Mathematics and Computer Science

General Information

Degrees and Areas of Concentration

The Department of Mathematics and Computer Science offers undergraduate and graduate degree programs, minors, and certificates.

At the undergraduate level, the department offers degree programs in mathematics and computer science.

In mathematics, the department offers work leading to the Bachelor of Arts (B.A.) in mathematics, the Bachelor of Science (B.S.) in mathematics, the B.S. in mathematics with an emphasis in data science (pending CBHE approval), the B.S. in mathematics with an emphasis in fiscal mathematics and, in cooperation with the College of Education, the Bachelor of Secondary Education (B.S.Ed.) in Secondary Education with an emphasis in mathematics and the B.A. or B.S. in mathematics with master’s level coursework for secondary teacher certification.

In computer science, the department offers the B.S. in computer science.

The department also offers minors in computer science, mathematics, and statistics, a Certificate in Actuarial Studies, a Certificate in Internet and Web, a Certificate in Mobile Apps and Ubiquitous Computing, a Certificate in Data Science, and in cooperation with the Department of Information Systems a joint Certificate in Cybersecurity.

At the graduate level, the department offers a Master of Arts (M.A.) degree in mathematics with an emphasis in mathematics or data science (pending CBHE approval), a Master of Science (M.S.) degree in computer science and a Doctor of Philosophy (Ph.D.) in mathematical and computational sciences – with options in mathematics, computer science, and statistics. The department also offers, in cooperation with the Department of Information Systems, a joint Certificate in Cybersecurity.

Undergraduate Programs Overview

The program leading to the B.A. in mathematics provides a broad grounding in different areas of mathematics, giving students the depth necessary to pursue various aims such as graduate studies or other career choices.

The B.S. in mathematics, the B.S. in mathematics with an emphasis in data science (pending CBHE approval), and the B.S. in mathematics with an emphasis in fiscal mathematics provide sufficient background in mathematics, statistics, and to some extent, computer science to produce graduates who can work in areas requiring applied mathematical techniques and tools. These degrees are structured to allow additional, optional, courses that enable the student to focus on a variety of further areas of interest. Moreover, students pursuing any of these degrees will graduate with greatly enhanced analytic and writing skills, which are valuable in a wide array of fields and professions.

The B.S.Ed. in secondary education with an emphasis in mathematics introduces students to those branches of mathematics most relevant to the teaching of secondary school mathematics.

The B.S. in computer science combines traditional computer science studies, with its depth and breadth, with more practical exposure to a wide variety of tools and technologies. Students in this program are exposed to thorough background in mathematics and statistics, and can also develop expertise in a specific area of interest through available certificates and electives, including those based on math or statistics such as AI and data science/analytics. In addition, students are prepared for working in groups, technical reading and writing, and professional and ethical aspects. Students completing this degree are well prepared for further graduate studies in computer science.

The Certificate in Actuarial Studies is designed to provide the education needed for entry level employment in the actuarial profession.

The Certificate in Data Science is designed to provide computing and statistical foundations for work with big data and data analytics.

The Certificate in Internet and Web is designed to provide a broad training in technologies related to the Internet and Web, with flexibility allowing a student to satisfy specific interests.

The Certificate in Mobile Apps and Ubiquitous Computing is designed to provide training in technologies and framework for mobile apps and computing.

The joint Certificate in Cybersecurity is designed to provide basic training in emerging areas of information, data, and network security.

Dual Programs

The Department offers dual degree programs in mathematics and computer science for students with strong academic records. The B.A./B.S. and M.A. dual degree program in mathematics and the B.S./M.S. dual degree program in computer science are designed to provide an opportunity for strong undergraduate majors to start earning graduate work credit before actually completing their undergraduate degree and to shorten, or accelerate, the time required as students to earn their graduate degrees.

Graduate Programs Overview

Students pursuing the M.A. degree in mathematics may choose the traditional track of M.A. in either pure or applied mathematics or the track in data science (pending CBHE approval). The traditional track is well suited for students preparing to teach at the high school or junior college level. Those who concentrate on applied courses in the traditional track will build a foundation for the application of mathematics in industry and the continuation of their education in the Ph.D. program in mathematical and computational sciences. Our graduates with the traditional track will have abilities in the basic areas of mathematics, and a breadth of knowledge in core subjects at the graduate level. They will study at least one area of mathematics or statistics in depth and will understand some of the contemporary research in mathematics and statistics. The M.A. with data science emphasis is well suited for students preparing to work in industry as data scientists. Our graduates with data science emphasis will acquire a solid foundation in statistics and computational skills with emphasis on applications to data science. Our graduates with either tracks will develop the ability to prepare and deliver oral and written presentations and the ability to pursue mathematical knowledge independently.

The M.S. degree in computer science emphasizes practical aspects of the field. Our graduates have good understanding of the software process and its challenges, good understanding of computers systems and its parts, and be exposed to a wide range of technologies. They will also be prepared for team work, independent research, and technical reporting.
and presentations. In addition, available electives allow the students to focus in specific areas of interest.

The Ph.D. program in mathematical and computational sciences has options in mathematics, computer science, and statistics. The mathematics and statistics options prepare students for a leadership role involving research and development in both industrial and academic settings. Students choosing one of these options will develop abilities in the basic areas of algebra, analysis, and statistics, and will possess breadth of knowledge in core subjects at the graduate level. They will study at least one area of mathematics or statistics in depth and will understand contemporary research in applied mathematics and statistics. They will develop the ability to prepare and deliver oral and written presentations, and they will possess the ability to pursue and produce mathematical or statistical knowledge independently.

Students choosing the computer science option will develop a breadth of abilities in the core areas of computer science at the graduate level. They will gain a depth of ability in contemporary research in their chosen subfield of computer science, and will be able to pursue independent research in their area of specialization.

Students may enroll in any of these graduate programs on a part-time basis, and with proper scheduling all can be completed in the evening.

**Career Outlook**

A degree in mathematics or computer science prepares well-motivated students for interesting careers. Our graduates find positions in industry, government, and education. The demand for individuals well trained in statistics, computer science, data science, and mathematics is greater than the available supply. In addition, a number of graduates in mathematics have elected careers in business, law and other related fields where they find logical and analytical skills valuable.

Graduates in computer science and mathematics from UMSL are located throughout the country, and they also have a strong local presence. They have careers in banking, health care, engineering and manufacturing, law, finance, public service, management, and actuarial management. Many are working in areas such as systems management, information systems and data management, scientific computing, and scientific positions in the armed services. Others have careers in education, especially at secondary and higher levels.

**Department Scholarships**

The Department of Mathematics and Computer Science offers many merit and need based scholarships available to department majors.

The Alumni Scholarship is a monetary award for outstanding undergraduate students open to all junior and senior department majors.

The Edward Z. Andalafte Memorial Scholarship is a monetary award for outstanding undergraduate department majors at the sophomore level or higher.

The Raymond and Thelma Balbes Scholarship in Mathematics is a monetary award for students at the sophomore level or higher who are pursuing a degree in mathematics, have an overall GPA of at least 3.0 and a GPA of at least 3.2 in mathematics and who have completed three semesters of calculus.

The Joseph M. and Mary A. Vogl Scholarship in Mathematics is a need based monetary award for mathematics majors.

The Computer Science Scholarship is a monetary award for outstanding computer science majors with preference given to freshman and sophomore students. Applicants must have a grade point average of 3.5 or higher in courses taken in the department.

The Boeing Company Scholars Program in Computer Science is a monetary award for full-time (at least 12 hours) upper-level undergraduate students in computer science. Recipients must have a minimum GPA of 3.2 and must maintain a GPA of 3.0. Preference will be given to traditionally underrepresented populations.

**Undergraduate Studies**

**General Education Requirements**

All department majors must satisfy the university and appropriate school or college general education requirements (http://bulletin.umsl.edu/ generaleducationrequirements). All mathematics courses may be used to meet the university’s general education breadth of study requirement in natural sciences and mathematics.

**Satisfactory/Unsatisfactory Restrictions**

All department majors may not take mathematical sciences or related area courses on a satisfactory/unsatisfactory basis. Students considering graduate study should consult with their advisers about taking work on a satisfactory/unsatisfactory basis.

**Degree Requirements**

All courses of the department presented to meet the degree requirements must be completed with a grade of C- or better. At least four courses numbered 3000 or above must be taken in residence. Students must have a 2.0 grade point average in the mathematical sciences courses completed.

Students enrolling in introductory mathematics courses should check the prerequisites to determine if a satisfactory score on the Mathematics Placement Test is necessary. Placement into introductory courses assumes a mastery of two years of high school algebra.

A minimum grade of C- is required to meet the prerequisite requirement for any course except with permission of the department.

Note: Courses that are prerequisites for higher-level courses may not be taken for credit or quality points if the higher-level course has been satisfactorily completed.

Many students are qualified, as a result of having studied calculus in high school, to begin their major with MATH 1900, Analytic Geometry and Calculus II, or MATH 2000, Analytic Geometry and Calculus III. These students are urged to consult with the department before planning their programs. Credit for MATH 1800, Analytic Geometry and Calculus I, will be granted to those students who complete MATH 1900 with a grade of C- or better.

Similarly, students who are ready to begin their computer science studies with CMP SCI 2250, Programming and Data Structures, will be granted credit for CMP SCI 1250, Introduction to Computing, once they complete CMP SCI 2250 with a grade of C- or better.

**Declaring the Mathematics Major**

Students seeking to major in mathematics are first designated as “pre-mathematics majors” until they have completed both MATH 1900 and MATH 2000 or equivalent courses. Upon successful completion of these
two courses with grades of C or better, students will be allowed to declare mathematics as their major. Each of these courses must be completed successfully within two attempts.

Degree Requirements in Mathematics

All mathematics majors in all undergraduate programs must complete the mathematics core requirements.

Core Requirements

1. The following courses are required:
   - CMP SCI 1250 Introduction to Computing 3
   - MATH 1320 Introduction to Probability and Statistics 3
   - MATH 1800 Analytic Geometry And Calculus I 5
   - MATH 1900 Analytic Geometry And Calculus II 5
   - MATH 2000 Analytic Geometry And Calculus III 5
   - MATH 2020 Introduction to Differential Equations 3
   - MATH 2450 Elementary Linear Algebra 3
   - MATH 3250 Foundations of Mathematics 3
   - or CMP SCI 3130 Design and Analysis of Algorithms 3
   - MATH 4100 Real Analysis I 3

   Total Hours: 33

2. The related area requirements as described below must be satisfied. Students seeking a double degree, either within this department or with another department, do not have to fulfill the related area requirements.

Bachelor of Arts in Mathematics

In addition to the core requirements and the College of Arts and Sciences' foreign language requirement, three mathematics courses at the 4000 level or higher must be completed. Of these, one must be MATH 4400, Introduction to Abstract Algebra.

Bachelor of Science in Mathematics

In addition to the core requirements, the B.S. in Mathematics degree requires:

1. Completing all of the following:
   - MATH 4160 Complex Analysis I 3
   - MATH 4400 Introduction To Abstract Algebra I 3
   - MATH 4450 Linear Algebra 3

   Total Hours: 9

2. Completing an additional three courses numbered above 4000 in mathematics, statistics or computer science, at least one of which must be in mathematics/statistics.

Bachelor of Science in Mathematics with an Emphasis in Fiscal Mathematics

Core Requirements

- CMP SCI 1250 Introduction to Computing 3
- MATH 1320 Introduction to Probability and Statistics 3
- MATH 1800 Analytic Geometry And Calculus I 5
- MATH 1900 Analytic Geometry And Calculus II 5
- MATH 2000 Analytic Geometry And Calculus III 5
- MATH 2450 Elementary Linear Algebra 3
- MATH 3250 Foundations of Mathematics 3
- or CMP SCI 3130 Design and Analysis of Algorithms 3
- MATH 4100 Real Analysis I 3
- MATH 4200 Mathematical Statistics I 3
- MATH 4210 Mathematical Statistics II 3
- MATH 2000 Analytic Geometry And Calculus III 5
- MATH 2020 Introduction to Differential Equations 3
- MATH 2450 Elementary Linear Algebra 3
- MATH 3250 Foundations of Mathematics 3
- MATH 4005 Exploratory Data Analysis with R 3

In addition, two further courses in mathematics, statistics or computer science numbered above 4000.

