Why study Computer Science at the University of Denver?
The Department of Computer Science is based in the University of Denver’s Daniel Felix Ritchie School of Engineering and Computer Science. The school reflects two of the University’s strongest traditions: academic integrity and a commitment to meeting student needs with dynamic new programs. The Department of Computer Science offers cutting-edge and innovative graduate degree programs:

- MS in Computer Science
- MS in Computer Science Systems Engineering
- MS in Cybersecurity
- PhD in Computer Science
- Dual degree Undergraduate/Graduate (BS+MS) in Computer Science

We are strong in research and particularly noted in software engineering, information security and privacy, and humane gaming.

Some of our other outstanding advantages include:

- Small classes taught by faculty, not teaching assistants
- Research-active faculty members who publish regularly, land impressive grants and win teaching awards
- An up-to-date curriculum that includes classes in modern software engineering, web technology, multimedia, mobile computing, networks, databases, cyber security and computer game development
- Students who create a peer culture defined by high expectations
- A small yet vital PhD program that enhances the department’s intellectual atmosphere

At the University of Denver, you will find opportunities to research, study leading-edge technology and tools, and gain an integrated knowledge. We emphasize interdisciplinary programs, so you will be ready to meet career challenges around the office or, if you choose, around the world.

In addition, Denver is a first-rate location for internships and jobs, as well as business and government partnerships. The campus is just minutes from the Denver Technological Center — home to many top tech companies — and we enjoy sweeping views of the Rocky Mountains.

doctor of philosophy in computer science

Following are the simple steps to apply for the Doctor of Philosophy in Computer Science at the University of Denver. If you have any questions about the process, please contact the Office of Graduate Studies (http://www.du.edu/learn/graduates).

Apply Online / Application Deadlines
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- A $65 non-refundable application fee is required for an application to be processed. Application fee waivers are available for McNair Scholars.

Course and Degree Prerequisites and Requirements
- Applicants for the PhD in computer science program must have proof of a bachelor’s degree in any discipline from a regionally accredited college or university.
- Prerequisite courses for PhD include:

<table>
<thead>
<tr>
<th>Course</th>
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</tr>
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<tr>
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  University of Denver  
  Office of Graduate Studies  
  Mary Reed Building, Room 5  
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  Denver, CO 80208-4802

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- Competitive GRE scores for students admitted to the Department of Computer Science are below.
  - PhD: Verbal 146; Quantitative 156; Analytical Writing Section 3.5
- Minimum GRE Scores (Prior to November 2011) for Graduate Students:
  - PhD: Verbal 400; Quantitative 720; Analytical 4.5

Personal Statement

- A personal statement of at least 300 words is required. The statement should include information concerning your life, education, practical experience, special interests and specific purpose for applying to the University of Denver. The statement should be submitted via upload through the online application process.
Resume / C.V.
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The Graduate Policies and Procedures provides complete details regarding admission requirements.

Master of science in Computer science or computer science systems engineering
Following are the simple steps to apply for the master’s programs in Computer Science at the University of Denver. If you have any questions about the process, please contact the Office of Graduate Studies (http://www.du.edu/learn/graduates).

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• A $65 non-refundable application fee is required for an application to be processed. Application fee waivers are available for McNair Scholars.

Course and Degree Prerequisites and Requirements
• Applicants for the MS in computer science program must have proof of a bachelor’s degree in any discipline from a regionally accredited college or university.
• Prerequisite courses for the MS include:
Computer Science

COMP 1671 Introduction to Computer Science I 4
COMP 1672 Introduction to Computer Science II 4
COMP 2673 Introduction to Computer Science III 4
COMP 2300 Discrete Structures in Computer Science 4
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• Competitive GRE scores for students admitted to the Department of Computer Science are below.

  • MS: Quantitative 152; Analytical Writing Section 2.0

• Minimum GRE Scores (Prior to November 2011) for Graduate Students:

  • MS: Verbal None; Quantitative 600; Analytical 4.0
Personal Statement
• A personal statement of at least 300 words is required. The statement should include information concerning your life, education, practical experience, special interests and specific purpose for applying to the University of Denver. The statement should be submitted via upload through the online application process.

