## Mathematics

### Undergraduate Study

For the undergraduate curriculum in liberal arts and sciences, major in mathematics, leading to the degree bachelor of science, see Liberal Arts and Sciences, Curriculum.

The program in mathematics offers training suitable for students planning to enter secondary school teaching, to work in mathematics and computation for industry or government, or to continue their studies in graduate school. Students may satisfy the major requirements in several ways, suitable for various career objectives. Graduates can construct rigorous arguments to demonstrate mathematical facts. They can communicate their mathematical methods to others and can justify their assumptions.

### Traditional Program

The traditional program of study for mathematics majors gives students a thorough grounding in mathematics. Graduates understand a broad range of mathematical topics and are familiar with a broad range of mathematical models. They have skills for solving problems in diverse situations. The program allows flexibility for specialization, and students are encouraged to steer their education according to career objectives.

### Mathematics courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 101</td>
<td>Orientation in Mathematics</td>
<td>1</td>
</tr>
<tr>
<td>MATH 165</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MATH 166</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MATH 201</td>
<td>Introduction to Proofs</td>
<td>3</td>
</tr>
<tr>
<td>MATH 265</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MATH 317</td>
<td>Theory of Linear Algebra</td>
<td>3-4</td>
</tr>
<tr>
<td>or MATH 407</td>
<td>Applied Linear Algebra</td>
<td></td>
</tr>
<tr>
<td>MATH 301</td>
<td>Abstract Algebra I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 414</td>
<td>Analysis I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 266</td>
<td>Elementary Differential Equations</td>
<td>3-4</td>
</tr>
<tr>
<td>or MATH 267</td>
<td>Elementary Differential Equations and Laplace Transforms</td>
<td></td>
</tr>
</tbody>
</table>

One of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MATH 492</td>
<td>Undergraduate Seminar</td>
<td>2</td>
</tr>
<tr>
<td>C I 480C</td>
<td>Pre-Student Teaching Experience III: Mathematics I</td>
<td>1</td>
</tr>
</tbody>
</table>

Additional Mathematics courses at the 300 level or above 15

Total Credits 45-47

1 C I 480C is available only for students seeking secondary school certification.

### Mathematics Plus

The Mathematics Plus option is for students who wish to establish a clear strength in a field of application of mathematics. They obtain the mathematics major by pursuing study of mathematics, through the upper division level, complementary to their application area. This program makes double majors more feasible and is appropriate for students who plan on employment or graduate study in the application field. It is not intended for students who plan on graduate study in mathematics. For more information, see the mathematics department web site or consult an adviser in mathematics.

### Secondary Education

For certification requirements for teaching of mathematics in grades 5-12, see the Mathematics Department and School of Education web sites or consult an adviser.

### Recommendations

The department strongly recommends that each student majoring in mathematics include in the program substantial supporting work beyond the minimum general education requirement of the college in one or more areas of application of mathematics, such as other mathematical
sciences, engineering, natural science, economics or finance. Particularly useful are:

- **COM S 207** Fundamentals of Computer Programming 3
- **COM S 208** Intermediate Computer Programming 3
- **PHIL 207** Introduction to Symbolic Logic 3
- **PHYS 221** Introduction to Classical Physics I 5
- **PHYS 222** Introduction to Classical Physics II 5
- **STAT 201** Introduction to Statistical Concepts and Methods 4

It also recommends that students contemplating graduate study in mathematics acquire a reading knowledge of French, German, or Russian.

**Credits Not Counted**

Credits earned in the following cannot be counted toward graduation by mathematics majors:

- **MATH 104** Introduction to Probability 3
- **MATH 105** Introduction to Mathematical Ideas 3
- **MATH 140** College Algebra 3
- **MATH 143** Preparation for Calculus 4
- **MATH 145** Applied Trigonometry 3
- **MATH 150** Discrete Mathematics for Business and Social Sciences 3
- **MATH 151** Calculus for Business and Social Sciences 3
- **MATH 160** Survey of Calculus 4
- **MATH 181** Calculus and Mathematical Modeling for the Life Sciences I 4
- **MATH 182** Calculus and Mathematical Modeling for the Life Sciences II 4
- **MATH 195** Mathematics for Elementary Education I 3
- **MATH 196** Mathematics for Elementary Education II 3

**Minor in Mathematics**

The department offers a minor in mathematics, which may be earned by credit in the following:

- **MATH 201** Introduction to Proofs 3
- **MATH 265** Calculus III 4

One of the following

- **MATH 317** Theory of Linear Algebra 4
- **MATH 407** Applied Linear Algebra 3

One of the following

- **MATH 301** Abstract Algebra I 3
- **MATH 304** Combinatorics 3
- **MATH 314** Graph Theory 3
- **MATH 350** Number Theory 3

- **MATH 421** Logic for Mathematics and Computer Science 3
- **MATH 435** Geometry I 3
- **MATH 436** Geometry II 3

One of the following

- **MATH 266** Elementary Differential Equations 3
- **MATH 267** Elementary Differential Equations and Laplace Transforms 4
- **MATH 331** Topology 3
- **MATH 341** Introduction to the Theory of Probability and Statistics I 3
- **MATH 365** Complex Variables with Applications 3
- **MATH 373** Introduction to Scientific Computing 3
- **MATH 414** Analysis I 3

**With 5-12 Teacher Certification**

**Freshman**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ENGL 150</td>
<td>3</td>
<td>MATH 166</td>
<td>4</td>
</tr>
<tr>
<td>LIB 160</td>
<td>1</td>
<td>STAT 201</td>
<td>4</td>
</tr>
<tr>
<td>MATH 101</td>
<td>1</td>
<td>C I 204</td>
<td>3</td>
</tr>
<tr>
<td>MATH 165</td>
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<td>C I 219</td>
<td>1</td>
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<tr>
<td>PSYCH 230</td>
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<td>C I 280L</td>
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<td>General Education</td>
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<td><strong>Total</strong></td>
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**Sophomore**