Related Requirements

- ECON 4100 Introduction to Econometrics 4
- ECON 4110 Applied Econometrics 4
- or ECON 4130 Business and Economic Forecasting 4

Complete two of the following courses:

- FINANCE 3503 Computer Applications in Finance 3
- FINANCE 3520 Investments 3
- FINANCE 3521 Financial Engineering: Applying Derivatives 3
- FINANCE 3523 Fixed Income Analysis 3
- FINANCE 3540 Introduction to Financial Institutions and Financial Markets 3

Total Hours: 68

Related Area Requirements for majors in Mathematics

Candidates for the B.A. in Mathematics must satisfy the requirements in one of the groups below with a grade of C-or better. Candidates for the B.S.Ed. in Mathematics and B.S. in Mathematics must satisfy the requirements in two of the groups below with a grade of C-or better.

If candidates choose group 2, then they cannot apply either of the two courses listed in that group towards the additional 4000 level mathematics courses (beyond the core requirements) that must be completed for each of these degrees.

Students seeking a double degree, either within this department or with another department do not have to fulfill the related area requirements.

Related Area Courses

1) Computer Science

Select two of the following:

- CMP SCI 2250 Programming and Data Structures
- CMP SCI 2700 Computer Organization and Architecture
- CMP SCI 3130 Design and Analysis of Algorithms
- CMP SCI 4140 Theory of Computation
- CMP SCI 4410 Introduction to Computer Graphics
- CMP SCI 4420 Introduction to Digital Image Processing

2) Statistics

- MATH 4200 Mathematical Statistics I 3
- MATH 4210 Mathematical Statistics II 3

3) Biology
B.S. Ed. in Secondary Education with Emphasis in Mathematics

The B.S. Ed. is a professional education degree designed for students who wish to pursue a teaching career in secondary schools. Much of the discipline-specific coursework parallels the B.A. or B.S. degree in the discipline; however, the Missouri Department of Elementary and Secondary Education (DESE) requires specific coursework for teacher certification. Therefore, students interested in the B.S. Ed. should contact the advising office (OASIS) 314-516-5937 in the College of Education for discipline-specific requirements. Note: To obtain teaching certification, DESE requires a 3.0 GPA in the discipline and professional education coursework, as well as a 2.75 GPA overall.

B.A. or B.S. in Mathematics with Master’s Level Coursework for Secondary Teacher Certification

In addition to the B.S. Ed., students may opt to complete a B.A. or B.S. degree in their discipline as an undergraduate, followed by admission to the Graduate School for Master’s level teaching certification. The College of Education has a one-year accelerated program for post-graduate certification called Teach in 12, or students can choose a traditional path to certification. Graduate coursework for certification can apply towards a Master’s Degree in Secondary Education, with additional coursework. Students interested in Master’s Level teacher certification should contact the advising office (OASIS) 314-516-5937 in the College of Education.

Declaring the Computer Science Major

Students seeking to major in computer science are first designated as “pre-computer science majors” until they have completed CMP SCI 2750 or equivalent course. Upon successful completion of this course with a grade of C- or better, students will be allowed to declare computer science as their major. This course must be completed successfully within two attempts.

Degree Requirements in Computer Science

Candidates for the B. S. Computer Science degree must complete the following work:

1) Computer Science Core
CMP SCI 1250 Introduction To Computing 3
CMP SCI 2250 Programming And Data Structures 3
CMP SCI 2261 Object-Oriented Programming 3
CMP SCI 2700 Computer Organization and Architecture 3
CMP SCI 2750 System Programming and Tools 3
CMP SCI 3010 Web Programming 3
CMP SCI 3130 Design and Analysis of Algorithms 3
CMP SCI 4250 Programming Languages 3
CMP SCI 4280 Program Translation 3
CMP SCI 4500 Introduction to the Software Profession 3
CMP SCI 4760 Operating Systems 3

2) Computer Science Electives
Select five more elective computer science courses, numbered above 3000. 15

3) Mathematics and Statistics
MATH 1320 Applied Statistics I 3
MATH 1800 Analytic Geometry And Calculus I 5
MATH 1900 Analytic Geometry And Calculus II 5
MATH 2450 Elementary Linear Algebra 3
MATH 3000 Discrete Structures 3

4) Additional Skills
ENGL 3130 Technical Writing 3

Total Hours 70

There are no related area requirements for majors in Computer Science.

BS and MS Dual Degree in Computer Science

BS and MS Dual Degree in Computer Science

The Integrated BS/MS ("2+3") dual degree program involves dual credit for qualified undergraduate Computer Science students. It allows the students to concurrently earn credit for some graduate courses while
working on their undergraduate degree, reducing the total hours needed for the subsequent MS degree by up to 12 credit hours.

**Entry Requirements**

Undergraduate majors can apply for provisional admission to this program if:

1. They have completed at least 60 credit hours of coursework.
2. Their overall GPA is 3.0 or higher.
3. Non-CS majors must at the same time become CS majors.

Upon acceptance to the program in the provisional status, the student continues to work toward his/her undergraduate degree in computer science.

After completion of a minimum of 90 hours and no more than 30 hours away from the undergraduate degree, a provisionally admitted student applies for formal admission to the graduate program. At this point, the student must meet the entry requirements for admission to the M.S. degree in Computer Science.

**Degree Requirements**

After acceptance into the program, the student continues to complete his/her undergraduate degree. The student is reclassified as a graduate student from the next semester and must pay graduate fees. The student will be assigned a graduate adviser to help optimize the transition to the graduate program. The student continues taking the undergraduate courses but is also allowed to take courses reserved for graduate students. The student completes all the courses to fulfill the requirements to complete his/her M.S. degree in Computer Science – but must also complete the undergraduate requirements. Up to 12 credit hours can be counted towards both the undergraduate and graduate degrees, substantially reducing the hours needed to complete the graduate program by itself.

A student may file for and receive the undergraduate degree at any time when all the requirements are completed, before or in the same semester in which the Master's degree is completed. A student must still complete all the requirements to get a B.S. degree, regardless of whether the student files for the degree or not. A student may choose to finish the studies just with a B.S.

**Minor Requirements**

The department offers minors in computer science, mathematics, and statistics. All courses presented for any of these minors must be completed with a grade of C- or better.

**Minor in Computer Science**

The requirements for the minor are:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 1250</td>
<td>Introduction To Computing</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 2250</td>
<td>Programming And Data Structures</td>
<td>3</td>
</tr>
<tr>
<td>Select three additional computer science courses numbered 2000 or above</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Total Hours</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

A minimum of two computer science courses numbered above 2000 must be taken in residence in the Department of Mathematics and Computer Science at UMSL.

**Minor in Mathematics**

The requirements for the minor are:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1800</td>
<td>Analytic Geometry And Calculus I</td>
<td>5</td>
</tr>
<tr>
<td>MATH 1900</td>
<td>Analytic Geometry And Calculus II</td>
<td>5</td>
</tr>
<tr>
<td>MATH 2000</td>
<td>Analytic Geometry And Calculus III</td>
<td>5</td>
</tr>
<tr>
<td>Select two additional three-hour mathematics courses numbered above 2400</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total Hours</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

A minimum of two mathematics courses numbered 2000 or above must be taken in residence in the Department of Mathematics and Computer Science at UMSL.

**Minor in Statistics**

The requirements for the minor are:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4200</td>
<td>Mathematical Statistics I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4210</td>
<td>Mathematical Statistics II</td>
<td>3</td>
</tr>
<tr>
<td>Select two additional courses in statistics numbered above 3000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total Hours</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

A minimum of two statistics courses numbered above 3000 must be taken in residence in the Department of Mathematics and Computer Science at UMSL.

**Certificate in Actuarial Studies**

Actuaries use the tools of economics, finance, and mathematics to evaluate and price risk. They are employed by insurance companies, pension funds, consulting firms, and a variety of other financial institutions. The actuarial profession has consistently been ranked as one of the most desirable professions in which to be employed. To become an actuary one must satisfy certain educational requirements, pass exams offered by the Society of Actuaries, and complete professional courses.

The Certificate in Actuarial Studies is designed to provide the education needed for entry level employment in the actuarial profession. Those who complete the certificate will satisfy some of the Validation by Educational Experience requirement of the Society of Actuaries and be prepared to take the first two actuarial examinations (P and FM).

Completion of the certificate requires the following courses. Please note that many of these courses have prerequisites so anyone pursuing the certificate should work carefully with an academic advisor.

**Required Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINANCE 3500</td>
<td>Financial Management</td>
<td>3</td>
</tr>
<tr>
<td>FINANCE 3521</td>
<td>Financial Engineering: Applying Derivatives</td>
<td>3</td>
</tr>
<tr>
<td>MATH 3010</td>
<td>Financial Mathematics I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 3020</td>
<td>Financial Mathematics II</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4200</td>
<td>Mathematical Statistics I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4210</td>
<td>Mathematical Statistics II</td>
<td>3</td>
</tr>
<tr>
<td>Total Hours</td>
<td></td>
<td>18</td>
</tr>
</tbody>
</table>
Residency Requirement: Of the above required six courses at least five must be taken at the University of Missouri-St. Louis.

Certificate in Internet and Web

The undergraduate Certificate in Internet and Web is a six-course (18 credit hours) program. It is designed to provide a broad training in technologies related to the Internet and Web, with flexibility allowing a student to satisfy specific interests. A minimum GPA of 2.5 is required for admission.

Required:

- CMP SCI 3010 Web Programming 3
- CMP SCI 4010 Advanced Web Development with Java 3
- CMP SCI 4011 Client-Side Technologies 3
- CMP SCI 4012 Introduction to Enterprise Web Development 3

Choose two of the following: 6

- CMP SCI 4020 Introduction to Android Apps: Android Fundamentals
- CMP SCI 4030 Introduction to Intelligent Web
- CMP SCI 4610 Database Management Systems
- CMP SCI 4730 Computer Networks and Communications
- CMP SCI 4750 Introduction to Cloud Computing
- INFSYS 3846 E-Commerce

Total Hours 18

A minimum of four courses must be taken in residence at UMSL. Courses may be substituted with the permission of the department. For more information, students can contact the department chair or email info@arch.umsl.edu.

Certificate in Data Science

The certificate program provides basic training on skills required for working in growing and popular fields involving data and data analysis. It provides both statistical and computational background while also allowing focus on specific technologies. A student pursuing this certificate can choose from one of the two tracks, the computational track and the statistical track. Each track consists of three required courses (9 credit hours) plus three additional elective courses (9 credit hours).

Required Courses for the Computational Track:

- CMP SCI 4340 Introduction to Machine Learning 3
- CMP SCI 4342 Introduction to Data Mining 3

Choose one from the following: 3

- MATH 4005 Exploratory Data Analysis with R
- MATH 4200 Mathematical Statistics I

Required Courses for the Statistical Track:

- MATH 4200 Mathematical Statistics I 3
- MATH 4210 Mathematical Statistics II 3

Choose one from the following: 3

- MATH 4250 Introduction to Statistical Methods in Learning and Modeling
- CMP SCI 4340 Introduction to Machine Learning

Electives for both tracks:

Select additional three courses from the following: 9

- CMP SCI 4030 Introduction to Intelligent Web
- CMP SCI 4300 Introduction to Artificial Intelligence Computation
- CMP SCI 4320 Introduction to Evolutionary Computation
- CMP SCI 4340 Introduction to Machine Learning
- CMP SCI 4342 Introduction to Data Mining
- CMP SCI 4370 Introduction to Biological Data Science
- CMP SCI 4390 Introduction to Deep Learning
- MATH 4005 Exploratory Data Analysis with R
- MATH 4090 Introduction to High-dimensional Data Analysis
- MATH 4200 Mathematical Statistics I
- MATH 4210 Mathematical Statistics II
- MATH 4220 Bayesian Statistical Methods
- MATH 4225 Introduction to Statistical Computing
- MATH 4250 Introduction to Statistical Methods in Learning and Modeling
- MATH 4260 Introduction to Stochastic Processes

Residency requirement: of the required six courses at least five must be taken at the University of Missouri – St. Louis. Elective courses may be substituted with the permission of the program director. For more information, contact the department chair or email info@arch.umsl.edu.

Certificate in Mobile and Ubiquitous Computing

The undergraduate Certificate in Mobile Apps and Ubiquitous Computing is a six-course (18 credit hours) program. It is designed to provide training in technologies and framework for mobile apps and computing. A minimum GPA of 2.5 is required for admission.

Required Courses:

- CMP SCI 4020 Introduction to Android Apps: Android Fundamentals 3
- CMP SCI 4220 Introduction to iOS Programming and Apps 3
- CMP SCI 4222 iOS Apps 3
- CMP SCI 4792 Mobile and Ubiquitous Computing 3

Choose two of the following: 6

- CMP SCI 4010 Advanced Web Development with Java
- CMP SCI 4610 Database Management Systems
- CMP SCI 4750 Introduction to Cloud Computing

Total Hours 18

A minimum of four courses must be taken in residence in the Department of Mathematics and Computer Science at UMSL. Courses may be substituted with the permission of the department. For more information, students can contact the department chair or email info@arch.umsl.edu.