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Master of Science in Cybersecurity
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Apply Online / Application Deadlines
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• A $65 non-refundable application fee is required for an application to be processed. Application fee waivers are available for McNair Scholars.
Course and Degree Prerequisites and Requirements

- Applicants for the MS in computer science program must have proof of a bachelor’s degree in any discipline from a regionally accredited college or university.
- Applicants must have the prerequisite knowledge equivalent to the following courses below and are required to pass a computer science placement exam prior to matriculation into the graduate program. Students with deficiencies will be eligible to complete the bridge courses prior to matriculation and are required to retake and pass the computer science placement exam prior to matriculation:

<table>
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<th>Course Title</th>
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<tr>
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<td>COMP 1672</td>
<td>Introduction to Computer Science II</td>
<td>4</td>
</tr>
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</tr>
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</tr>
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</table>

- Or students without the prerequisite knowledge may successfully complete the following four bridge courses and are required to pass a computer science placement exam prior to matriculation into the graduate program. Students with deficiencies will be required to demonstrate prerequisite knowledge equivalent to the courses listed above prior to matriculation and are required to retake and pass the computer science placement exam prior to matriculation:

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<tr>
<td>COMP 2001</td>
<td>Bridge Course I: Computer Science Theory Basics</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2002</td>
<td>Bridge Course II: Computer Science Theory Advanced</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2003</td>
<td>Bridge Course III: Computer Science Systems Basics</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2004</td>
<td>Bridge Course IV: Computer Science Systems Advanced</td>
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The Graduate Policies and Procedures provides complete details regarding admission requirements.
DOCTOR OF PHILOSOPHY IN COMPUTER SCIENCE

The department currently has faculty to support PhD students in the following areas:

- Artificial Intelligence
- Computational Geometry
- Humane Games
- Graphics
- Networks
- Parallel and Distributed Algorithms
- Security and Privacy
- Software Systems Engineering

Degree Requirements

Coursework Requirements

Three quarters minimum of COMP 4600

<table>
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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Seminar in Computer Science</td>
<td>1-4</td>
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</table>

At least 36 credits must be at the 4000-level courses

Up to 24 credits may be taken in other relevant disciplines, as approved by the Computer Science Department Graduate Committee.

Courses should be chosen in consultation with, and are subject to the approval of, the student's advisor.

Total Credits 90

Minimum credit hours required: 90 beyond BA or BS degree

Additional Degree Requirements applicable to PhD Students without a Master's Degree in Computer Science

- Must complete the requirements of the Computer Science Master's Degree with a thesis option within 3 years (9 quarters).

Additional Degree Requirements applicable to PhD Students with a 2 year Master's Degree in Computer Science or Related Field

- May take a proficiency test in the four required courses for Master’s Degree. The test may be offered at a time other than the official final exam time of the term. A grade of B+ (B plus) or better must be obtained in the test.
- If the student chooses not to take the proficiency test, the student must register and attend classes for the four required courses. A grade of B+ (B plus) or better must be obtained in the courses.

Non-coursework Requirements:

- Completion of a written dissertation that makes a significant contribution to the research literature in computer sciences.
- Completion of a tool requirement.
- Qualifying Examination
- Preliminary Examination

Qualifying & Dissertation Examinations

Qualifying Exam

Every PhD student must pass the Qualifying Exam. It consists of two parts, the Breadth Requirement and the Written and Oral exam.

1. Breadth Requirement: To fulfill the Breadth Requirement the student must take 5 graded courses (20 Quarter Credits) at the 3000 and 4000 level (not including independent study, internship, or independent research). At most, two may be at the 3000 level. At least three must be at the 4000 level. The course work should cover at least three distinct areas. Five areas should include a sequence of 3000 and 4000 level courses. The GPA in these courses must be at least 3.7/4.0. No course with a grade below a B may be used to fulfill this requirement. Graduate computer science courses taken at another university and transferred for credit at DU may be applied to the Breadth requirement up to a maximum of 2 courses (8 quarter credits).

2. Written and Oral Exam: Before being admitted to this exam, the student must have fulfilled the Breadth Requirement.

The student selects an area of examination from the list of areas in Table 1. The Written part of the exam is a take home exam. It is a handed out on a Friday and is due the following Tuesday. The Oral Exam is held the following Friday. The take home exam consists of a set of research questions, a set of related papers and instructions. The student should prepare a written report of at least 10 but no more than 20 pages with answers to the questions. Study guides or other relevant material to prepare for the exam can be obtained from the chair of the examination committee. The oral portion of the exam is based on a student presentation in which the student explains and defends his/her answers. During the Oral Exam, questions in other areas of computer science may also be asked.

A failed exam may be retaken once (in the same or another area). Sufficiently prior to the exam date, the department chair will appoint an examination committee of three tenure-track faculty. One of the committee members must be in the area in which the examination will be held. The student's advisor is allowed to be on the committee. The committee creates the take home exam and grades it. After the Oral Exam, the committee makes a
recommendation to the CS faculty on whether the student passes or fails. If the faculty agrees, the committee recommendation stands. If there is a disagreement, the faculty as a whole decides.