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<tr>
<th>Fall</th>
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<th>Spring</th>
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<tbody>
<tr>
<td>MATH 201</td>
<td>3</td>
<td>MATH 266 or 267 - Differential Equations</td>
<td>3-4</td>
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<tr>
<td>MATH 265</td>
<td>4</td>
<td>MATH 317</td>
<td>4</td>
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<tr>
<td>ENGL 250</td>
<td>3</td>
<td>C I 333</td>
<td>3</td>
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<tr>
<td>C I 202</td>
<td>3</td>
<td>COM S 107 or 207 - Programming</td>
<td>3</td>
</tr>
<tr>
<td>General Education</td>
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<td>General Education</td>
<td>3</td>
</tr>
<tr>
<td>Take Praxis-I by October 1</td>
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<td>GPA for Admission to Teacher Ed</td>
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<tr>
<td><strong>Total</strong></td>
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**Junior**

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<tr>
<td>MATH 301</td>
<td>3</td>
<td>MATH 342</td>
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<td>MATH 341</td>
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<td>MATH 397</td>
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<td>MATH 435</td>
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<td>MATH 436</td>
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<td>C I 406</td>
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<td>C I 280A</td>
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<tr>
<td>Communication Choice</td>
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<td>C I 426</td>
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Students in all ISU majors must complete a three-credit course in U.S. diversity and a three-credit course in international perspectives. Check [http://www.registrar.iastate.edu/courses/div-ip-guide.html](http://www.registrar.iastate.edu/courses/div-ip-guide.html) for a list of approved courses. Discuss with your adviser how the two courses that you select can be applied to your graduation plan.

LAS majors require a minimum of 120 credits, including a minimum of 45 credits at the 300/400 level. Three of the required 45 300+ level credits must be earned in a general education group outside the group of your major. You must also complete the LAS foreign language requirement and any high school unmet admissions requirements.

Students pursuing licensure to teach grades 5 – 12 must meet the general education and professional teacher education requirements established by the University Teacher Education Program. (Check [http://www.education.iastate.edu/te/](http://www.education.iastate.edu/te/) for the requirements.

### Without Teacher Certification

#### Freshman

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<thead>
<tr>
<th>Credits</th>
<th>Spring</th>
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<tbody>
<tr>
<td>MATH 101</td>
<td>1 MATH 166</td>
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<tr>
<td>MATH 165</td>
<td>4 Social Science Choice</td>
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</tr>
<tr>
<td>ENGL 150</td>
<td>3 Arts &amp; Humanities Choice</td>
<td>3</td>
</tr>
<tr>
<td>LIB 160</td>
<td>1 Natural Science Choice</td>
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<tr>
<td>Natural Science Choice</td>
<td>3 Electives</td>
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<td>Electives</td>
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<td><strong>Total</strong></td>
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#### Sophomore

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<tr>
<td>MATH 201</td>
<td>3 MATH 267</td>
<td>4</td>
</tr>
<tr>
<td>MATH 265</td>
<td>4 MATH 317</td>
<td>4</td>
</tr>
<tr>
<td>Social Science Choice</td>
<td>3 ENGL 250</td>
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### Junior

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<tr>
<th>Credits</th>
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<tr>
<td>MATH Two-Course</td>
<td>3 MATH Two-Course</td>
<td>3</td>
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<tr>
<td>MATH 301 or 414</td>
<td>3 MATH 301 or 414</td>
<td>3</td>
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<tr>
<td>Arts &amp; Humanities Choice</td>
<td>3 Communication Choice</td>
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<tr>
<td>Foreign Language/Electives</td>
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<tr>
<td>Natural Science Choice</td>
<td>Electives</td>
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<td><strong>Total</strong></td>
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### Senior

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<tr>
<th>Credits</th>
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<tbody>
<tr>
<td>MATH Choice, Level 300+</td>
<td>3 MATH Choice, Level 300+</td>
<td>3</td>
</tr>
<tr>
<td>MATH 492 or MATH Choice, Level 300+</td>
<td>3 Electives</td>
<td>9-10</td>
</tr>
<tr>
<td>Arts &amp; Humanities Choice</td>
<td>3 Electives</td>
<td>9-10</td>
</tr>
<tr>
<td>Electives</td>
<td>6-7</td>
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<tr>
<td><strong>Total</strong></td>
<td>14-16</td>
<td>14-16</td>
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</tbody>
</table>
Every mathematics major must complete at least one of the following sequences:

a. Algebra – MATH 301 AND MATH 302
b. Analysis – MATH 414 and MATH 415
c. Discrete – MATH 304 and MATH 314
d. Geometry – MATH 435 and MATH 436
e. Numerical – MATH 373 and MATH 481

If you use 301/302 or 414/415, then add an additional MATH Elective (300+).

Note that some courses are taught only in fall or only in spring, so plan appropriately.

ENGL 302, 305, 309, or 314, or JL MC 201, or MATH 491.

Graduate Study
The department offers programs leading to a Master of Science or Doctor of Philosophy degree in mathematics or applied mathematics, as well as minor work for students whose major is in another department. The department also offers a program leading to the degree of Master of School Mathematics (M.S.M.).

Students desiring to undertake graduate work leading to the M.S. or Ph.D. degree should prepare themselves by taking several upper division mathematics courses. It is desirable that these credits include introduction to analysis and abstract algebra.

The M.S. degree requires a student to take at least 30 credit hours and to write a creative component or thesis. Additionally, students must pass a comprehensive oral examination over their coursework and their creative component or thesis. See the online Mathematics Graduate Handbook for specific requirements.