Graduate Studies

The Department of Mathematics and Computer Science offers an M.A. degree in mathematics with emphasis in mathematics, a Ph.D. degree in mathematical and computational sciences (with options in mathematics,
Admission

Applicants must meet the general admission requirements of the Graduate School, described elsewhere in this Bulletin. Additional admission requirements for specific programs are listed below.

Mathematics Programs

Applicants must have at least a bachelor’s degree in mathematics or in a field with significant mathematical content. Examples of such fields include computer science, economics, engineering and physics. An applicant’s record should demonstrate superior achievement in undergraduate mathematics.

Individuals may apply for direct admission to either the M.A. or Ph.D. program. Candidates for the M.A. degree may choose to concentrate in either pure or applied mathematics. Students in the M.A. program who want to transfer to the Ph.D. program upon successful completion of 15 credit hours must fill out a new application through Graduate Admissions.

Students intending to enter the Ph.D. program must have a working ability in modern programming technologies. A student with a deficiency in this area may be required to take courses at the undergraduate level in computer science.

Applicants for the Ph.D. program must, in addition, submit three letters of recommendation and scores from the Graduate Record Examination (GRE) general aptitude test.

Computer Science Programs

Applicants must have at least a bachelor’s degree, preferably in computer science or in a related area. Applicants with bachelor’s degrees outside of computer science must demonstrate significant proficiency in computer science by showing competence (proving related academic or professional experience, or taking a test) in the following areas. Courses in parenthesis are UMSL courses that can be used to fulfill the requirement.

• Programming skills in C or C++ and Java (CMP SCI 1250 or CMP SCI 2250, and CMP SCI 2261)
• Proficiency with Object-Oriented concepts and terminology (CMP SCI 2261)
• Proficiency with dynamic data structures (CMP SCI 2250)
• Proficiency with computer organization, architecture, or assembly level programming (CMP SCI 2700)
• Proficiency with design and time/space analysis of algorithms (CMP SCI 3130)
• Familiarity with Unix/Linux/OSX and with command-line scripting with tools (CMP SCI 2750)

Students must also have satisfactorily completed mathematics courses equivalent to the following UMSL courses:

- Two semesters of calculus (MATH 1800 and MATH 1900)
- A course in elementary linear algebra (MATH 2450)
- A course in discrete mathematics (MATH 3000)

An elementary course in probability or statistics (MATH 1320)

A student missing some of the above requirements may be admitted on restricted status if there is strong supportive evidence in other areas. The student will have to take the missing courses, or otherwise demonstrate proficiency. Special regulations of the Graduate School that apply to students on restricted status are described in the UMSL Bulletin.

Preliminary Advisement

Incoming students are assigned advisers with whom they should consult before each registration period to determine an appropriate course of study. If necessary, students may be required to complete undergraduate course work without receiving graduate credit.

Students interested in the Ph.D. program in mathematical and computational sciences with the computer science option must follow the requirements for that program and that option.

Master of Arts in Mathematics

( emphasis areas pending CBHE approval)

Candidates for the M.A. degree must complete 30 hours of course work with at least 15 hours of courses numbered 5000 or above. All courses numbered below 5000 must be completed with grades of at least B. The selections of the courses numbered 5000 or above need the prior approval of the graduate advisor. The program has two options:

- Mathematics option
- Data Science option

For the mathematics option, the courses taken must include those listed below in the mathematics core and other seven mathematics courses numbered 4000 or higher with at least five courses numbered 5000 or above. For the data science option, the courses taken must include the data-science core courses listed below and five elective courses chosen from the listed below in the data-science electives. Up to 2 courses in the data-science electives can be substituted with other courses upon student’s request and graduate program director’s approval.

Students who have already completed courses equivalent to those in the core may substitute other courses numbered above 4000. All substitutions of courses for those listed in the core require the prior approval of the graduate director.

Thesis Option

Either for the mathematics option or for the data science option, the non-core course work may consist of an M.A. thesis written under the direction of a faculty member in the Department of Mathematics and Computer Science. A thesis is not, however, required for this degree. A student who wishes to write a thesis should enroll in 6 hours of MATH 6900, M.A. Thesis. Students writing an M.A. thesis must defend their thesis in an oral exam administered by a committee of three department members which includes the thesis director.

Mathematics

Core Course

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4100</td>
<td>Real Analysis I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4160</td>
<td>Complex Analysis I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4450</td>
<td>Linear Algebra</td>
<td>3</td>
</tr>
</tbody>
</table>

7

Mathematics and Computer Science
complete the required courses for graduate admission. Undergraduate credit hours. Meanwhile the student will be advised toward his/her undergraduate degree until the student completes 90-102 hours. Students submit their applications to the department. Once a student is admitted in this program, the student is allowed to take graduate courses (paid with graduate fees). A student’s application meeting the minimal requirements does not mean the student is automatically admitted in this program. The math graduate committee will review the application and make a decision. In case the application is approved, the student needs to complete a formal application for admission into the graduate program and is recommended for admission by the graduate committee.

**Degree Program**

1. The current separate requirements for BA/BS and MA in math remain unchanged.
2. Once the student is admitted in this program, the student is allowed to take graduate courses (paid with graduate fees).
3. The student in this program can apply up to 12 credit hours of 4000- and-above level courses towards both the bachelor and master’s degrees. The student may get the BA/BS and MA degrees at the same time.
4. In case a student cannot complete the master’s degree for some reason, up to 12 credit hours of graduate level courses can be applied towards the BA/BS degree.
5. Students will pay graduate fees for all courses after being admitted and starting the program.

**Master of Science in Computer Science**

Candidates for the M.S. degree in Computer Science must complete 30 hours of course work, subject to the Graduate School regulations. Of these, at least 18 hours must be numbered 5000 or above, with at least one course numbered 6000 or above, chosen with the prior approval of the Graduate Director. All courses numbered below 5000 must be completed with grades of at least B-. Outside computer science, up to 6 hours of related course work is allowed upon permission of the Graduate Director.

Students must satisfy all of the following core requirements:

<table>
<thead>
<tr>
<th>Course</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 4760</td>
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<td>CMP SCI 5700</td>
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<td>CMP SCI 5500</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 5130</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours 15

Waiving or substituting for a specific requirement can be done on the basis of prior course work or experience at the discretion of the Graduate Director, but it will not reduce the total hours required for the degree.

Additionally, students must attend at least five different seminars or colloquium presentations in the department.

**Thesis Option**

Students may choose to write an M.S. thesis under the direction of a faculty member in the Department of Mathematics and Computer Science. A thesis is not, however, required for this degree.
student who wishes to write a thesis should enroll in 6 hours of CMP SCI 6900, Thesis. Students writing an M.S. thesis must defend their thesis in an oral exam administered by a committee of three department members which includes the thesis director.

**Doctor of Philosophy in Mathematical and Computational Sciences**

The program has three options:

1. Mathematics Option
2. Computer Science Option
3. Statistics Option

The requirements for the Ph.D. degree include the following:

1. Course work
2. Ph.D. candidacy
3. Doctoral dissertation

The requirements are described in detail below.

1. **Course Work**
   - A minimum of 60 hours of courses numbered 4000 or above.
   - In the Mathematics Option, at least 33 hours must be in courses numbered 5000 or above.
   - In the Computer Science Option, at least 45 hours must be in courses numbered 5000 or above.
   - In the Statistics Option, at least 33 hours must be in courses numbered 5000 or above.
   - At most 9 hours of a student's enrollment in MATH 7990 (Dissertation Research) may be counted. Students are expected to maintain a 3.0 average on a 4.0 scale. All courses numbered below 5000 must be completed with a grade of at least B. Courses outside the Department of Mathematics and Computer Science will require approval of the graduate director.

When students who have earned a Master's degree are admitted to the doctoral program, appropriate credits of course work may be applied toward meeting the requirements for the doctoral degree, subject to Graduate School regulations and the approval of the graduate director. The same applies to those with some appropriate graduate credits but without a completed Master's degree.

2. **Ph.D. Candidacy**
   - Advancement to Ph.D. candidacy is a three-step process consisting of:
     a. Completing 18 hours of 5000 level courses other than MATH 7990, Ph.D. Dissertation Research.
     b. Passing the comprehensive examination.
     c. Selecting a Ph.D. committee and preparing a dissertation proposal and defense of the proposal.

**Qualifying Examination**

A student must fulfill the following requirements.

**Basic Requirement**

Pass one written examination covering fundamental topics. This examination would normally take place within the first 12 credit hours of study after admission to the Ph.D. program.

**Mathematics Option**

Topics from real analysis, complex analysis, and linear algebra:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4100</td>
<td>Real Analysis I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4160</td>
<td>Complex Analysis I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4450</td>
<td>Linear Algebra</td>
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</tr>
<tr>
<td><strong>Total Hours</strong></td>
<td></td>
<td><strong>9</strong></td>
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</table>

**Computer Science Option**

Topics from the theory of programming languages, operating systems, analysis of algorithms, and computer systems:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP SCI 4250</td>
<td>Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 4760</td>
<td>Operating Systems</td>
<td>3</td>
</tr>
<tr>
<td>CMP SCI 5130</td>
<td>Advanced Data Structures And Algorithms</td>
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</tr>
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<td>CMP SCI 5700</td>
<td>Computer Systems</td>
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<tr>
<td><strong>Total Hours</strong></td>
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<td><strong>12</strong></td>
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</tbody>
</table>

**Statistics Option**

Topics from real analysis, linear algebra, and mathematical statistics:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4100</td>
<td>Real Analysis I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4450</td>
<td>Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>MATH 4200</td>
<td>Mathematical Statistics I</td>
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<td>MATH 4210</td>
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<tr>
<td><strong>Total Hours</strong></td>
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<td><strong>12</strong></td>
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</tbody>
</table>

**Additional Requirement**

After fulfilling the basic requirement above, the student must meet one of the following:

1. Pass a written examination in an area of the student's interests. This examination would normally take place within the first 24 credit hours of study after admission to the Ph.D. program.

2. Write a survey paper in a specialized area under the direction of a member of the graduate faculty. The student should propose to take this option when he/she has already finished at least 2 graduate level courses and has the approval of the graduate committee. The paper should be submitted within four semesters, at which time an oral examination given by a committee of at least three members of the graduate faculty must be passed.

In both parts 1) and 2), the graduate committee will determine if the topics are consistent with the option that the student is pursuing.

**Dissertation Committee and Dissertation Proposal**

After completing the comprehensive examinations, each student chooses a dissertation advisor and prepares a Dissertation Proposal. Usually
students choose an advisor from contacts made through their course work. The dissertation committee will be formed, and the student will meet with this committee for an oral defense of his/her dissertation proposal. The dissertation proposal is a substantial document describing the problem to be worked on and the methods to be used, as well as demonstrating the student’s proficiency in written communication.

**Doctoral Dissertation**

Each Ph.D. candidate must write a dissertation that is an original contribution to the field on a topic approved by the candidate’s Ph.D. Committee and the department, and which meets the standards and requirements set by the Graduate School including the public defense of the dissertation. Students working on a dissertation may enroll in MATH 7990, Ph.D. Dissertation Research. A maximum of 9 hours in MATH 7990 can be used toward the required hours of work in courses numbered 5000 or above.

**BS and MS Dual Degree in Computer Science**

The Integrated BS/MS (“2+3”) dual degree program involves dual credit for qualified undergraduate Computer Science students. It allows the students to concurrently earn credit for some graduate courses while working on their undergraduate degree, reducing the total hours needed for the subsequent MS degree by up to 12 credit hours.

**Entry Requirements**

Undergraduate majors can apply for provisional admission to this program if:

1. They have completed at least 60 credit hours of coursework.
2. Their overall GPA is 3.0 or higher.
3. Non-CS majors must at the same time become CS majors.

Upon acceptance to the program in the provisional status, the student continues to work toward his/her undergraduate degree in computer science.

After completion of a minimum of 90 hours and no more than 30 hours away from the undergraduate degree, a provisionally admitted student applies for formal admission to the graduate program. At this point, the student must meet the entry requirements for admission to the M.S. degree in Computer Science.

**Degree Requirements**

After acceptance into the program, the student continues to complete his/her undergraduate degree. The student is reclassified as a graduate student from the next semester and must pay graduate fees. The student will be assigned a graduate adviser to help optimize the transition to the graduate program. The student continues taking the undergraduate courses but is also allowed to take courses reserved for graduate students. The student completes all the courses to fulfill the requirements to complete his/her M.S. degree in Computer Science – but must also complete the undergraduate requirements. Up to 12 credit hours can be counted towards both the undergraduate and graduate degrees, substantially reducing the hours needed to complete the graduate program by itself.