**Preliminary Examination**

Following successful completion of the Qualifying Examination, each student will prepare a dissertation proposal and take the Preliminary Examination. Passing this examination admits the student to Ph.D. candidacy. The dissertation proposal should be prepared in close consultation with the student's advisor, and should be available to all committee members at least two weeks prior to the examination. It should reflect an extensive critical literature survey, and contain an accurate assessment of the state-of-the-art in the area of research, a precise statement of the problem to be solved, motivation for pursuing the research, and evidence to the effect that there is a good likelihood the problem is solvable with reasonable effort.

For full-time students, the Preliminary Examination must be taken within 5 quarters of passing the Qualifying Examination. Successful completion of the Preliminary Examination results in agreement between the student and the committee as to what will constitute successful completion of the dissertation research. The committee may choose to reconvene the examination to allow the student to further research the problem, complete additional course work, or revise the dissertation proposal document.

The examining committee consists of at least 3 Computer Science faculty members, including the advisor. The preliminary exam is a one hour oral closed exam. If a student passed the preliminary exam, but subsequently switches advisor and hence topic, the preliminary exam must be repeated within one year to ensure capability of the student and feasibility of the project.

**Possible Thesis Proposal Outline**

1. Intro
   a. Problem
   b. Research questions, scope
2. Background
   a. Lit search
   b. Open Problems
   c. Analysis with respect to research questions
3. Approach
4. Preliminary results
5. Plan for completion of work including timeline
6. Risks and risk mitigation
7. References

**Dissertation Defense**

After the dissertation has been completed, the student must defend it in a final examination, as specified by the Office of Graduate Studies.

**Tool requirement**

It is strongly recommended that students satisfy their tool requirement by demonstrating proficiency in a modern computer typesetting system suitable for writing technical papers that include mathematical equations and graphics. The faculty advisor must approve the specific system used to satisfy this requirement. Other options include reading competency in two languages selected from French, German, and Russian; a series of outside courses in another discipline; or significant laboratory experience involving computer science.

**Master of Science in Computer Science**

The MS program in computer science prepares students for advancement in academic or industrial careers. The program is designed to provide students with a breadth of advanced knowledge in computer science, while permitting them to achieve depth in areas of current interest within the computing field, as well as the emerging technologies that will be gaining importance in the future.

**Degree Requirements**

**Coursework Requirements**

Requires 48 quarter hours of graduate-level course work including:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3351</td>
<td>Programming Languages</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3361</td>
<td>Operating Systems I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3371</td>
<td>Advanced Data Structures &amp; Algorithms</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3200</td>
<td>Discrete Structures</td>
<td>4</td>
</tr>
</tbody>
</table>

3 COMP courses at the 4000-level (other than COMP 499X) are required of which at least one must be a designated "theory" class.

**Advanced programming requirement**
Students must also choose and complete two courses from the following list of COMP courses that include an advanced programming component. Students must complete at least two of the courses listed below at the University of Denver. These courses must be approved by an advisor. The current pre-approved list includes:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 4362</td>
<td>Operating Systems II</td>
</tr>
<tr>
<td>COMP 3353</td>
<td>Compiler Construction</td>
</tr>
<tr>
<td>COMP 3621</td>
<td>Computer Networking</td>
</tr>
<tr>
<td>COMP 3801</td>
<td>Introduction Computer Graphics</td>
</tr>
</tbody>
</table>

Seminar attendance requirement
Students must complete three quarters of COMP 4600 - Seminar (0 credits). A passing grade is required for successful completion.

Non-thesis option
A maximum of 12 quarter hours may be earned in Independent Study (COMP 4991), provided the student can find an advisor for such independent study. No thesis is required. Not eligible for support (GTA, GRA)

Thesis option
A maximum of 12 credits may be earned for thesis credits (COMP 4995). A thesis is required. Students should also note the following: A maximum of 8 quarter hours may be earned in approved courses outside the COMP designation, including transfer credits from another university. Such credit must be approved in writing by an advisor from the computer science faculty. A student receiving any support from the department (GTA, GRA) must complete the degree requirements as per the Thesis option.

Total Credits
48

Minimum credits required for degree: 48

Non-coursework Requirements
- If the thesis option is chosen, a thesis and oral defense are required.

Master of Science in Computer Science Systems Engineering

Every candidate for the MS in computer science systems engineering degree must complete 45 quarter hours of credit, at least 36 of which must be completed at the University of Denver. To satisfy graduation requirements, candidates must maintain a course GPA of 3.0. In addition, a grade of C or better must be obtained in each course for that course to count toward the 45 quarter hour requirement. Six courses at the 4000-level are required. The degree is designed for the working professional. The prerequisites for this degree are the same as those for the MS in computer science.