The Ph.D. degree requires a student to take 48 credit hours of coursework in addition to research hours, pass written qualifying examinations, pass an oral preliminary exam, and perform an original research project culminating in a dissertation which is defended by an oral exam. Ph.D. candidates must have at least one year of supervised teaching experience. See the on-line Mathematics Graduate Handbook for specific requirements.

The M.S.M. degree is primarily for in-service secondary mathematics teachers. Students desiring to pursue the M.S.M degree should present some undergraduate work in mathematics beyond calculus. Candidates for the M.S.M. degree must write an approved creative component and pass a comprehensive oral examination over their course work and their creative component.

Courses primarily for undergraduates:

MATH 010: High School Algebra
(4-0) Cr. 0. F.S.
For students who do not have adequate facility with topics from high school algebra or do not meet the algebra admission requirement. The course is divided into tracks of one- and two-semester lengths. For most students a diagnostic exam will determine which track must be taken. Students will receive a grade in MATH 25 or MATH 30 respectively depending on the level of material covered. Satisfactory completion of MATH 30 is recommended for students planning to take MATH 140, MATH 143, MATH 145, MATH 150, or MATH 151, while MATH 25 is sufficient for MATH 104, MATH 105, MATH 195, STAT 101 or STAT 105. Students must complete MATH 30 to remove a deficiency in the algebra admission requirement. Topics include signed numbers, polynomials, rational and radical expressions, exponential and logarithmic expressions, and equations. Offered on a satisfactory-fail basis only.

MATH 025: High School Algebra
(4-0) Cr. 0. F.S.
Students should initially enroll in MATH 10. See description of MATH 10. Offered on a satisfactory-fail basis only.

MATH 030: High School Algebra
(4-0) Cr. 0. F.S.
Students should initially enroll in MATH 10. See description of MATH 10. Offered on a satisfactory-fail basis only.

MATH 101: Orientation in Mathematics
(1-0) Cr. 1. F.S.
For new majors. Campus resources and opportunities available to students. Careers and programs of study in mathematics. Mathematical reasoning, culture and resources. Description of main branches of mathematics. Offered on a satisfactory-fail basis only.

MATH 104: Introduction to Probability
(3-0) Cr. 3. F.S.SS.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry
Permutations, combinations, probability, expected value, and applications. Either MATH 104 or MATH 150 may be counted toward graduation, but not both.

MATH 105: Introduction to Mathematical Ideas
(3-0) Cr. 3. F.S.SS.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry
Introduction to contemporary mathematics with an emphasis on use of mathematics to solve real world problems. Typical topics are the mathematics of voting, methods of fair division and apportionment, and elementary game theory.
MATH 106: Discovering Mathematics
(3-0) Cr. 3. F.S.
Inquiry-based approach to mathematics, emphasizing the art, history, and beauty of the subject. Typical topics are mathematics from art, music, puzzles, patterns, and reasoning.

MATH 140: College Algebra
(3-1) Cr. 3. F.S.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry; or MATH 30.
Coordinate geometry, quadratic and polynomial equations, functions, graphing, rational functions, exponential and logarithmic functions, inverse functions, quadratic inequalities, systems of linear equations.
Prepares students for MATH 160. Students in the College of Liberal Arts and Sciences may not count MATH 140 toward the General Education Requirements.

MATH 143: Preparation for Calculus
(4-0) Cr. 4. F.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry; or MATH 140.
Preparation for MATH 160, MATH 165, and MATH 181. Functions, graphing, basic trigonometry, logarithms, exponentials. Emphasis on co-variational reasoning. Students in the College of Liberal Arts and Sciences may not count MATH 143 toward General Education Requirements. Only one of MATH 143 and MATH 145 may count toward graduation.

MATH 145: Applied Trigonometry
(3-0) Cr. 3. F.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry; or minimum of C- in MATH 140.
Students in the College of Liberal Arts and Sciences may not count MATH 145 toward the General Education Requirements. Only one of MATH 143 and MATH 145 may count toward graduation.

MATH 150: Discrete Mathematics for Business and Social Sciences
(2-1) Cr. 3. F.S.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry
Linear equations and inequalities, matrix algebra, linear programming, discrete probability. Either MATH 104 or MATH 150 may be counted toward graduation, but not both.

MATH 151: Calculus for Business and Social Sciences
(2-1) Cr. 3. F.S.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry
Differential calculus, applications to max-min problems, integral calculus and applications. Will not serve as prerequisite for MATH 265 or MATH 266. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or the sequence MATH 181-MATH 182 may be counted toward graduation.

MATH 160: Survey of Calculus
(4-0) Cr. 4. F.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of geometry; or MATH 143; or MATH 140
Analytic geometry, derivatives and integrals of elementary functions, simple differential equations, and applications. Will not serve as a prerequisite for MATH 265 or MATH 266. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or the sequence MATH 181-MATH 182 may be counted toward graduation.

MATH 165: Calculus I
(4-0) Cr. 4. F.S.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of geometry, 1 semester of trigonometry; or MATH 143
Differential calculus, applications of the derivative, introduction to integral calculus. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or the sequence MATH 181-MATH 182 may be counted toward graduation.

MATH 166: Calculus II
(4-0) Cr. 4. F.S.S.
Prereq: Minimum of C- in MATH 165 or high math placement scores
Integral calculus, applications of the integral, infinite series, parametric curves and polar coordinates. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or the sequence MATH 181-MATH 182 may be counted toward graduation.