A student may file for and receive the undergraduate degree at any time when all the requirements are completed, before or in the same semester in which the Master’s degree is completed. A student must still complete all the requirements to get a B.S. degree, regardless of whether the student files for the degree or not. A student may choose to finish the studies just with a B.S.

**Financial Assistance**

Any student who intends to apply for financial assistance, in the form of a teaching assistantship or a research assistantship, is required to have three letters of recommendation submitted with the application to the graduate program in Mathematics or Computer Science. The application must include scores on the GRE general aptitude test. Applicants are also encouraged to submit scores in the GRE subject area test in Mathematics or Computer Science. Applications for financial assistance should be submitted before February 15 prior to the academic year in which the student expects to begin graduate study. Notifications of awards are generally made March 15, and students awarded financial assistance are expected to return letters of acceptance by April 15.

**Sample Four Year Plans**

Mathematics BA (p. 10) Mathematics BS (p. 11) Computer Science BS (p. 11)

**Mathematics BA**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Hours</th>
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</tr>
</thead>
<tbody>
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<td>Fall</td>
<td></td>
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<td>CMP SCI 1250</td>
</tr>
<tr>
<td>ENGL 1100</td>
<td>3</td>
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</tr>
<tr>
<td>MATH 1030</td>
<td>3</td>
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<td>MATH 1035</td>
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<td>EXPLORE - Social Sciences</td>
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<tr>
<td>EXPLORE - Humanities &amp; Fine Arts</td>
<td>3</td>
<td>CORE - US History &amp; Government</td>
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<td>EXPLORE - Social Sciences</td>
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<tr>
<td>MATH 1320</td>
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<table>
<thead>
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<tbody>
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<tr>
<td>MATH 3250</td>
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<td>ENGL 3100</td>
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<th>Fourth Year</th>
<th>Hours</th>
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<tbody>
<tr>
<td>Fall</td>
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<td></td>
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<tr>
<td>MATH 4100</td>
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<td>MATH 4400</td>
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<tr>
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</tbody>
</table>

Total Hours: 118

1. INTDSC 1003 is required only for first-time freshmen and transfer students with less than 24 college credits.

*Please Note: This plan is an example of what a four year plan could look like for a typical student. Placement exam scores in math as well as the*
completion of coursework may change the plan. It should not be used in the place of regular academic advising appointments. All students are encouraged to meet with their advisor each semester. All requirements are subject to change.

**Mathematics BS**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTDSC 1003</td>
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<td>MATH 1800</td>
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<tr>
<td>ENGL 1100</td>
<td>3</td>
<td>CMP SCI 1250</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1030</td>
<td>3</td>
<td>Cultural Diversity Requirement</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1035</td>
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<td>EXPLORE - Social Sciences</td>
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<tr>
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<td>CORE – Communication Proficiency</td>
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<table>
<thead>
<tr>
<th>Second Year</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>MATH 1320</td>
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<td>MATH 2000</td>
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<td>MATH 1900</td>
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<td>CORE – US History &amp; Government</td>
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<table>
<thead>
<tr>
<th>Third Year</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 3250</td>
<td>3</td>
<td>MATH 2020</td>
<td>3</td>
</tr>
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<td>ENGL 3100</td>
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<td>MATH 2450</td>
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</tr>
<tr>
<td>General Education</td>
<td>6</td>
<td>CMP SCI/ MATH/ STAT 4000+ level course</td>
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</tr>
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<td></td>
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<td>Related area course</td>
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<td>Elective or minor</td>
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<table>
<thead>
<tr>
<th>Fourth Year</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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<tbody>
<tr>
<td>MATH 4100</td>
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<td>MATH 4400</td>
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Total Hours: 124-126

1 INTDSC 1003 is required only for first-time freshmen and transfer students with less than 24 college credits.

**Please Note:** This plan is an example of what a four year plan could look like for a typical student. Placement exam scores in math as well as the completion of coursework may change the plan. It should not be used in the place of regular academic advising appointments. All students are encouraged to meet with their advisor each semester. All requirements are subject to change.

**Computer Science Courses**

**CMP SCI 1011 Introduction to the Internet and World Wide Web: 3 semester hours**

Intended for any student wishing to utilize the Internet and World Wide Web more effectively. Topics include networking basics, the Internet and World Wide Web, browsers, search engines, Web Services, utilities, tools, online privacy and security. Students will learn to develop a personal web page using skills acquired in the course.

**CMP SCI 1012 Learning to Program Using Virtual Worlds: 3 semester hours**

Introduces modern programming principles without requiring the knowledge of a traditional programming language. Instead, this course utilizes a novel graphical approach that enables the student to create, populate, and manipulate virtual 3-dimensional worlds which resemble video games. The development of these worlds allows students to gain direct experience and skills in using computers to solve problems. Students will create worlds of varying complexity.
**CMP SCI 1250 Introduction to Computing: 3 semester hours**
Prerequisites: MATH 1030 or MATH 1045 with B- or better, or MATH 1100, or MATH 1800, or a 70% on the proctored UMSL ALEKS Math Placement obtained at most one year prior to enrollment in this course. This course provides an introduction to the concepts of computation, problem solving, and computer systems. It covers fundamental programming constructs, basic data types, and modularization using a modern high level language. Problem solving skills are developed through a progression of programming projects.

**CMP SCI 2250 Programming and Data Structures: 3 semester hours**
Prerequisite: CMP SCI 1250. Continuation of CMP SCI 2250. Discusses properties and implementation of abstract data types such as lists, trees, stacks and queues. Introduces procedural and class abstraction, basic program architecture, use of interfaces, modular programming, and file processing.

**CMP SCI 2261 Object-Oriented Programming: 3 semester hours**
Prerequisite: CMP SCI 2250. Introduces object-oriented concepts, terminology, and notation (UML) using Java. Covers encapsulation, classes, objects, inheritance, and the use of class libraries. Additional topics may include graphical user interfaces, applets, and related tools and technologies.

**CMP SCI 2700 Computer Organization and Architecture: 3 semester hours**
Prerequisites: CMP SCI 1250 and CMP SCI 2250 (CMP SCI 2250 can be taken concurrently). This course introduces details of computer systems from architectural and organizational points of view. It covers data representation, basic digital logic circuits, memory types and hierarchies, I/O and storage devices, CPU architectures such as RISC, CISC, parallel, and multi-core.

**CMP SCI 2750 System Programming and Tools: 3 semester hours**
Prerequisites: CMP SCI 2250 and CMP SCI 2700 (CMP SCI 2700 can be taken concurrently). This course covers systems programming, scripting, libraries, utilities, and development tools. Additional programming topics include piping, binary files, exception handling, command-line arguments and symbolic debugging. This course also explores tools available in the Unix/Linux environments.

**CMP SCI 3010 Web Programming: 3 semester hours**
Prerequisites: CMP SCI 2261 (or concurrent enrollment). This course provides a survey of current Web technologies including markup languages (such as HTML/XHTML, CSS, XML), client side languages (such as JavaScript), server side languages (such as PERL, PHP), and Web protocols. Client-server computing projects are a course requirement.

**CMP SCI 3130 Design and Analysis of Algorithms: 3 semester hours**
Prerequisites: CMP SCI 2250, MATH 1320, and MATH 3000. This course addresses the design and analysis of fundamental algorithms in computer science. Studies basic sorting algorithms, priority queues, order statistics, search trees, and hash tables. Analysis techniques may involve time and space complexity analysis of both iterative and recursive algorithms, analysis of algorithm correctness, and amortized complexity analysis. Additional topics may include data compression, string manipulation, greedy algorithms, dynamic programming, and graph traversal.

**CMP SCI 3200 .NET Framework: 3 semester hours**
Prerequisites: CMP SCI 3010. This course introduces the .NET framework and related languages and technologies. Topics will include Visual Studio and C# for OOP and web applications. Additional topics may include ASP.NET with MVC, data access, and windows communication.

**CMP SCI 3410 Video Game Design and Development: 3 semester hours**
Prerequisites: CMP SCI 2261. This course covers major aspects of the design and development of video games, including world/level design, game UI design, game character design, game engine programming, 2D/3D modeling and rendering, game physics and animation. This is a project-based course in which students learn to apply acquired knowledge and skills to building a video game in a team environment.

**CMP SCI 3710 Assembly Language Programming: 3 semester hours**
Prerequisite: CMP SCI 2700. Explores machine architecture concepts and principles through a study of assembly language programming. Topics covered include integer and floating point arithmetic, procedures, conditional processing, strings, macros, and interfaces to high level languages. Programming projects using a commercially available assembly language will be required.

**CMP SCI 3760 Cyber Threats and Defense: 3 semester hours**
Prerequisites: CMP SCI 2250. This course provides students with the basic foundation knowledge in various cyber threats, defense methods and mechanisms. For cyber threats, the course uses an adversary model (resources, capabilities, intent, motivation, access) to cover threats such as password cracking, backdoors, trojans, viruses, wireless attacks, sniffing, spoofing, session hijacking, denial of service, DDoS, BOTs, MAC spoofing, web app attacks, zero-day exploits, and vulnerabilities that enable them. Cyber threat topics include attack timing, social engineering, attack indication, attack trees, insider problem, covert channels, and threat information sources (e.g., CERT). Typical cyber defense mechanisms will also be covered including intrusion detection, honeytrap and honeynets, network monitoring and traffic analysis, access control, DMZ and proxies, network hardening.

**CMP SCI 3780 Software Security: 3 semester hours**
Prerequisites: CMP SCI 2261, CMP SCI 2750, and CMP SCI 3010. This course introduces the basic software security principles and pitfalls, including topics such as buffer, integer and string problems, runtime errors, SQL and command injection. Additional topics may include data protection, secure file access, password and network security.

**CMP SCI 3990 Undergraduate Internship in Computer Science: 3 semester hours**
Prerequisites: Consent of Advisor. The internship provides for a student to attain field experience in an organization related to Computer Science. A student is engaged off-campus for an assignment of at least 320 hours working on a project as directed by his/her supervisor in the host organization. The project should be approved by the student's academic advisor, or a designated faculty member, who will monitor the student's progress. The course cannot be repeated for credit.

**CMP SCI 4010 Advanced Web Development with Java: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 3010; or graduate standing. This course covers more advanced Java topics, along with related concepts and technologies for Web development. Topics may include database connectivity, multi threading, security, networking, MVC pattern, testing and source control for Java applications, and server-side topics such as servlets and web servers.

**CMP SCI 4011 Client-Side Technologies: 3 semester hours**
Prerequisites: CMP SCI 3010. This course explores in depth the current state-of-the-art front-end, client-side technologies, focusing on JavaScript. Topics may include MongoDB, AngularJS, React, jQuery, Node.js, Express.js, and CSS.
**CMP SCI 4012 Introduction to Enterprise Web Development: 3 semester hours**
Prerequisites: CMP SCI 4010. This course covers design and implementation issues for enterprise web development, and some popular advanced technologies. Topics include MVC and persistence frameworks, such as Spring and Hibernate. Other topics may include Java Web services, EJB, messaging standards such as JMS, and Java EE design patterns. Students will develop enterprise-level web application projects. Credit cannot be earned for both CMP SCI 4012 and CMP SCI 5012.

**CMP SCI 4020 Introduction to Android Apps: Android Fundamentals: 3 semester hours**
Prerequisites: CMP SCI 4010, or consent of the instructor. This course covers the fundamental programming principles, software architecture and user experience considerations underlying handheld software applications and their development environments. Involves in-depth, hands-on examples, implemented on the Android platform, and discussion of security. Credit not granted for both CMP SCI 4020 and CMP SCI 5020.

**CMP SCI 4030 Introduction to Intelligent Web: 3 semester hours**
Prerequisites: CMP SCI 3010 and CMP SCI 3130. This course covers the application of artificial intelligence and other modern techniques to help construct, navigate, and experience the Web. Topics may include retrieval models, classification, mining, association, topology, and indexing algorithms such as PageRank and HITS. Credit cannot be earned for both CMP SCI 4030 and CMP SCI 5030.

**CMP SCI 4140 Theory of Computation: 3 semester hours**
Prerequisites: CMP SCI 3130 or graduate standing. This course provides an introduction to the theory of computation. It describes basic computational models, such as finite state machines, pushdown automata, Turing machines and grammars. It also covers the concept of nondeterministic computation and the relationships between different computational models. Additionally it discusses decidability, reducibility, and classification of problems into complexity classes based on their time and space complexity, such as P, NP, and PSPACE.