Degree requirements
Coursework requirements
Required courses
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3361</td>
<td>Operating Systems I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3381</td>
<td>Software Engineering I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3705</td>
<td>Topics in Computer Science</td>
<td>1-4</td>
</tr>
</tbody>
</table>

Application area core (pre-approval required)
The pre-approved application core:
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENMT 4100</td>
<td>Systems Engineering</td>
</tr>
<tr>
<td>ENMT 4000</td>
<td>Space Systems Design I</td>
</tr>
<tr>
<td>or ENMT 4010</td>
<td>Space Systems Design II</td>
</tr>
</tbody>
</table>

Theory Course (e.g., COMP 3702)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3702</td>
<td>Topics in Database</td>
</tr>
</tbody>
</table>

Capstone
2

Independent study
2

Computer science electives
12

Total Credits
45

Minimum credits required for degree: 45

Non-coursework Requirements
- Capstone

Master of Science in Cybersecurity

The MS program in Cybersecurity prepares students for advancement in academic or industrial careers. The program is designed to provide students with a breadth of advanced knowledge in computer science, along with domain knowledge in the field of information security. Network storage that holds sensitive information – from personal identities to financial records and national secrets – are increasingly vulnerable to malicious attacks.
We are witnessing growing concerns and interests in cybersecurity in our globally interconnected society. The increasing dependence of our lives on information technology infrastructures continues to stimulate strong support for this expertise.

**Degree Requirements**

**Coursework Requirements**

Requires a total of 48 quarter hours of graduate-level coursework

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3731</td>
<td>Computer Forensics</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3361</td>
<td>Operating Systems I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4621</td>
<td>Computer Networking</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4384</td>
<td>Secure Software Engineering</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4721</td>
<td>Computer Security</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4722</td>
<td>Network Security</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4723</td>
<td>Ethical Hacking</td>
<td>4</td>
</tr>
</tbody>
</table>

8 credits from some combination of the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3904</td>
<td>Internship/Co-Op in Computing</td>
<td>0-10</td>
</tr>
<tr>
<td>COMP 4995</td>
<td>Independent Research</td>
<td>1-17</td>
</tr>
<tr>
<td>COMP 4991</td>
<td>Independent Study</td>
<td>1-10</td>
</tr>
</tbody>
</table>

12 Elective Credits

Students must choose and complete 12 credits of cybersecurity related electives. Elective credits need pre-approval from an advisor.

**Total Credits**

48

Minimum credits required for degree: 48

**Non-coursework Requirements**

- Capstone

**Undergraduate + Graduate BS/MS**

The Department of Computer Science at the University of Denver offers a Dual Degree Bachelor of Science and Masters in Computer Science. The BS/MS in Computer Science encompasses the theory and techniques by which information is encoded, stored, communicated, transformed, and analyzed. It is concerned with the theory of algorithms (that is, effective procedures or programs), with the structure of languages for the expression of algorithms, and with the design of algorithms for the solution of practical problems. A central concern is the study of the computer systems (hardware and software) for the automatic execution of these algorithms prepares students for advancement in academic or industrial careers. The program is designed to provide students with a breadth of advanced knowledge in computer science, while permitting them to achieve depth in areas of current interest within the computing field, as well as the emerging technologies that will be gaining importance in the future.

The degree is strongly based in mathematics and, in fact, a student will automatically acquire sufficient credits for a minor in mathematics. One additional minor is required. The second minor may be in any discipline other than mathematics or computer science.

**Total Credit Hours:** 183 at the undergraduate level (UG) for the Bachelor's degree + 36 at the graduate level (GR) for the master's of science degree

**Required courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 1671</td>
<td>Introduction to Computer Science I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 1672</td>
<td>Introduction to Computer Science II</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2300</td>
<td>Discrete Structures in Computer Science</td>
<td>1-4</td>
</tr>
<tr>
<td>COMP 2355</td>
<td>Intro to Systems Programming</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2370</td>
<td>Introduction to Algorithms &amp; Data Structures</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2673</td>
<td>Introduction to Computer Science III</td>
<td>4</td>
</tr>
<tr>
<td>COMP 2691</td>
<td>Introduction to Computer Organization</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3351</td>
<td>Programming Languages</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3361</td>
<td>Operating Systems I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3371</td>
<td>Advanced Data Structures &amp; Algorithms</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3200</td>
<td>Discrete Structures</td>
<td>4</td>
</tr>
</tbody>
</table>
Other Requirements

Students who intend to obtain a BS/MS in Computer Science must satisfy all the requirements of the Bachelor of Science degree as outlined in the University of Denver Undergraduate Bulletin. One of the two minor areas required in the B.S. program must be in mathematics. The other minor may be in any field. Upon completion of the BS requirements, the student must satisfy the 36 hours at the graduate level of required coursework for the MS.