MATH 166H: Calculus II, Honors
(4-0) Cr. 4. F.
Prereq: Permission of instructor and MATH 165 or high math placement scores
Integral calculus, applications of the integral, infinite series, parametric curves and polar coordinates. Additional material of a theoretical, conceptual, computational, or modeling nature. Some of the work may require more ingenuity than is required for MATH 166. Preference will be given to students in the University Honors Program. Only one of MATH 151 or MATH 160, the sequence MATH 165-MATH 166, or the sequence MATH 181-MATH 182 may be counted toward graduation.
MATH 181: Calculus and Mathematical Modeling for the Life Sciences I
(4-0) Cr. 4. F.S.
Prereq: Satisfactory performance on placement assessment, 2 years of high school algebra, 1 year of high school geometry, 1 semester of trigonometry; or MATH 143
Exponential and logarithm functions, difference equations, derivatives, and applications of the derivative. Examples taken from biology. Only one of MATH 151, MATH 160, the sequence MATH 165- MATH 166, or the sequence MATH 181-MATH 182 may be counted towards graduation.

MATH 182: Calculus and Mathematical Modeling for the Life Sciences II
(4-0) Cr. 4. S.
Prereq: MATH 181
Integration, first and second order differential equations, applications of the definite integral, introduction to multivariable calculus. Examples taken from biology. Only one of MATH 151, MATH 160, the sequence MATH 165-MATH 166, or the sequence MATH 181-MATH 182 may be counted towards graduation.

MATH 195: Mathematics for Elementary Education I
(2-2) Cr. 3. F.S.
Prereq: Satisfactory performance on placement assessment, 2 years high school algebra, 1 year of high school geometry, enrollment in elementary education or early childhood education
Whole number operations through analysis of properties, theoretical and hands-on models, mathematical analysis of elementary students’ thinking; standard and non-standard algorithms; structure of the decimal system; linear measurement; two- and three-dimensional geometric shapes and spatial sense; number theory; algebra as it relates to elementary curricula/teaching profession. Students in the College of Liberal Arts and Sciences may not count MATH 195 toward General Education Requirements.

MATH 196: Mathematics for Elementary Education II
(2-2) Cr. 3. F.S.
Prereq: Minimum of C- in MATH 195 and enrollment in elementary education or early childhood education
Integer, fraction and decimal operations through analysis of properties, theoretical and hands-on models, mathematical analysis of elementary students’ thinking; standard and non-standard algorithms; structure of the decimal system; linear measurement; two- and three-dimensional measurement; probability and statistics; proportional reasoning; algebra as it relates to elementary curricula/teaching profession.

MATH 201: Introduction to Proofs
(3-0) Cr. 3. F.S.
Prereq: MATH 166 or MATH 166H
Logic and techniques of proof including induction. Communicating mathematics. Writing proofs about sets, functions, real numbers, limits, sequences, infinite series and continuous functions.

MATH 207: Matrices and Linear Algebra
(3-0) Cr. 3. F.S.SS.
Prereq: 2 semesters of calculus
Systems of linear equations, determinants, vector spaces, linear transformations, orthogonality, least-squares methods, eigenvalues and eigenvectors. Emphasis on applications and techniques. Only one of MATH 207 and MATH 317 may be counted toward graduation.

MATH 265: Calculus III
(4-0) Cr. 4. F.S.SS.
Prereq: Minimum of C- in MATH 166 or MATH 166H
Analytic geometry and vectors, differential calculus of functions of several variables, multiple integrals, vector calculus.

MATH 265H: Calculus III, Honors
(4-0) Cr. 4. F.S.
Prereq: Permission of the instructor; and MATH 166 or MATH 166H
Analytic geometry and vectors, differential calculus of functions of several variables, multiple integrals, vector calculus. Additional material of a theoretical, conceptual, computational, or modeling nature. Some of the work may require more ingenuity than is required in MATH 265. Preference will be given to students in the University Honors Program.

MATH 266: Elementary Differential Equations
(3-0) Cr. 3. F.S.SS.
Prereq: Minimum of C- in MATH 166 or MATH 166H

MATH 267: Elementary Differential Equations and Laplace Transforms
(4-0) Cr. 4. F.S.SS.
Prereq: Minimum of C- in MATH 166 or MATH 166H
Same as MATH 266 but also including Laplace transforms and series solutions to ordinary differential equations.

MATH 268: Laplace Transforms
(1-0) Cr. 1. F.S.SS.
Prereq: MATH 266
Laplace transforms and series solutions to ordinary differential equations. Together, MATH 266 and MATH 268 are the same as MATH 267.
MATH 269: Systems of Differential Equations
(1-0) Cr. 1. F.S.SS.
Prereq: Familiarity with ordinary differential equations of first and second order, permission of department.
Systems portion of MATH 266 and MATH 267: Eigenvalue methods for systems of first order linear equations. Introduction to stability and phase plane analysis. For students supplementing transfer courses in differential equations in order to earn credit in MATH 266 or 267. Students with credit in MATH 266 or MATH 267 may not earn credit in MATH 269.

MATH 290: Independent Study
Cr. 1-3. Repeatable.
Prereq: Permission of the instructor.
Independent study.

MATH 290H: Independent Study, Honors
Cr. 1-3. Repeatable.
Prereq: Permission of the instructor.
Independent study.

MATH 297: Intermediate Topics for School Mathematics
(2-2) Cr. 3. F.
Prereq: Enrollment in elementary education and minimum of C- in MATH 196
Mathematical reasoning and topics in Euclidean and non-Euclidean geometry, including transformations, congruence, and similarity; exploration of probability with simulations; linearity and connections to Calculus; fractals and fractal dimension.

MATH 301: Abstract Algebra I
(3-0) Cr. 3. F.S.
Prereq: MATH 166 or MATH 166H, MATH 317 or MATH 407, and grade of C- or better in MATH 201

MATH 302: Abstract Algebra II
(3-0) Cr. 3. S.
Prereq: MATH 301
Theory of rings and fields. Introduction to Galois theory. Emphasis on writing proofs.

MATH 304: Combinatorics
(3-0) Cr. 3. F.
Prereq: MATH 166 or MATH 166H; MATH 201 or experience with proofs
Enumeration strategies involving permutations, combinations, partitions, binomial coefficients, inclusion-exclusion principle, recurrence relations, generating functions. Additional topics selected from probability, algebraic combinatorics, and applications.