**CMP SCI 4220 Introduction to iOS Programming and Apps: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 2750; or graduate standing. This course will use Swift for building iOS apps. It also introduces Xcode, Interface Builder, basic design patterns like MVC and delegation, and core libraries for Swift and iOS. Additional topics may include network communication, data persistence, basic animation, and mapping. This is a project-oriented class that will require significant use of a Mac with Xcode installed.

**CMP SCI 4222 iOS Apps: 3 semester hours**
Prerequisites: CMP SCI 4220 or consent of the instructor. This course focuses on building more sophisticated iOS apps. May include networking such as web services, Bluetooth and wifi connectivity, graphics and animation in 2-d and 3-d, autolayouts, OpenGL, advanced data sources such as plist and core data, source control and unit testing. May also discuss security topics. Credit not granted for both CMP SCI 4222 and CMP SCI 5222.

**CMP SCI 4250 Programming Languages: 3 semester hours**
Prerequisites: CMP SCI 2261 or graduate standing. This course studies the principles, approaches, and trade-offs in modern programming languages, including a comparative study of syntax, semantics, and pragmatics. It also examines major programming paradigms: object-oriented, imperative, functional and logic.

**CMP SCI 4280 Program Translation: 3 semester hours**
Prerequisites: CMP SCI 2700, CMP SCI 2750, CMP SCI 3130, and CMP SCI 4250, or graduate standing. This course focuses on methods, techniques, and mechanisms used to create the abstraction from high level programming to machine level execution. Using program translation as an example of a complex task, this course also teaches how to manage and develop solutions for complex programming problems using modular incremental development and testing using an individual semester long project.

**CMP SCI 4300 Introduction to Artificial Intelligence: 3 semester hours**
Prerequisites: CMP SCI 3130. This course provides an introduction to artificial intelligence. The list of topics may include search, planning, knowledge-based reasoning, probabilistic inference, machine learning, natural language processing, and practical applications. Credit cannot be granted for both CMP SCI 4300 and CMP SCI 5300.

**CMP SCI 4320 Introduction to Evolutionary Computation: 3 semester hours**
Prerequisites: CMP SCI 2261, CMP SCI 2750 and CMP SCI 3130. This course introduces the concepts of nature-inspired problem solving with artificial evolution using selection, crossover, mutation and inheritance. It discusses applications of evolutionary algorithms, overviews the existing models and instances, and analyzes specific instances such as genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. Credit not granted for both CMP SCI 4320 and CMP SCI 5320.

**CMP SCI 4340 Introduction to Machine Learning: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course provides an introduction to machine learning in the context of applications such as data mining, natural language processing, and adaptive computer systems. The course reviews several supervised, unsupervised, and reinforcement machine learning techniques such as naïve Bayes networks, clustering, and decision trees. Selected concepts in computational learning theory may also be covered. Credit cannot be granted for both CMP SCI 4340 and CMP SCI 5340.

**CMP SCI 4342 Introduction to Data Mining: 3 semester hours**
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course provides an introduction to data mining principles, algorithms and applications. Topics may include data preprocessing, data transformation, similarity and dissimilarity measures, data representation, classification techniques, association analysis, cluster analysis, regression, dimension reduction, and anomaly detection. Credit not granted for both CMP SCI 4342 and CMP SCI 5342.

**CMP SCI 4370 Introduction to Biological Data Science: 3 semester hours**
Prerequisites: CMP SCI 3130 or consent of instructor. This course provides an introduction into several key areas of biological data science, with a focus upon genetic data. Relevant background topics in genetics, current issues, and a variety of available resources will be explored. Upon successful completion of this course, the student will be able to evaluate algorithms for analyzing genetic data, including assessments of sources of errors and analysis of time and space complexity; address shortcomings in existing approaches; and implement efficient and effective software for exposing information hidden in genetic data. Credit cannot be granted for both CMP SCI 4370 and CMP SCI 5370.
**CMP SCI 4390 Introduction to Deep Learning: 3 semester hours**  
Prerequisites: CMP SCI 3130 or consent of instructor. This course introduces mathematical foundations for deep learning, and follows with practical applications using selected domains such as image classification or protein predictions. It also covers dense neural networks, convolutional neural networks, recurrent neural networks, and other state-of-the-art networks. Credit cannot be granted for both CMP SCI 4390 and CMP SCI 5390.

**CMP SCI 4410 Introduction to Computer Graphics: 3 semester hours**  
Prerequisites: CMP SCI 2250 and MATH 2450. This course covers the theoretical foundation and algorithms for computer graphics. Students learn the basics of graphics programming for modeling, rendering, and animation of 2D and 3D objects, using standard graphics API. A brief discussion of special graphics hardware, such as GPU, may be included. Credit cannot be granted for both CMP SCI 4410 and CMP SCI 5410.

**CMP SCI 4420 Introduction to Digital Image Processing: 3 semester hours**  
Prerequisites: MATH 1900, MATH 2450, CMP SCI 2750, and CMP SCI 3130. This course focuses on image analysis and visual perception. Students learn data structures and algorithms for image processing, region and texture analysis, image filtering, edge detection, contour following, and image enhancement in both spatial and frequency domain. Other topics may include color processing, coding for storage, retrieval, transmission, and image restoration. Credit cannot be granted for both CMP SCI 4420 and CMP SCI 5420.

**CMP SCI 4500 Introduction to the Software Profession: 3 semester hours**  
Prerequisites: CMP SCI 2261, CMP SCI 3010, and MATH 3000. This course focuses on software development and on the skills required for success in the software profession. Topics related to software development may include software process, models and views, software architectures, documentation, and testing strategies. Topics related to the profession may include ethics, licensing, copyright, trademarks, and professional conduct. Individual and group projects, research, and presentations may be required in this capstone course.

**CMP SCI 4520 Introduction to Object-Oriented Analysis and Design: 3 semester hours**  
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course covers object-oriented development, using UML and following an agile process. It discusses elements of analysis, requirements, design, implementation and deployment, such as use cases, static and dynamic models, patterns, and frameworks. This course includes a semester long project. Credit not granted for both CMP SCI 4520 and CMP SCI 5520.

**CMP SCI 4610 Database Management Systems: 3 semester hours**  
Prerequisites: CMP SCI 3010 and MATH 3000; or graduate standing. This course focuses on database theory and applications, with emphasis on the relational model. Topics include database design, modeling, file systems, indexing, integrity constraints, relational algebra, normalization, transaction processing, and concurrency control. Students are exposed to emerging DBMS technologies and applications. Several programming projects will be required using a popular SQL server.

**CMP SCI 4700 Computer Forensics: 3 semester hours**  
Prerequisites: CMP SCI 2750 and CMP SCI 3010; or graduate standing. This course explores topics and methodologies for examining digital evidence, along with some principles of the investigative process. Includes memory, file system, operating system, network, and mobile device forensics. This course addresses both theory and hands-on aspects for conducting digital forensic examinations.

**CMP SCI 4730 Computer Networks and Communications: 3 semester hours**  
Prerequisites: CMP SCI 2750 and MATH 1320; or graduate standing. This course provides a broad overview of computer networks and communications. Covers the fundamental principles and protocols across the whole layering structure of the Internet protocol stack. A top-down approach covers multiple topics including network application layer, transport layer, network layer, link layer, and physical layer protocols. May also include a range of related technologies such as WWW, HTTP, FTP, DNS, SMTP, TCP, UDP, ICMP, IPv4, IPv6, OSPF, RIPv2, BGP, IEEE 802.11 (WiFi), cellular networks, LANs, Ethernet, CSMA/CD, CDMA, multimedia networking, network management, and security in Internet.

**CMP SCI 4732 Introduction to Cryptography for Computer Security: 3 semester hours**  
Prerequisites: MATH 3000 or consent of instructor. This course provides an introduction to cryptography as it applies to computer security. It describes cryptographic code-making and code-breaking, and how they are integrated within larger security systems. Topics include symmetric encryption algorithms like AES, asymmetric encryption using prime number factorization and elliptic curves, message authentication codes, key exchange protocols and attacks on all these systems. Additional topics may include onion networks and blockchain technology, as well as possible attacks on those systems. Credit cannot be granted for more than one of CMP SCI 4732, CMP SCI 4780, and CMP SCI 5732.

**CMP SCI 4740 Introduction to High Performance Computing: 3 semester hours**  
Prerequisites: CMP SCI 2750 and CMP SCI 3130. This course introduces algorithms for multiprocessor and multi-core architectures. Students learn the models of modern parallel computation and techniques to take advantage of parallel architectures for distributed and shared memory multi-processor architectures. Credit not granted for both CMP SCI 4740 and CMP SCI 5740.

**CMP SCI 4750 Introduction to Cloud Computing: 3 semester hours**  
Prerequisites: CMP SCI 2750. This course provides an introduction to development and deployment of applications in the cloud space. Touches on different aspects of cloud computing such as IaaS, PaaS, and SaaS. Includes significant discussion on legal and security aspects of clouds in the marketplace. May also include public, private, and hybrid clouds, and Internet of Things. Credit not granted for both CMP SCI 4750 and CMP SCI 5750.

**CMP SCI 4760 Operating Systems: 3 semester hours**  
Prerequisites: CMP SCI 2750 and CMP SCI 3130; or graduate standing. This course covers the structure of a generic operating system, considering in detail the algorithms for interprocess communication, process scheduling, resource management, memory management, file systems, and device management. It presents examples from contemporary operating systems and requires practical projects implemented within a modern operating system or simulator environment.

**CMP SCI 4780 Computer and Network Security: 3 semester hours**  
Prerequisites: CMP SCI 4730 or graduate standing. This course provides a broad overview of computer and network security technologies and concerns from multiple perspectives, such as cryptography, Public Key Infrastructures (PKI), hashes and message digests, computer viruses and malware, email security, TCP/IP security, IPSec, Secure Socket Layer (SSL), Transport Layer Security (TLS), Virtual Private Networks (VPN), Firewall, AAA (Authentication, Authorization, Accounting), wireless and mobile systems security, secure identifications (IDs), cloud security, privacy and integrity, network attacks, system monitoring, and Intrusion Detection System (IDS). Management and human factors related to security will also be discussed.
CMP SCI 4782 Information Security: 3 semester hours
Prerequisites: CMP SCI 4730 or CMP SCI 4732 or CMP SCI 4780 or consent of instructor. This course covers topics related to maintaining security in an organizational infrastructure, including risk analysis of the environment, access level and control including multi-factor authentication, and detection capabilities to ensure adequate security monitoring. Additional topics may include network level protections, firewalls, intrusion detection/prevention systems, securing web and mobile applications, securing cloud implementations, and overall architectural considerations for system security. Credit not granted for both CMP SCI 4782 and CMP SCI 5782.

CMP SCI 4792 Mobile and Ubiquitous Computing: 3 semester hours
Prerequisites: CMP SCI 4730 or consent of instructor. This course covers mobile and wireless networking and provides a comprehensive treatment of wireless data and telecommunication networks. Topics include recent trends in mobile and wireless networking, wireless coding and modulation, wireless signal propagation, wireless local area networks, millimeter wave gigabit wireless networks, vehicular wireless networks, white spaces, Bluetooth and Bluetooth Smart, wireless personal area networks, wireless protocols for Internet of Things (IoT), and cellular networks.

CMP SCI 4880 Individual Studies: 1-3 semester hours
Prerequisites: Consent of instructor. This course allows a student to pursue individual studies under the supervision of a faculty member. It may include development of a software project. The course may be repeated for credit.

CMP SCI 4890 Topics in Computer Science: 3 semester hours
Prerequisites: Consent of the Instructor. This course covers a special topic in computer science to be determined by recent developments in the field and the interests of the instructor. This course may be taken for credit more than once so long as the topic discussed in each semester is different.

CMP SCI 5012 Enterprise Web Development: 3 semester hours
Prerequisites: CMP SCI 4010 or consent of instructor. Covers design and implementation issues for enterprise web development, and some popular advanced technologies. Topics include MVC and persistence frameworks, such as Spring and Hibernate. Other topics may include Java Web services, EJB, messaging standards such as JMS, and Java EE design patterns. Students will develop enterprise-level web application projects. Credit cannot be earned for both CMP SCI 4012 and CMP SCI 5012.

CMP SCI 5020 Android Apps: Android Fundamentals: 3 semester hours
Prerequisites: CMP SCI 4010 or consent of instructor. Covers the fundamental programming principles, software architecture and user experience considerations underlying handheld software applications and their development environments. Involves in-depth, hands-on examples, implemented on the Android Platform, and discussion of security. Credit not granted for both CMP SCI 4020 and CMP SCI 5020.

CMP SCI 5030 Intelligent Web: 3 semester hours
Prerequisite: Graduate standing. This course covers the application of artificial intelligence and other modern techniques to help construct, navigate, and experience the Web. Topics may include retrieval models, classification, mining, association, topology, and indexing algorithms such as PageRank and HITS. Credit cannot be earned for both CMP SCI 4030 and CMP SCI 5030.

