - Intro to Gas Dynam ME 240 - Dynam & Vibrations PHYS 340 - Waves, Heat, Light PHYS 401 - Inter Mechanics STATS 406 - Statistical Computing STATS 426 - Intro Theory Stats

1. \_\_\_\_\_  
 2. \_\_\_\_\_  
 3. \_\_\_\_\_

**\*\*Students are encouraged to include EECS 283 and MATH 451 in their program, and to also consider doing a minor in another scientific discipline.**

### (c) Operations Research and Modeling\*\* (3 courses)

Mathematical modeling refers generally to the representation of real-world problems in mathematical terms. In some sense this is necessary for any application of mathematics, but the term is used more often to refer to applications of mathematics to biological, mechanical, and human systems. Analysis of such systems involves complex mathematical descriptions and leads to large problems which can be solved only by use of a computer. Operations Research studies integrated systems including health care, education, manufacturing processes, finance, and transportation. Because the emphasis is on the analysis and operation of systems, practitioners are also qualified to deal with managerial problems. Career opportunities are available in many parts of industry and government.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 420 - Adv Linear Algebra Math 433 - Intro to Diff Geom Math 462 - Math Models Math 463 - Math Modeling in Biology Math 561 - Linear Prog I I Math 562 - Cont. Optimization Math	CHE 510 - Math Meths in ChemE IOE 515 - Stochastic Processes IOE 543 - Scheduling IOE 610 - Linear Prog II IOE 611 - Nonlinear Prog IOE 612 - Network Flows IOE 614 - Integer Prog STATS 426 - Intro Theory Stats

1. \_\_\_\_\_  
 2. \_\_\_\_\_  
 3. \_\_\_\_\_

**\*\* Most students should include Math 561 and Stats 426.**

*(d) Probabilistic Methods\*\* (3 courses)*

Probability theory deals with the mathematics of randomness and its applications. It is the basis of mathematical statistics, where the goal is to draw inferences from samples. Non-statistical applications are found in many branches of the social, biological, and physical sciences, as well as in engineering. Because of the intimate connection between probability and statistics, students electing this option will usually include statistics courses in their program and sometimes have a second major in Statistics.

Students in the Probabilistic Methods Program may choose to pursue a second major in Informatics (especially the Data Mining and Information Analysis track). This combination is a powerful recommendation to a prospective employer that the student can think quantitatively about information; collect, manage, analyze, and visualize massive datasets; and that the student has both the computational tools and the rigorous analytical methods to reason about information.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>two</b> of the following courses:	Math 423 - Math of Finance Math 523 - Risk Theory Math 525 - Probability Theory Math 526 - Discrete State Stochastic Process Math 574 - Biological Sequence Analysis EECS 502 - Stochastic Processes	STATS 406 - Intro to Stat Comp STATS 426 - Intro Theory Stats STATS 430 - Applied Probability STATS 466 - Stat Quality Control STATS 500 - Applied Stats STATS 501 - Applied Stats II STATS 550 - Bayesian Decision
Select the following <b>Probability</b> course:	Math 525	1. _____ 2. _____ 3. _____

**\*\*Students electing this option must complete Math 525.**

*(e) Mathematical Economics\*\* (3 courses)*

One definition of economics is the study of the optimal allocation of scarce resources. Several mathematical techniques are fundamental to this study: constrained optimization using Lagrange multipliers, n-dimensional calculus, especially the Implicit Function Theorem (dependence of a solution on parameters), dynamics, probability and statistics to deal with inherent uncertainty, game theory to deal with decisions in which the actions of one agent affect the options of others, and proofs for understanding the derivation of economic principles.

To ensure coverage of these topics, students choosing the Mathematical Economics option will usually choose Math 351 or 451 as their basic analysis course; Math 423, Stat 426, Econ 452, Econ 453, or Econ 454 as courses from the options list; and Econ 401 and a mathematics course at the 400-level or above as their related courses. A student who completes this option should find opportunities available in business, government, and research organizations which collect, analyze, and model data having economic, social, and political parameters. **Many students in this program pursue a second major in Economics;** this combination is a powerful recommendation to a prospective employer that the student can think quantitatively, understand complex reasoning, and work with economic models.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 420 - Adv. Linear Algebra Math 423 - Math of Finance Math 424 - Compound Interest & Life Ins Math 452 - Advanced Calc II Math 462 - Math Models Math 471 - Intro Num Methods Math 472 - Num Meth w/Fin Ap Math 474 - Intro Stochastic Analysis for Fin	Math 523 - Risk Theory Math 561 - Linear Program I Math 562 - Cont. Optimiz Math Math 623 - Comput. Finance ECON 409 - Game Theory ECON 452 - Intro Econometrics ECON 453 - Adv Stats & Econ I ECON 454 - Adv Stats & Econ II STATS 426 - Intro to Thy Stats
		1. _____ 2. _____ 3. _____

*(f) Control Systems\*\* (3 courses)*

Control Systems is a fascinating field which draws upon knowledge in many areas of mathematics. It pervades industry, and its practitioners can be found in such diverse fields as automotive pollution control, avionics, and process control in manufacturing. A control designer will need to interface with the modeling group to develop a mathematical description of the system to be controlled, and perhaps with the testing group to characterize disturbances or other uncertainties affecting the system. The required performance of the system will then be ascertained from the intended use and translated into a set of mathematical specifications for a closed-loop system. At this stage the designer will select from an arsenal of tools for the controller analysis and synthesis—this generally requires a solid foundation in linear algebra, differential equations, real analysis, and probability.