MATH 314: Graph Theory
(3-0) Cr. 3. S.
Prereq: MATH 166 or MATH 166H; MATH 201 or experience with proofs
Structure and extremal properties of graphs. Topics are selected from: trees, networks, colorings, paths and cycles, connectivity, planarity, directed graphs, matchings, Ramsey theory, forbidden structures, enumeration, applications.

MATH 317: Theory of Linear Algebra
(4-0) Cr. 4. F.S.
Prereq: Credit or enrollment in MATH 201
Systems of linear equations, determinants, vector spaces, inner product spaces, linear transformations, eigenvalues and eigenvectors. Emphasis on writing proofs and results. Only one of MATH 207 and MATH 317 may be counted toward graduation.

MATH 317: Theory of Linear Algebra
CROSSLISTED:

MATH 331: Topology
(3-0) Cr. 3. Alt. F., offered even-numbered years.
Prereq: MATH 301
Set theory, metric spaces, topological spaces, continuity, connectedness, homeomorphisms, compactness, and topological invariants. Examples from surfaces, knots, and various abstract objects. Emphasis on writing proofs.

MATH 341: Introduction to the Theory of Probability and Statistics I
(Cross-listed with STAT). (3-0) Cr. 3. F.S.
Prereq: MATH 265 (or MATH 265H)
Probability; distribution functions and their properties; classical discrete and continuous distribution functions; multivariate probability distributions and their properties; moment generating functions; simulation of random variables and use of the R statistical package. Credit for both STAT 341 and STAT 447 may not be applied toward graduation.

MATH 342: Introduction to the Theory of Probability and Statistics II
(Cross-listed with STAT). (3-0) Cr. 3. F.S.
Prereq: STAT 341; MATH 207 or MATH 317
Transformations of random variables; sampling distributions; confidence intervals and hypothesis testing; theory of estimation and hypothesis tests; linear model theory; use of the R statistical package for simulation and data analysis.

MATH 350: Number Theory
(Cross-listed with COM S). (3-0) Cr. 3. S.
Prereq: MATH 201 or COM S 230
Divisibility, integer representations, primes and divisors, linear diophantine equations, congruences, and multiplicative functions. Applications to cryptography.
MATH 365: Complex Variables with Applications  
(3-0) Cr. 3. S.  
Prereq: MATH 265  
Functions of a complex variable, including differentiation, integration and series expansions, residues, evaluation of integrals, conformal mapping.

MATH 373: Introduction to Scientific Computing  
(3-0) Cr. 3. F.  
Prereq: MATH 265  

MATH 385: Introduction to Partial Differential Equations  
(3-0) Cr. 3. F.S.  
Prereq: MATH 265 and one of MATH 266, MATH 267  
Separation of variables methods for elliptic, parabolic, and hyperbolic partial differential equations. Topics from Fourier series, Sturm-Liouville theory, Bessel functions, spherical harmonics, and method of characteristics.

MATH 397: Teaching Secondary Mathematics Using University Mathematics  
(2-2) Cr. 3. S.  
Prereq: MATH 201, MATH 301  
Coursework in university mathematics including calculus, abstract algebra, discrete mathematics, geometry, and other topics as it relates to teaching mathematics in grades 5-12.

MATH 398: Cooperative Education  
Cr. R. Repeatable, maximum of 2 times. F.S.S.  
Prereq: Permission of the department cooperative education coordinator; junior classification  
Required of all cooperative education students. Students must register for this course prior to commencing each work period.

MATH 407: Applied Linear Algebra  
(Dual-listed with MATH 507). (3-0) Cr. 3. F.  
Prereq: MATH 317; or MATH 207 and experience writing proofs  
Advanced topics in applied linear algebra including eigenvalues, eigenvalue localization, singular value decomposition, symmetric and Hermitian matrices, nonnegative and stochastic matrices, matrix norms, canonical forms, matrix functions. Applications to mathematical and physical sciences, engineering, and other fields.

MATH 414: Analysis I  
(3-0) Cr. 3. F.S.S.  
Prereq: Minimum of C- in MATH 201  
A careful development of calculus of functions of one real variable: real number properties, sequences and series, limits, continuity, differentiation, and integration.

MATH 415: Analysis II  
(3-0) Cr. 3. S.  
Prereq: MATH 414; MATH 265; and MATH 317 or MATH 407  
Sequences and series of functions of a real variable, uniform convergence, power series, metric spaces, calculus of functions of two or more real variables.

MATH 421: Logic for Mathematics and Computer Science  
(Cross-listed with COM S). (3-0) Cr. 3. S.  
Prereq: MATH 301 or MATH 207 or MATH 317 or COM S 230  
Propositional and predicate logic. Topics selected from Horn logic, equational logic, resolution and unification, foundations of logic programming, reasoning about programs, program specification and verification, model checking and binary decision diagrams, temporal logic and modal logic.

MATH 424: Introduction to High Performance Computing  
(Cross-listed with COM S, CPR E). (2-2) Cr. 3. F.  
Prereq: MATH 265; MATH 207 or MATH 317  
UNIX, serial programming for high performance, OpenMP for high performance, shared memory parallelization. Semester project required.

MATH 435: Geometry I  
(3-0) Cr. 3. F.  
Prereq: MATH 207 or MATH 317  
Euclidean geometry. Points, lines, circles, triangles, congruence, similarity, properties invariant under rigid motions. Synthetic, analytic, and axiomatic methods.

MATH 436: Geometry II  
(3-0) Cr. 3. S.  
Prereq: Cr. F.  
Continuation of Euclidean geometry with topics from elliptic, projective, or hyperbolic geometry. Emphasis on analytic methods.