CMP SCI 5130 Advanced Data Structures and Algorithms: 3 semester hours
Prerequisites: Graduate standing in Computer Science. This course covers analysis of time and space complexity of iterative and recursive algorithms along with performance bounds, design of data structures for efficient performance, sorting algorithms, probabilistic algorithms, divide and conquer strategies, various algorithms on graphs, and np completeness.

CMP SCI 5222 Advanced iOS Apps: 3 semester hours
Prerequisites: CMP SCI 4220 or consent of instructor. Focuses on building sophisticated apps using iOS. Will cover recent developments in networking such as web services, Bluetooth and wifi connectivity, graphics and animation in 2-d and 3-d, autolayouts, OpenGL, advanced data sources such as plist and core data, source control and unit testing. May also discuss security topics. Credit not granted for both CMP SCI 4222 and CMP SCI 5222.

CMP SCI 5300 Artificial Intelligence: 3 semester hours
Prerequisites: Graduate standing. This course provides an introduction to artificial intelligence. The list of topics may include search, planning, knowledge-based reasoning, probabilistic inference, machine learning, natural language processing, and practical applications. Credit cannot be granted for both CMP SCI 4300 and CMP SCI 5300.

CMP SCI 5320 Evolutionary Computation: 3 semester hours
Prerequisites: Graduate standing in Computer Science. This course introduces the concepts of nature-inspired problem solving with artificial evolution using selection, crossover, mutation and inheritance. It discusses applications of evolutionary algorithms, overviews the existing models and instances, and analyzes specific instances such as genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. Credit not granted for both CMP SCI 4320 and CMP SCI 5320.

CMP SCI 5340 Machine Learning: 3 semester hours
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to machine learning in the context of applications such as data mining, natural language processing, and adaptive computer systems. The course reviews several supervised, unsupervised, and reinforcement machine learning techniques such as naive Bayes networks, clustering, and decision trees. Selected concepts in computational learning theory may also be covered. Credit cannot be granted for both CMP SCI 4340 and CMP SCI 5340.

CMP SCI 5342 Data Mining: 3 semester hours
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to data mining principles, algorithms and applications. Topics may include data preprocessing, data transformation, similarity and dissimilarity measures, data representation, classification techniques, association analysis, cluster analysis, regression, dimension reduction, and anomaly detection. Credit not granted for both CMP SCI 4342 and CMP SCI 5342.

CMP SCI 5370 Biological Data Science: 3 semester hours
Prerequisites: Graduate standing in Computer Science or consent of instructor. This course provides an introduction into several key areas of biological data science, with a focus upon genetic data. Relevant background topics in genetics, current issues, and a variety of available resources will be explored. Upon successful completion of this course, the student will be able to evaluate algorithms for analyzing genetic data, including assessments of sources of errors and analysis of time and space complexity; address shortcomings in existing approaches; and implement efficient and effective software for exposing information hidden in genetic data. Credit cannot be granted for both CMP SCI 4370 and CMP SCI 5370.
**CMP SCI 5390 Deep Learning: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course reviews a typical machine learning recipe, mathematical foundations for deep learning, and provides an introduction to deep learning. Topics include dense neural networks, convolutional neural networks, and recurrent neural networks. The course will cover building, training, and using deep neural networks for solving various machine learning problems like image classification and protein contact prediction. Credit cannot be granted for both CMP SCI 4390 and CMP SCI 5390.

**CMP SCI 5410 Computer Graphics: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course covers the theoretical foundation and algorithms of computer graphics. Students learn the basics of graphics programming for modeling, rendering, and animation of 2D and 3D objects, using standard graphics API. A brief discussion of special graphics hardware, such as GPU, may be included. Credit cannot be granted for both CMP SCI 4410 and CMP SCI 5410.

**CMP SCI 5420 Digital Image Processing: 3 semester hours**
Prerequisites: Graduate Standing in Computer Science. This course focuses on image analysis and visual perception. Students learn data structures and algorithms for image processing, region and texture analysis, image filtering, edge detection, contour following, and image enhancement in both spatial and frequency domain. Other topics may include color processing, coding for storage, retrieval, transmission, and image restoration. Credit cannot be granted for both CMP SCI 4420 and CMP SCI 5420.

**CMP SCI 5500 Software Engineering: 3 semester hours**
Prerequisite: Graduate standing. Introduces software engineering as a discipline, discusses stages of the software life cycle, compares development models such as waterfall, prototyping and incremental/iterative, covers requirements analysis, effort and cost estimation, compares structured and object-oriented analysis and design methods. Discusses verification/validation, quality assurance, software reliability, testing methods, maintenance, documentation, project management and team structure, metrics, and available tools.

**CMP SCI 5520 Object Oriented Analysis and Design: 3 semester hours**
Prerequisite: Graduate Standing in Computer Science. This course covers object-oriented development, illustrated with a visual modeling language and following an agile process. Discusses elements of analysis, requirements, design, implementation, and deployment such as use cases, static and dynamic diagrams, patterns, and frameworks. This course includes a semester long project starting with requirements and culminating with deployment. Credit not granted for both CMP SCI 4520 and CMP SCI 5520.

**CMP SCI 5520 Intelligent Information Retrieval: 3 semester hours**
Prerequisites: CMP SCI 4300 or CMP SCI 5300. This course studies techniques for analysis of information by statistical, syntactical, and logical methods. Topics related to multimedia information are also discussed.

**CMP SCI 5700 Computer Systems: 3 semester hours**
Prerequisite: Graduate standing in Computer Science. This course focuses on parallel computing architectures, including RISC, pipelining, vector processing, SIMD, MIMD, and array processing. It introduces different memory and I/O subsystems, hardware description languages, and it demonstrates performance enhancement using different architectures studied.

**CMP SCI 5732 Cryptography for Computer Security: 3 semester hours**
Prerequisites: Graduate standing. This course provides an introduction to cryptography as it applies to computer security. It describes cryptographic code-making and code-breaking, and how they are integrated within larger security systems. Topics include symmetric encryption algorithms like AES, asymmetric encryption using prime number factorization and elliptic curves, message authentication codes, key exchange protocols and attacks on all these systems. Additional topics may include onion networks and blockchain technology, as well as possible attacks on those systems. Credit cannot be granted for more than one of CMP SCI 4732, CMP SCI 4780, and CMP SCI 5732.

**CMP SCI 5740 High Performance Computing: 3 semester hours**
Prerequisite: Graduate Standing in Computer Science. This course introduces algorithms for multiprocessor and multi-core architectures. Students learn the models of modern parallel computation and techniques to take advantage of parallel architectures for distributed and shared memory multi-processor architectures. Credit not granted for both CMP SCI 4740 and CMP SCI 5740.

**CMP SCI 5750 Cloud Computing: 3 semester hours**
Prerequisites: Graduate standing. Provides an introduction to development and deployment of applications in the cloud space. Touches on different aspects of cloud computing such as IaaS, PaaS, and SaaS. Includes significant discussion on legal and security aspects of clouds in the marketplace. May also include public, private, and hybrid clouds, and Internet of Things. Credit not granted for both CMP SCI 4750 and CMP SCI 5750.

**CMP SCI 5782 Advanced Information Security: 3 semester hours**
Prerequisites: CMP SCI 4730 or CMP SCI 4732 or CMP SCI 4780 or CMP SCI 5732 or consent of instructor. The topics covered in this course are risk analysis to understand the security requirements of an environment; access controls to understand the level of controls needed for different practical situations, including multi-factor authentication; detection capabilities, to ensure adequate security monitoring for information systems; network level protections, with firewalls, intrusion detection/prevention systems; securing the web and mobile applications and cloud implementations; and overall security architecture to understand how various controls can provide the security-in-depth that is required in the current environment. Credit not granted for both CMP SCI 4750 and CMP SCI 5782.

**CMP SCI 5794 Security of IoT Systems: 3 semester hours**
Prerequisites: CMP SCI 4730 or consent of the department. This course covers the cutting-edge techniques on the emerging edge cloud and wireless/mobile Internet of Things (IoT) systems. It covers the IoT reference architecture, integrated IoT security architecture, major threats and vulnerabilities with the IoT devices and edge cloud, and defense mechanisms. It includes hands-on labs on both the vulnerabilities and defense of the systems. Credit cannot be granted for both CMP SCI 4794 and CMP SCI 5794.

**CMP SCI 5870 Computer Science Seminar: 1-3 semester hours**
Prerequisites: Graduate standing. This is a seminar on various topics. Substantial student reading and participation is expected. It may be taken more than once for credit with the consent of the department.
Mathematics and Computer Science

**CMP SCI 5880 Computer Science Independent Project: 1-3 semester hours**
Prerequisites: Graduate standing and consent of instructor. This course offers the student an opportunity to work on an advisor-supervised project, individually or in a group. A student may repeat the course for up to 6 credit hours total, but at most 6 hours can be accumulated for CMP SCI 5880 and CMP SCI 6900.

**CMP SCI 5890 Topics in Computer Science: 1-3 semester hours**
Prerequisites: Graduate standing. This course offers various topics not offered on a regular basis. This course may be taken for credit more than once so long as the topic discussed in each semester is different.

**CMP SCI 5900 Graduate Internship in Computer Science: 3 semester hours**
Prerequisites: Consent of Advisor. The internship provides for a student to attain field experience in an organization related to Computer Science. A student is employed off-campus for an assignment of at least 320 hours working on a project as directed by his/her supervisor in the host organization. The project should be approved by the student's academic advisor, or a designated faculty member, who will monitor the student's progress. The student is responsible for having the project supervisor at the company establish contact with the academic advisor to establish schedule and goals, and a procedure to evaluate the goals. The student will submit a written report to the advisor at the end of internship. The course cannot be repeated for credit. Students completing this course will be allowed only up to three hours of Independent Study (CMP SCI 5880).

**CMP SCI 6320 Advances in Evolutionary Computation: 3 semester hours**
Prerequisites: CMP SCI 5320. This course focuses on some advanced topics in genetic and evolutionary computation (both theory and applications). Topics may include genetic algorithm variants, intelligent metaheuristics, evolutionary machine learning, differential evolution, swarm intelligence, learning classifier systems, and Markov models. A substantial part of the course will be based on selected topics from recent literature. This is a project-based course, with the project typically involving literature search and conducting and reporting research. Projects may involve developing specific applications or implementing a specific model.

**CMP SCI 6340 Genetic Programming: 3 semester hours**
Prerequisites: CMP SCI 5320. This course provides an in-depth exploration of Genetic programming, including advanced concepts such as scalability, evolution of modularity and regularity, and constrained evolution with CGP, STGP, or CFG-based GP. It may be reading, research, or application oriented.

**CMP SCI 6410 Topics in Computer Graphics: 3 semester hours**
Prerequisites: CMP SCI 4410 or CMP SCI 5410. This course covers various aspects of advanced graphics techniques, such as geometric modeling, rendering, shading, texturing, and computer animation. The course provides an in-depth study of recent advanced topics in computer graphics.

**CMP SCI 6420 Topics In Image Processing and Multimedia: 3 semester hours**
Prerequisites: CMP SCI 5420. This course covers new developments in digital image processing, computer vision, and multimedia. Topics to be covered may include image databases, object tracking, and large-scale data visualization.

**CMP SCI 6900 Thesis: 1-6 semester hours**
Prerequisites: Completion of at least 12 graduate credits and approval of research topic by thesis advisor. This course is designed for those students intending to present a thesis as part of their M.S. program. At most 6 hours can be accumulated for CMP SCI 5880 and CMP SCI 6900.

**Mathematics Courses**

**MATH 0005 Intermediate Algebra: 3 semester hours**
Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. Prepares students for college level mathematics courses. Covers systems of linear equations and inequalities, polynomials, rational expressions, exponents, quadratic equations, graphing linear and quadratic functions. This course carries no credit towards any baccalaureate degree.

**MATH 1020 Contemporary Mathematics (MOTR MATH 120): 3 semester hours**
Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. Presents methods of problem solving, centering on problems and questions which arise naturally in everyday life. May include aspects of algebra and geometry, the mathematics of finance, probability and statistics, exponential growth, and other topics chosen from traditional and contemporary mathematics which do not employ the calculus. May be taken to meet the mathematical proficiency requirement, but may not be used as a prerequisite for other mathematics courses. Designed for students who do not plan to take calculus. Credit will not be granted for MATH 1020 if credit has been granted for MATH 1310, MATH 1800, MATH 1100, MATH 1102, or MATH 1105. Concurrent enrollment in MATH 1020 and any of these courses is not permitted.