Instructions	Course(s)	Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 354 - Fourier Analysis Math 420 - Adv Linear Algebra Math 451 - Advanced Calc I Math 454 - Bound Val Prob f or PDE Math 462 - Math Models Math 471 - Intro Numerical Methods Math 555 - Intro Cmplx Var Math 561 - Linear Prog I Math 562 - Cont Optimization Methods	EECS 376 - Found. of Comp Sci. EECS 460 - Control Sys Analys./Des. EECS 476 - Data Mining EECS 560 - Linear Systems Thry EECS 561 - Digital Control Sys EECS 562 - Nonlinear Systems EECS 565 - Linear Feedback EECS 567 - Intro to Robotics STATS 426 - Intro to Thy Stats
		1. _____ 2. _____ 3. _____

**\*\* Students planning to pursue graduate study in this area are recommended to include Math 451 and EECS 476 in their programs.**

*(g) Mathematical Physics*

Among all of the disciplines which make significant use of mathematics, physics has the longest history. Indeed, several areas of mathematics were developed for the purpose of solving problems in physics. This option allows a student to pursue interests in physics which use undergraduate mathematics. **It is designed to facilitate a concurrent major in Physics.** Every program must include at least two of the Physics courses from the list below. Note that although Physics 401 is a prerequisite to several of these, it does not count as one of the option courses.

Instructions	Course(s)		Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 404 - Intermediate Diff Equations Math 433 - Intro to Diff. Geom. Math 454 - Bound Val. Prob for PDE Math 471 - Intro to Numerical Methods Math 555 - Intro to Complex Variables	PHYS 405 - Intermed Elec & Magnetism PHYS 406 - Stat & Thermal Phys PHYS 413 - Intro Nonlinear Dyn PHYS 435 - Gravitational Phys PHYS 452 - Methods of Theoretical Phys II PHYS 453 - Quantum Mechanics	1. _____ 2. _____ 3. _____

*(h) Mathematical Biology*

Ever since the advent of high-powered computing, it has become obvious that mathematics can contribute a great deal to biological and medical research. Indeed, in many cases mathematical approaches can answer questions that cannot be addressed by other means, and thus mathematics is often an indispensable tool for biological research. Typical areas of application include such diverse areas as the topology of DNA, genetic algorithms, cell physiology, cancer biology and control strategies, micro-circulation and blood flow, the study of infectious diseases such as AIDS, the biology of populations, neuroscience and the study of the brain, developmental biology and embryology, the study of hormone secretion and endocrine control, and bioinformatics. The Mathematical Biology option will thus be appropriate for any student with an interest in biology or medicine and a desire to apply the mathematics they learn to current and important biological problems.

An **additional prerequisite** to this major is completion of the Introductory Biology sequence (Bio 171 and 172). Students electing this option must complete Math 463 (Math Modeling in Biology), a second math course from the options list below and one advanced level (numbered over 300) course in biological sciences.

The options list below contains approved biological sciences courses but other courses in Biology, Physiology, Microbiology/Immunology, Neuroscience, Bioinformatics, or Natural Resources and Environment can be accepted with approval of your mathematics advisor. Recommended cognate courses include STATS 426, STATS 510 and quantitative courses focused on biological processes such as BIOPHYS 370, BIOPHYS/PHYS/CHEM 417, EEB/CMPLXSYS 430 and EEB/MATH 466.

Instructions	Course(s)		Student Elections (enter your course selections here)
Select <b>three</b> of the following courses:	Math 404 - Intermediate Diff Equations Math 452 - Advanced Calc II Math 454 - Bound Val. Prob for PDE Math 462 - Mathematical Models Math 463 - Math Modeling in Biology Math 471 - Intro to Numerical Methods Math 558 - Applied Nonlinear Dynamics	Math 559 - Comp. & Math. Neuroscience Math 563 - Adv. Math Methods for Bio. Sci. Math 564 - Topics in Math Bio Math 568 - Math/Comp Neuro BIO 305 - Genetics CHEM 351 - Fund. Of Biochem  MCDB 310/BioChem 415 - Int. Biochem MICROBIOL 301 - Intro to Microbiology	1. _____ 2. _____ 3. _____