MATH 439: Mathematics of Fractals and Chaos  
(3-0) Cr. 3. Alt. F., offered odd-numbered years.  
Prereq: MATH 265 and either MATH 266 or MATH 267  
Iteration of maps; classification of periodic points; bifurcation theory; chaos; Julia sets and the Mandelbrot set; fractals and fractal dimension.
MATH 474: Mathematics of Finance  
(3-0) Cr. 3. S.  
Prereq: MATH 265; STAT 101 or 104 or 105 or 201 or 226.  
Applications of mathematical methods to problems in finance. Lagrange Multiplier Method, applications to mean-variance portfolio selection and utility maximization, binomial asset pricing model. Binary Martingales, Optional Stopping Theorem, Central Limit Theorem, applications to financial derivative pricing.

MATH 481: Numerical Methods for Differential Equations  
(Cross-listed with COM S). (3-0) Cr. 3. S.  
Prereq: MATH 265 and either MATH 266 or MATH 267; knowledge of a programming language  

MATH 490: Independent Study  
Cr. 1-3. Repeatable, maximum of 9 credits.  
Prereq: Permission of instructor.  
No more than 9 credits of Math 490 or Math 490H may be counted toward graduation.

MATH 490H: Independent Study: Honors  
Cr. 1-3. Repeatable, maximum of 9 credits.  
Prereq: Permission of the instructor.  
No more than 9 credits of Math 490 or Math 490H may be counted toward graduation.

MATH 491: Undergraduate Thesis  
Cr. 2-3.  
Writing and presenting a formal mathematics paper. Upon approval by the department, the paper will satisfy the departmental advanced English requirement.

MATH 492: Undergraduate Seminar  
(2-0) Cr. 2. F.S.  
Prereq: MATH 317 or MATH 407  
Introduction to independent mathematical thought, with emphasis on oral communication of an advanced topic. Seminar content varies.

MATH 495: Special Topics  
Cr. arr. Repeatable, maximum of 9 credits.  
Prereq: Permission of instructor  
Topics of current interest.

MATH 497: Teaching Secondary School Mathematics  
(Cross-listed with CI). (3-0) Cr. 3. F.  
Prereq: 15 credits in college mathematics. If in a teacher licensure program, concurrent enrollment in CI 426 or CI 526.  
Develop an understanding of instructional planning, lesson implementation, and assessment in grades 5-12 mathematics, with a focus on reform-based mathematics, equity, and conceptual understanding.

Courses primarily for graduate students, open to qualified undergraduates:

MATH 501: Introduction to Real Analysis  
(3-0) Cr. 3. F.  
Prereq: MATH 265 and (MATH 207 or MATH 317)  
A development of the real numbers. Study of metric spaces, completeness, compactness, sequences, and continuity of functions. Differentiation and integration of real-valued functions, sequences of functions, limits and convergence, equicontinuity.

MATH 502: Topology  
(3-0) Cr. 3. S.  
Prereq: MATH 414 or MATH 501  
Introduction to general topology. Topological spaces, continuous functions, connectedness, compactness. Topics selected from countability and separation axioms, metrization, and complete metric spaces. Topics in algebraic topology.

MATH 504: Abstract Algebra I  
(3-0) Cr. 3. F.  
Prereq: MATH 302  
Algebraic systems and their morphisms, with emphasis on groups and rings.

MATH 505: Abstract Algebra II  
(3-0) Cr. 3. S.  
Prereq: MATH 504  
Continuation of Math 504. Algebraic systems and their morphisms, with emphasis on modules and fields.

MATH 507: Applied Linear Algebra  
(Dual-listed with MATH 407). (3-0) Cr. 3. F.  
Prereq: MATH 317; or MATH 207 and experience writing proofs  
Advanced topics in applied linear algebra including eigenvalues, eigenvalue localization, singular value decomposition, symmetric and Hermitian matrices, nonnegative and stochastic matrices, matrix norms, canonical forms, matrix functions. Applications to mathematical and physical sciences, engineering, and other fields.
MATH 510: Linear Algebra
(3-0) Cr. 3. F.
Prereq: MATH 317 or MATH 407 or (MATH 207 and one of MATH 301 or MATH 414)
Advanced topics in linear algebra including canonical forms; unitary, normal, Hermitian and positive-definite matrices; variational characterizations of eigenvalues.

MATH 511: Functions of a Single Complex Variable
(3-0) Cr. 3. S.
Prereq: MATH 414 or MATH 501
Theory of analytic functions, integration, topology of the extended complex plane, singularities and residue theory, maximum principle, conformal mapping, meromorphic functions, argument principle.

MATH 515: Real Analysis I
(3-0) Cr. 3. F.
Prereq: MATH 414 or MATH 501
Lebesgue measure and Lebesgue integral, one variable differentiation theory, Fubini and Tonelli theorems in R^n, Lp spaces.

MATH 516: Real Analysis II
(3-0) Cr. 3. S.
Prereq: MATH 515

MATH 517: Finite Difference Methods
(3-0) Cr. 3. S.
Prereq: MATH 481 or MATH 561

MATH 519: Methods of Applied Mathematics I
(3-0) Cr. 3. F.
Prereq: MATH 414 or MATH 501

MATH 520: Methods of Applied Mathematics II
(3-0) Cr. 3. S.
Prereq: MATH 519
Continuation of MATH 519.

MATH 525: Numerical Analysis of High Performance Computing
(Cross-listed with COM S, CPR E). (3-0) Cr. 3. S.
Prereq: CPR E 308 or MATH 481; experience in scientific programming; knowledge of FORTRAN or C
Introduction to parallelization techniques and numerical methods for distributed memory high performance computers. A semester project in an area related to each student’s research interests is required.