**MATH 1021 Choice and Chance: 3 semester hours**
Same as PHIL 1021. Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. This course provides an introduction to inductive logic and the theory of probability in an organized and systematic way, so as to give students tools for more effective decision-making. We will introduce the probability calculus, basic concepts of utility theory, decision theory and different approaches to understanding probability. This course is designed to be accessible to students of all levels. Satisfies mathematics proficiency.

**MATH 1025 Geometry in the Real World: 3 semester hours**
Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. Presents topics in geometry designed to enrich the student's understanding of mathematics. Geometry as it applies to the physical world and such fields as art, music, nature, motion, architecture and city planning will be examined. This course is designed to be accessible to students of all levels. Satisfies mathematics proficiency.

**MATH 1030 College Algebra (MOTR MATH 130): 3 semester hours**
Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course, or approval of the department. Topics in algebra and probability, polynomial functions, the binomial theorem, logarithms, exponentials, and solutions to systems of equations.
MATH 1035 Trigonometry: 2 semester hours
Prerequisite: MATH 1030 or MATH 1040, or concurrent registration in either of these two courses, or a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. A study of the trigonometric and inverse trigonometric functions with emphasis on trigonometric identities and equations.

MATH 1040 College Algebra for Science and Engineering: 4 semester hours
Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. Topics in this course include factoring, simplifying rational functions, functions and their graphs, solving linear and nonlinear equations, polynomial functions, inverse functions, the binomial theorem, logarithms, exponentials, solutions to systems of equations using matrices, solutions to nonlinear systems of equations, and sequences. Students will also study trigonometric and inverse trigonometric functions with emphasis on trigonometric identities and equations.

MATH 1045 PreCalculus (MOTR MATH 150): 5 semester hours
Prerequisites: A satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course, or consent of the department. This course covers topics including factoring, simplifying rational functions, functions and their graphs, solving linear and nonlinear equations, polynomial functions, inverse functions, the binomial theorem, logarithms, exponentials, solutions to systems of equations using matrices, solutions to nonlinear systems of equations, and sequences. Students will also study trigonometric and inverse trigonometric functions with emphasis on trigonometric identities and equations.

MATH 1100 Basic Calculus: 3 semester hours
Prerequisites: MATH 1030 or MATH 1040 or MATH 1045 or a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. This course introduces plane analytic geometry and basic differential and integral calculus with applications to various areas. No credit for Mathematics majors. Credit not granted for both MATH 1800 and MATH 1100.

MATH 1102 Finite Mathematics: 3 semester hours
Prerequisites: MATH 1030 or MATH 1040 or MATH 1045 or a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. This course introduces logic and set theory, partitions and counting problems, elementary probability theory, stochastic processes, Markov chains, vectors and matrices, linear programming, and game theory.

MATH 1105 Basic Probability and Statistics: 3 semester hours
Prerequisites: MATH 1030 or MATH 1040 or MATH 1045 or a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. An introduction to probability and statistics. Topics include the concept of probability and its properties, descriptive statistics, discrete and continuous random variables, expected value, distribution functions, the central limit theorem, random sampling and sampling distributions. Credit not granted for more than one of MATH 1310, MATH 1320, and MATH 1105.

MATH 1150 Structure of Mathematical Systems I: 3 semester hours
Prerequisites: 45 hours of college credit and a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course OR successful completion of MATH 1030 no more than 2 years prior to enrollment in this course. This course examines topics including problem solving, patterns, sets, numeration systems, whole numbers and operations, positive rational numbers and operations, and an introduction to variables and equations, with an emphasis placed on using multiple techniques for each of the aforementioned topics.

MATH 1310 Elementary Statistical Methods: 3 semester hours
Prerequisites: MATH 1030 or MATH 1040 or MATH 1045 or a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course. An introduction to the basic tools and elementary methods of statistics, such as testing of hypotheses, analysis of variance, method of least squares, and time series. A student may not receive credit for more than one of MATH 1310, MATH 1320, and MATH 1105.

MATH 1320 Introduction to Probability and Statistics: 3 semester hours
Prerequisites: MATH 1030 or MATH 1040 or MATH 1045 or consent of the department. The course will cover basic concepts and methods in probability and statistics. Topics include descriptive statistics, probabilities of events, random variables and their distributions, sampling distributions, estimation of population parameters, confidence intervals and hypothesis testing for population means and population proportions, chi-square tests. A student may not receive credit for more than one of MATH 1310, MATH 1320 and MATH 1105.

MATH 1800 Analytic Geometry and Calculus I: 5 semester hours
Prerequisites: MATH 1030 and MATH 1035, or MATH 1040 and MATH 1045, or a satisfactory score on the UMSL ALEKS Math Placement Examination, obtained at most one year prior to enrollment in this course, or approval of the department. This course provides an introduction to differential and integral calculus. Topics include limits, derivatives, related rates, Newton's method, the Mean-Value Theorem, Max-Min problems, the integral, the Fundamental Theorem of Integral Calculus, areas, volumes, and average values.

MATH 1900 Analytic Geometry and Calculus II: 5 semester hours
Prerequisite: MATH 1800. Topics include conic sections, rotation of axes, polar coordinates, exponential and logarithmic functions, inverse (trigonometric) functions, integration techniques, applications of the integral (including mass, moments, arc length, and hydrostatic pressure), parametric equations, infinite series, power and Taylor series.

MATH 2000 Analytic Geometry and Calculus III: 5 semester hours
Prerequisite: MATH 1900. Topics include vectors, cylindrical and spherical coordinates, vector-valued functions, arc length and curvature, functions of several variables, partial and directional derivatives, gradients, extrema, Lagrange multipliers, multiple integrals, change of variables, surface area, vector fields, Stokes' Theorem.
MATH 2010 Introduction to Inquiry Approaches to STEM Education (STEP I): 1 semester hour
Same as CHEM 2010, PHYSICS 2010, BIOL 2010, and SEC ED 2010. Prerequisites: Concurrent enrollment BIOL 1821, BIOL 1831, CHEM 1111, CHEM 1121, PHYSICS 2111, PHYSICS 2112, MATH 1800, or MATH 1900 or have a declared STEM major. Students who want to explore teaching careers become familiar with lesson plan development by writing, teaching and observing lessons in a local school class. Students build and practice inquiry-based lesson design skills and become familiar with and practice classroom management in the school setting. As a result of the STEP I experiences students should be able to decide whether to continue to explore teaching as a career and ultimately finishing the remainder of the WE TEACH MO curriculum leading to teacher certification. The classroom observations and teaching represent a major field component and requires at least one two hour block of free time during the school day once a week.

MATH 2020 Introduction to Differential Equations: 3 semester hours
Prerequisite: MATH 2000. Topics will be chosen from: linear differential equations, equations with constant coefficients, laplace transforms, power series solutions, systems of ordinary differential equations.

MATH 2300 Introduction to Discrete Structures: 3 semester hours
Prerequisites: MATH 1100 or MATH 1800, and CMP SCI 1250. This course treats fundamental mathematical concepts in discrete structures useful for computer science. Topics include logic, sets, equivalence relations and partitions, functions, elementary number theory, cardinality, basic combinatorial methods, trees and graphs.

MATH 2450 Elementary Linear Algebra: 3 semester hours
Prerequisite: MATH 1100 or MATH 1900. An introduction to linear algebra. Topics will include complex numbers, geometric vectors in two and three dimensions and their linear transformations, the algebra of matrices, determinants, solutions of systems of equations, eigenvalues and eigenvectors.

MATH 2510 Structure of Mathematical Systems II: 3 semester hours
Prerequisites: MATH 1150. Topics include an introduction to probability, statistics, and displays of data; a study of elementary geometry, including points, lines, planes, angles, properties of triangles, properties of quadrilaterals, other 2- and 3-dimensional shapes; similarity; measurement and conversions; Pythagorean Theorem; perimeter; area; surface area, and volume. This course does not apply towards the elective requirements for any of the majors, minors or related areas in mathematics and statistics.

MATH 3000 Discrete Structures: 3 semester hours
Prerequisites: MATH 1900 or MATH 1100, and CMP SCI 1250 or equivalent. This course introduces fundamental concepts and important data structures in Discrete Mathematics and serves as an important foundation for subsequent courses in Computer Science. It provides a formal system on which mathematical reasoning is based, and various problem-solving strategies with emphasis on the algorithmic approach (both iterative and recursive). Topics include logic, sets, functions and relations; methods of proof, including mathematical induction; elements of number theory; order of growth and basic analysis of algorithms efficiency; recurrence relations; basic counting methods; graphs and trees. Credit not granted for students with Mathematics major.

MATH 3010 Financial Mathematics I: 3 semester hours
Prerequisites: MATH 1900 or MATH 1100, and MATH 1320 or SCMA 3300 (or equivalents). This course introduces the theory of interest, annuities (certain), annuities with differing pay periods, amortization schedules and sinking funds.

MATH 3020 Financial Mathematics II: 3 semester hours
Prerequisites: MATH 3010. This course introduces the premium-discount formula for bonds, bond amortization, term structure of interest rates and pricing theory for options.

MATH 3100 Problem Solving in Mathematics: 1 semester hour
Prerequisite: MATH 2000. Course will train students to solve and write solutions to challenging mathematical problems, like those found in competitive exams like the Putnam Exam.

MATH 3250 Foundations of Mathematics: 3 semester hours
Prerequisites: MATH 1900 and CMP SCI 1250. The course will focus on developing an understanding of proofs and rigorous mathematical reasoning. Topics will include logic, sets, relations, functions, number theory, and counting methods.

MATH 3320 Applied Statistics: 3 semester hours
Prerequisites: MATH 1320. The course will cover topics including multiple regression, analysis of variance, generalized linear models, and applications of these methods. Using R for statistical analysis will be part of the course.

MATH 3350 Structure of Mathematical Systems III: 3 semester hours
Prerequisites: MATH 2510. Topics from MATH 1150 and MATH 2510 are continued. Other topics include integers and the real number system, relations and functions, coordinate system and linear equations, congruence, geometric constructions, geometric proofs, isometries, tesselations, and trigonometry. This course does not apply towards the elective requirements for any of the majors, minors or related areas in mathematics and statistics.

MATH 4005 Exploratory Data Analysis with R: 3 semester hours
Prerequisites: MATH 2000 and MATH 2450. The study of ordinary differential equations and partial differential equations is continued with applications in such areas as physics, engineering and biology.
MATH 4070 Introduction to Nonlinear Optimization: 3 semester hours
Prerequisites: MATH 1320, MATH 2000, MATH 2450 and (MATH 3000 or MATH 3250). This course will introduce the theory, methods, and applications of nonlinear optimization. It will cover convex functions, convex analysis, linear and quadratic programs, semidefinite programs, and other optimization problems. Topics may include duality theory, algorithms of descent method, Newton's method and interior-point methods, and applications to signal processing, statistics and other fields will be covered. Credit cannot be earned for both MATH 4070 and MATH 5070.

MATH 4080 Introduction to Scientific Computation: 3 semester hours
Prerequisites: MATH 2000 and MATH 2450. This course will introduce fundamental algorithms in numerical linear algebra, matrix factorizations including SVD and QR, direct and iterative methods for solving linear systems, least squares problems and eigenvalue problems. Other topics covered will be chosen from numerical integration and differentiation, iterative methods for ODEs and PDEs, Discrete Fourier transform and FFT, spline smoothing and kernel smoothing. Credit cannot be earned for both MATH 4080 and MATH 5080.

MATH 4090 Introduction to High-dimensional Data Analysis: 3 semester hours
Prerequisites: MATH 1320, MATH 2000 and MATH 2450. This course introduces several advanced classical and modern techniques for modeling and analysis of high-dimensional datasets with low-dimensional structures. The topics covered in this course include principal component analysis, factor analysis, clustering-based methods, and sparse and low-rank recovery theory and algorithms. Credit cannot be earned for both MATH 4090 and MATH 5090.

MATH 4100 Real Analysis I: 3 semester hours
Prerequisites: MATH 3250, or CMP SCI 3130, or consent of instructor. This course provides an introduction to real analysis in one variable. Topics include the real number system, limits, continuity, differentiability, and sequences and series of functions.

MATH 4160 Complex Analysis I: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3250 or CMP SCI 3130; consent of instructor. This course introduces groups, rings, and fields, with an emphasis on groups and rings.

MATH 4225 Introduction to Statistical Computing: 3 semester hours
Prerequisites: MATH 1320, MATH 2000, MATH 2450. This course provides an introduction to statistical computing and analysis of high-dimensional datasets with low-dimensional structures. Topics may include principal component analysis, factor analysis, clustering-based methods, and sparse and low-rank recovery theory and algorithms. Credit cannot be earned for both MATH 4225 and MATH 5225.