MATH 533: Cryptography
(Cross-listed with CPR E, INFAS). (3-0) Cr. 3. S.
Prereq: MATH 301 or CPR E 310 or COM S 330
Basic concepts of secure communication, DES and AES, public-key cryptosystems, elliptic curves, hash algorithms, digital signatures, applications. Relevant material on number theory and finite fields.

MATH 535: Steganography and Digital Image Forensics
(Cross-listed with CPR E, INFAS). (3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: E E 524 or MATH 317 or MATH 407 or COM S 330
Basic principles of covert communication, steganalysis, and forensic analysis for digital images. Steganographic security and capacity, matrix embedding, blind attacks, image forensic detection and device identification techniques. Related material on coding theory, statistics, image processing, pattern recognition.

MATH 540: Seminar in Mathematics Education
(1-0) Cr. 1. SS.
Prereq: Enrollment in the Master of School Mathematics program or professional studies in education
MATH 540A: Seminar in Mathematics Education: Assessment, equity, and teaching of statistics.
(1-0) Cr. 1.
**Prereq:** Enrollment in the Master of School Mathematics program or professional studies in education
Research studies in mathematics learning and teaching, exemplary practices in mathematics education, and current state and national trends in the mathematics curriculum in grades K-12. Topics are offered on a 3-year cycle. Offered SS 2017.

MATH 540B: Seminar in Mathematics Education: Geometry and discrete mathematics, and problem solving.
(1-0) Cr. 1.
**Prereq:** Enrollment in the Master of School Mathematics program or professional studies in education

MATH 540C: Seminar in Mathematics Education: Teaching of analysis, algebra, and the use of technology.
(1-0) Cr. 1.
**Prereq:** Enrollment in the Master of School Mathematics program or professional studies in education
Research studies in mathematics learning and teaching, exemplary practices in mathematics education, and current state and national trends in the mathematics curriculum in grades K-12. Topics are offered on a 3-year cycle. Offered SS 2016.

MATH 545: Intermediate Calculus
(4-0) Cr. 4.
**Prereq:** 3 semesters of calculus and enrollment in the master of school mathematics program
Offered on a 3-year cycle, offered SS. 2016. The fundamental concepts of calculus which are critical to the effective understanding of the material in first year calculus. Emphasis is on a constructivist approach to learning, cooperative groups, problem solving, and use of technology.

MATH 547: Discrete Mathematics and Applications
(4-0) Cr. 4.
**Prereq:** Enrollment in the master of school mathematics program
Offered on a 3-year cycle, offered SS. 2018. Applications of graph theory, game theory, voting theory, recursion, combinatorics, and algebraic structures. Issues in integrating discrete topics into the secondary curriculum. Use of the computer to explore discrete mathematics.

MATH 549: Intermediate Geometry
(3-0) Cr. 3.
**Prereq:** MATH 435 or equivalent and enrollment in the master of school mathematics program
Offered on a 3-year cycle, offered SS. 2018. A study of geometry with emphasis on metrics, the group of isometries, and the group of similarities. Specific spaces studied normally include the Euclidean plane, the 2-sphere, projective 2-space, and hyperbolic geometry. Emphasis on analytical methods. Incorporation of geometry software.

MATH 554: Introduction to Stochastic Processes
(Cross-listed with STAT). (3-0) Cr. 3. F.
**Prereq:** STAT 542
Markov chains on discrete spaces in discrete and continuous time (random walks, Poisson processes, birth and death processes) and their long-term behavior. Optional topics may include branching processes, renewal theory, introduction to Brownian motion.

MATH 557: Ordinary Differential Equations and Dynamical Systems
(3-0) Cr. 3. F.
**Prereq:** MATH 415 or MATH 501
The initial-value problem, existence and uniqueness theorems, continuous dependence on parameters, linear systems, stability and asymptotic behavior of solutions, linearization, dynamical systems, bifurcations, and chaotic behavior.

MATH 561: Numerical Analysis I
(3-0) Cr. 3. F.
**Prereq:** MATH 414 or MATH 501
Approximation theory, including polynomial interpolation, spline interpolation and best approximation; numerical differentiation and integration; numerical methods for ordinary differential equations.

MATH 562: Numerical Analysis II
(3-0) Cr. 3. S.
**Prereq:** MATH 317
Numerical linear algebra including LU factorization, QR factorization, linear least squares, singular value decompositions, eigenvalue problems, and iterative methods for large linear systems.
MATH 565: Continuous Optimization
(3-0) Cr. 3. S.
Prereq: MATH 265 and one of MATH 317, 507, 510
Theory and methods for constrained and unconstrained optimization. Steepest-descent, conjugate gradient, Newton and quasi-Newton, line search and trust-region, first and second order necessary and sufficient conditions, linear, quadratic and general nonlinear programming.

MATH 566: Discrete Optimization
(3-0) Cr. 3. F.
Prereq: MATH 317 or MATH 507 or MATH 510
Algorithms for linear programming, integer and combinatorial optimization. Linear programming, duality theory, simplex algorithm; the solution of the shortest-path, minimum spanning tree, max-flow/min-cut, minimum cost flow, maximum matching, and traveling salesman problems; integer linear programming, branch-and-bound, local and global search algorithms; matroids and greedy algorithms.

MATH 577: Linear Systems
(Cross-listed with AER E, E E, M E). (3-0) Cr. 3. F.
Prereq: E E 324 or AER E 331 or MATH 415; and MATH 207

MATH 578: Nonlinear Systems
(Cross-listed with AER E, E E, M E). (3-0) Cr. 3. S.
Prereq: E E 577

MATH 590: Independent Study
Cr. arr. Repeatable.

MATH 591: Orientation for Mathematics Graduate Students I
(0.5-0) Cr. 0.5. F.
Fall semester orientation seminar. Required for graduate students in Mathematics and Applied Mathematics. Topics include teaching at the university level and communication of mathematics. Offered on a satisfactory-fail basis only.

MATH 592: Orientation for Mathematics Graduate Students II
(0.5-0) Cr. 0.5. S.
Spring semester orientation seminar. Required for graduate students in Mathematics and Applied Mathematics. Topics include teaching at the university level and communication of mathematics. Offered on a satisfactory-fail basis only.

MATH 595: Special Topics
Cr. arr. Repeatable.

MATH 599: Creative Component
Cr. arr.

Courses for graduate students:

MATH 601: Mathematical Logic
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: MATH 504
Model theory of propositional and predicate logic, the Soundness Theorem, the Compactness Theorem, the Goedel-Henkin Completeness Theorem, the Incompleteness Theorem, computability theory. As time permits: modal and temporal logic, set theory (the continuum hypothesis). Emphasis on the relationship between `provable' and `true' and the relationship between `computable' and `definable'.

MATH 605: Design Theory and Association Schemes
(3-0) Cr. 3. Alt. F., offered even-numbered years.
Prereq: MATH 504

MATH 606: Enumerative Combinatorics and Ordered Sets
(3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: MATH 504
Ordered sets and lattices. Generating functions. Moebius inversion and other enumeration methods.

MATH 607: Graph Theory
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: MATH 314 or MATH 504
Structural theory of graphs. Topics include basic structures (trees, paths and cycles), networks, colorings, connectivity, topological graph theory, Ramsey theory, forbidden graphs and minors, applications.

MATH 608: Extremal Graph Theory
(3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: MATH 607
Study of extremal graph problems and methods. Topics include canonical Ramsey theory, generalizations of Turan's theorem, Szemeredi's regularity lemma, random graph theory.

MATH 610: Seminar
Cr. arr.
MATH 615: General Theory of Algebraic Structures I
(3-0) Cr. 3. Alt. F., offered even-numbered years.
Prereq: MATH 504
First semester of full-year course. Subalgebras, homomorphisms, congruence relations, and direct products. Lattices and closure operators. Varieties and quasivarieties of algebras, free algebras, Birkhoff's theorems, clones, Mal'cev conditions. Advanced topics.

MATH 616: General Theory of Algebraic Structures II
(3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: MATH 615
Continuation of MATH 615.

MATH 617: Category Theory
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: MATH 504
Categories and functors and their applications.

MATH 618: Representation Theory
(3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: MATH 504
Representations of algebraic structures. Content varies by semester.

MATH 624: Manifolds, Tensors and Differential Geometry
(3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: MATH 501 or MATH 515

MATH 633: Functional Analysis
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: MATH 515
Fundamental theory of normed linear spaces and algebras, such as topology and continuity, duality and spectral theory, emphasizing aspects that provide a framework for the study of the spectrum of an operator, analytic function theory, and modern operator theory.

MATH 641: Foundations of Probability Theory
(Cross-listed with STAT). (3-0) Cr. 3. F.
Prereq: MATH 414 or MATH 501 or equivalent course.

MATH 642: Advanced Probability Theory
(Cross-listed with STAT). (3-0) Cr. 3. S.
Prereq: STAT 641, or STAT 543 and MATH 515.

MATH 645: Advanced Stochastic Processes
(Cross-listed with STAT). (3-0) Cr. 3. S.

MATH 646: Mathematical Modeling of Complex Physical Systems
(Cross-listed with PHYS). (3-0) Cr. 3. S.
Modeling of the dynamics of complex systems on multiple scales: Classical and dissipative molecular dynamics, stochastic modeling and Monte-Carlo simulation; coarse grained nonlinear dynamics, interface propagation and spatial pattern formation.

MATH 655: Partial Differential Equations I
(3-0) Cr. 3. F.
Prereq: MATH 515 or MATH 519
Study of model problems of elliptic, parabolic and hyperbolic types, first order equations, conservation laws, transform methods, introduction to linear partial differential equations of arbitrary order, fundamental solutions.
MATH 656: Partial Differential Equations II  
(3-0) Cr. 3. S.  
Prereq: MATH 655  
Sobolev spaces, general theory of second order linear elliptic, parabolic and hyperbolic partial differential equations, first order linear hyperbolic systems, variational methods, fixed point methods.

MATH 666: Finite Element Methods  
(3-0) Cr. 3. Alt. F., offered even-numbered years.  
Prereq: MATH 516 or MATH 520 or MATH 561 or MATH 656  
Weak and variational formulations of elliptic problems; weak derivatives and Sobolev spaces; Lax-Milgram theorem, Bramble-Hilbert lemma; examples of finite element spaces; polynomial approximation theory; error estimates for finite element methods; implementation issues; mixed finite element methods for Stokes problems; applications.

MATH 680: Advanced Topics  
Cr. 3. Repeatable.

MATH 680A: Advanced Topics: Algebra  
Cr. 3. Repeatable.

MATH 680B: Advanced Topics: Analysis  
Cr. 3. Repeatable.

MATH 680C: Advanced Topics: Applied Mathematics  
Cr. 3. Repeatable.

MATH 680D: Advanced Topics: Combinatorics  
Cr. 3. Repeatable.

MATH 680E: Advanced Topics: Differential Equations  
Cr. 3. Repeatable.

MATH 680F: Advanced Topics: Linear Algebra  
Cr. 3. Repeatable.

MATH 680G: Advanced Topics: Logic and Foundations  
Cr. 3. Repeatable.

MATH 680H: Advanced Topics: Number Theory  
Cr. 3. Repeatable.

MATH 680I: Advanced Topics: Numerical Analysis  
Cr. 3. Repeatable.

MATH 680J: Advanced Topics: Optimization  
Cr. 3. Repeatable.

MATH 680K: Advanced Topics: Probability  
Cr. 3. Repeatable.

MATH 680L: Advanced Topics: Topology  
Cr. 3. Repeatable.

MATH 699: Research  
Cr. arr. Repeatable.