MATH 4230 Numerical Analysis I: 3 semester hours
Prerequisites: MATH 2020, MATH 2450, and the ability to program in an upper-level language. Solutions of equations, interpolation and approximation, numerical differentiation and integration, and numerical solutions of initial value problems in ordinary differential equations. Selected algorithms will be programmed for solution on computers.

MATH 4250 Introduction to Statistical Methods in Learning and Modeling: 3 semester hours
Prerequisites: MATH 2000 and MATH 2450. This course will introduce basic statistical principles and methods for modeling, inference, prediction and classification. The topics will be chosen from linear regression, basis expansion methods, kernel smoothing methods, model regularization, model selection and assessment, and other nonparametric methods. Credit cannot be earned for both MATH 4250 and MATH 5250.

MATH 4260 Introduction to Stochastic Processes: 3 semester hours
Prerequisites: MATH 4200. Basic theory and applications of stochastic processes. Markov chains, recurrent and transient states, stationary distributions, ergodic theorem, renewal processes, discrete martingales and stationary processes.

MATH 4350 Theory of Numbers: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3000 or MATH 3250; or consent of instructor. This course examines the properties of integers, multiplicative functions, congruences, primitive roots, and quadratic residues.

MATH 4390 Topics in Probability and Statistics: 3 semester hours
Prerequisites: Consent of instructor. A seminar on special topics in probability and statistics to be determined by the interests of the instructor. May be repeated for credit provided different topics are studied.

MATH 4400 Introduction to Abstract Algebra I: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3250 or CMP SCI 3130; or consent of instructor. This course introduces groups, rings, and fields, with an emphasis on groups and rings.

MATH 4450 Linear Algebra: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3250 or CMP SCI 3130; or consent of instructor. This course focuses on topics selected from vector spaces, bases, linear transformations, matrices, canonical forms, eigenvalues, hermitian and unitary matrices, inner product spaces, and quadratic forms.
MATH 4460 Introduction to Coding Theory: 3 semester hours  
Prerequisites: MATH 2450 and either MATH 3000 or MATH 3250. This course is an introductory course in coding theory. Topics may include linear codes, generator and parity check matrices, dual codes, weight and distance, encoding and decoding, and the Sphere Packing Bound; various examples of codes like the Hamming codes, Golay codes, binary Reed-Muller codes, and the hexacode; Shannon's theorem for the binary symmetric channel, upper and lower bounds on the size of linear and nonlinear codes; constructions and properties of finite fields, basic theory of cyclic codes; concepts of idempotent generator, generator polynomial, zeros of a code, and defining sets, special families of BCH and Reed-Solomon cyclic codes as well as generalized Reed-Solomon codes. Credit cannot be granted for both MATH 4460 and MATH 5460.

MATH 4500 Special Readings: 1-10 semester hours  
Prerequisites: 6 credit hours at the Math 4000 level and consent of the instructor. Advanced topics in Mathematics. May be repeated for credit if the topic differs.

MATH 4550 Combinatorics: 3 semester hours  
Prerequisites: MATH 2450 and either MATH 3000 or MATH 3250; or consent of instructor. This course introduces advanced counting methods including the use of generating functions for the solution of recurrences and difference equations. Additional topics may include: graphs and trees, combinatorial designs, combinatorial games, error-correcting codes, and finite-state machines.

MATH 4580 Mathematical Logic: 3 semester hours  
Prerequisites: MATH 2450 and one of MATH 3250, CMP SCI 3130, or PHIL 4460; or consent of instructor. This course focuses on a study of the logic of mathematics by the axiomatic method, with a development of the propositional calculus and restricted predicate calculus emphasizing its application to the foundations of mathematics.

MATH 4620 Projective Geometry: 3 semester hours  
Prerequisites: MATH 2000, MATH 2450, and either MATH 3250 or CMP SCI 3130; or consent of instructor. This course provides an analytic approach to the study of projective spaces. Theorems of Desargues, Pascal, and Brianchon and projective properties of conics are studied.

MATH 4660 Foundations of Geometry: 3 semester hours  
Prerequisites: MATH 2450 and either MATH 3250 or CMP SCI 3130; or consent of instructor. This course focuses on a development of portions of Euclidean geometry from a selected set of axioms, including a discussion of consistency, independence, categoricity, and completeness of the axioms.

MATH 4670 Introduction to Non-Euclidean Geometry: 3 semester hours  
Prerequisites: MATH 2000, MATH 2450, and either MATH 3250 or CMP SCI 3130; or consent of instructor. This course focuses on a summary of the history of the non-Euclidean geometries and a study of hyperbolic plane geometry.

MATH 4800 Introduction to Topology: 3 semester hours  
Prerequisites: MATH 2000 and either MATH 3250 or CMP SCI 3130; or consent of instructor. This course focuses on the study of topological spaces, including the concepts of limit, continuity, connectedness, compactness, etc. Special emphasis is placed on, and examples taken from, the space of real numbers.

MATH 4890 Topics in Mathematics: 3 semester hours  
Prerequisite: Consent of instructor.

MATH 4995 Internship in Actuarial Science: 1-3 semester hours  
Same as ECON 4995. Prerequisites: Junior standing and consent of program director. Supervised off-campus training in a private or public sector position in which the student applies the knowledge and skills learned in their actuarial science coursework. The internship is monitored by a faculty member and the student must provide a written report at the end of the project. This course may be repeated for a maximum of 6 credit hours.

MATH 5060 Computational Harmonic Analysis: 3 semester hours  
Prerequisites: MATH 4030, MATH 4100 and MATH 4450. The course covers the basics of Fourier analysis and wavelet analysis. Topics include Fourier transforms and series, discrete Fourier transform, discrete cosine transform and their fast computational schemes, fast wavelet transform, and the lifting scheme. Additional topics include industrial standards for image compression and several aspects of signal processing.

MATH 5070 Nonlinear Optimization: 3 semester hours  
Prerequisites: Graduate standing. This course will introduce the theory, methods, and applications of nonlinear optimization. It will cover convex functions, convex analysis, linear and quadratic programs, semidefinite programming and other optimization problems. Topics chosen from duality theory, algorithms of descent method, Newton's method and interior-point methods, and applications to signal processing, statistics and other fields will be covered. Topics are the same as Math 4070 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both Math 4070 and Math 5070.

MATH 5080 Scientific Computation: 3 semester hours  
Prerequisites: Graduate standing. This course will introduce fundamental algorithms in numerical linear algebra, matrix factorizations including SVD and QR, direct and iterative methods for solving linear systems, least squares problems and eigenvalue problems. Other topics covered will be chosen from numerical integration and differentiation, iterative methods for ODE's and PDE's, Discrete Fourier transform and FFT, spline smoothing and kernel smoothing. Topics are the same as MATH 4080 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4080 and MATH 5080.

MATH 5090 High-dimensional Data Analysis: 3 semester hours  
Prerequisites: Graduate standing. This course introduces several advanced classical and modern techniques for modeling and analysis of high-dimensional datasets with low-dimensional structures. The methods covered in this course include principal component analysis, factor analysis, clustering-based methods, and sparse and low-rank recovery theory and algorithms. Topics are the same as MATH 4090 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4090 and MATH 5090.

MATH 5100 Real Analysis II: 3 semester hours  
Prerequisites: MATH 4100. Introduction to measure and integration. Topics include the Riemann-Stieltjes integral, Lebesgue measure, measurable functions, the Lebesgue integral, Radon-Nikodym and Fubini theorems and the basics of Lp-spaces.

MATH 5110 Differential Manifolds: 3 semester hours  
Prerequisites: MATH 4100, MATH 4450, and MATH 4800. An introduction to smooth manifolds and maps. Topics will include the Implicit Function Theorem, Sard's Theorem, transversality, intersection and degree theory, differential forms and integration on manifolds.
MATH 5140 Set Theory and Metric Spaces: 3 semester hours
Prerequisites: MATH 4100 or consent of instructor. Naive set theory, cardinal arithmetic, ordinal numbers, the axiom of choice and equivalents, metric spaces, convergence, continuity, contraction principles and applications. Construction of completions and examples like real numbers and p-adic numbers. Other topics could include the Stone-Weierstrass theorem and metrizability theorems.

MATH 5160 Complex Analysis II: 3 semester hours
Prerequisites: MATH 4160 and either MATH 4100 or MATH 4800. A second course in complex analysis, emphasizing the theory of analytic functions, and including various topics like the Riemann mapping theorem, normal families, analytic continuation, representations of analytic functions, and elliptic functions.

MATH 5225 Statistical Computing: 3 semester hours
Prerequisites: Graduate standing. This course will introduce fundamental algorithms in Monte Carlo methods: random variable generation, Monte Carlo integration, Monte Carlo optimization, Markov chain Monte Carlo, Metropolis-Hastings algorithm, Gibbs sampler, Langevin algorithms and Hamilton Monte Carlo, perfect, iterated and sequential importance sampling. Other topics covered may include particle systems, hidden Markov models, parallel and cloud computing. Topics are the same as MATH 4085 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4225 and MATH 5225.

MATH 5250 Statistical Methods in Learning and Modeling: 3 semester hours
Prerequisites: Graduate standing. This course will introduce basic statistical principles and methods for modeling, inference, prediction and classification. The topics will be chosen from linear regression, basis expansion methods, kernel smoothing methods, model regularization, nonparametric methods, and model selection and assessment. Topics are the same as MATH 4250 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4250 and MATH 5250.

MATH 5320 Topics in Statistics and its Applications: 3 semester hours
Prerequisites: MATH 4210 or consent of instructor. The course studies classical and recently developed statistical procedures selected from areas including multivariate analysis, linear and non-linear models, nonparametric methods, and statistical learning. Emphasis is on applications of the procedures.

MATH 5460 Coding Theory: 3 semester hours
Prerequisites: Graduate standing. This course is an introductory course in coding theory. Topics may include linear codes, generator and parity check matrices, dual codes, weight and distance, encoding and decoding, and the Sphere Packing Bound; various examples of codes like the Hamming codes, Golay codes, binary Reed–Muller codes, and the hexacode; Shannon's theorem for the binary symmetric channel, upper and lower bounds on the size of linear and nonlinear codes; constructions and properties of finite fields, basic theory of cyclic codes; concepts of idempotent generator, generator polynomial, zeros of a code, and defining sets, special families of BCH and Reed–Solomon cyclic codes as well as generalized Reed–Solomon codes. Topics are the same as MATH 4460 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4460 and MATH 5460.

MATH 5500 Directed Readings: 1-6 semester hours
Prerequisite: Consent of instructor. Independent readings at an advanced level.

MATH 5550 Topics in Advanced Math for the Teacher: 3 semester hours
Prerequisite: Consent of instructor. This course will look at various topics in Algebra, Analysis, and Geometry that will deepen a teacher's understanding of the Mathematics of the precollegiate curriculum. It can be taken more than once for credit.

MATH 5600 Topics in Computation: 3 semester hours
Prerequisite: Consent of instructor. The course will cover various advanced topics in computation, and can be taken more than once for credit. Examples of such topics are: computer graphics, computer architecture, theories of language, analysis of operating systems, numerical geometry and computer aided design, etc.

MATH 5700 Topics in Applied Mathematics: 3 semester hours
Prerequisite: Consent of instructor. The course will cover various advanced topics on applied mathematics, and can be taken more than once for credit. Examples of such topics are: fast transforms, digital filters, etc.

MATH 5710 Topics in Analysis: 3 semester hours
Prerequisites: MATH 5100 or consent of instructor. Topics selected from the areas of Fourier analysis, harmonic analysis, functional analysis, special functions, generalized functions, and partial differential equations. May be taken more than once for credit with consent of department.

MATH 5770 Advanced Topics in Nonlinear Optimization: 3 semester hours
Prerequisites: MATH 4070 or MATH 5070; or consent of the instructor. Topics chosen from theory and algorithms of Lagrange multipliers, algorithms for solving variational inequalities, forward-backward splitting algorithms and proximal alternating minimization algorithm for non-convex optimization problems.

MATH 5820 Topics in Algebra: 3 semester hours
Prerequisite: Consent of instructor. Topics selected from the theory of groups, rings, fields, algebras and other algebraic systems. May be taken more than once for credit with consent of department.

MATH 6900 Masters Thesis: 1-6 semester hours
Prerequisite: Consent of instructor. Thesis work under the supervision of a faculty member. The course is designed for those students intending to present a thesis as part of their M.A. program. Students who do not write a thesis cannot apply MATH 6900 to a degree.

MATH 7990 Ph.D. Dissertation Research: 1-9 semester hours
Prerequisite: Completion of comprehensive examinations. May be taken for no more than nine hours.