The eleven courses listed above total 44 quarter hours. An additional 28 hours of 3000-level computer science electives are required. COMP 2400 or COMP 2901, or COMP 2555 may be used to satisfy 8 credits of the required 3000-level elective credits, but COMP 3904 may not be used in this way. In addition there are 3 COMP courses at the 4000-level (other than COMP 4991) are required of which at least one must be a designated "theory" class and one must be a designated "Advanced Programming" course and completion of three quarters of COMP 4600 Seminar (0 credits).

Advanced Programming Requirement

Students must also choose and complete two courses from the following list of COMP courses that include an advanced programming component. Students must complete at least two of the courses listed below at the University of Denver. These courses must be approved by an advisor. The current pre-approved list includes:

- COMP 4362 Operating Systems II 4
- COMP 3353 Compiler Construction 4
- COMP 3621 Computer Networking 4
- COMP 3801 Introduction Computer Graphics 4

Math Minor Requirement

Minimum of 20 quarter hours in MATH courses numbered 1951 or higher. Discrete Structures in Computer Science (COMP 2300) may be counted toward the math minor. Courses not covered by the foregoing two sentences must be approved in writing by a mathematics faculty advisor.

For students entering DU Fall 2010 or later: At least 50% of the required credit hours for minor must be completed at the University of Denver.

All electives, especially the MATH and COMP electives, should be selected in close consultation with an academic advisor from the Computer Science Department. The courses for the non-mathematics minor (see Minor courses above) should be selected in consultation with an academic advisor from the department in which the minor is administered.

Sample schedule

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall</strong></td>
<td></td>
<td><strong>Winter</strong></td>
<td><strong>Spring</strong></td>
<td><strong>Credits</strong></td>
</tr>
<tr>
<td>COMP 1671</td>
<td>4</td>
<td>COMP 1672</td>
<td>COMP 2673</td>
<td>4</td>
</tr>
<tr>
<td>MATH 1951</td>
<td>4</td>
<td>MATH 1952</td>
<td>COMP 2300</td>
<td>1-4</td>
</tr>
<tr>
<td>FSEM</td>
<td>4</td>
<td>WRIT 1122</td>
<td>WRIT 1133</td>
<td>4</td>
</tr>
<tr>
<td>Foreign Language 1</td>
<td>8</td>
<td>Foreign Language 2</td>
<td>Foreign Language 3</td>
<td>9-12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Year</th>
<th>Credits</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall</strong></td>
<td></td>
<td><strong>Winter</strong></td>
<td><strong>Spring</strong></td>
<td><strong>Credits</strong></td>
</tr>
<tr>
<td>COMP 2370</td>
<td>4</td>
<td>COMP 2691</td>
<td>COMP 2355</td>
<td>4</td>
</tr>
<tr>
<td>MATH 2XXX/3XXX Elective</td>
<td>4</td>
<td>MATH 1953</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>AI-Natural</td>
<td>4</td>
<td>AI-Society</td>
<td>SI-Society</td>
<td>4</td>
</tr>
<tr>
<td>SI-Natural</td>
<td>4</td>
<td>SI-Natural</td>
<td>SI-Natural</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Third Year</th>
<th>Credits</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall</strong></td>
<td></td>
<td>COMP 3361</td>
<td>COMP 3351</td>
<td>4</td>
</tr>
<tr>
<td>COMP Elective</td>
<td>4</td>
<td>ASEM</td>
<td>Minor Course 3</td>
<td>4</td>
</tr>
<tr>
<td>Minor Course 1</td>
<td>4</td>
<td>Minor Course 2</td>
<td>Elective</td>
<td>4</td>
</tr>
<tr>
<td>SI-Society</td>
<td>4</td>
<td>Elective</td>
<td>Elective</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fourth Year</th>
<th>Credits</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall</strong></td>
<td></td>
<td>COMP 3200</td>
<td>COMP 3371</td>
<td>4</td>
</tr>
<tr>
<td>COMP Elective</td>
<td>4</td>
<td>Minor Course 5</td>
<td>COMP Elective</td>
<td>4</td>
</tr>
<tr>
<td>Minor Course 4</td>
<td>4</td>
<td>Elective</td>
<td>Elective</td>
<td>4</td>
</tr>
<tr>
<td>Elective</td>
<td>4</td>
<td>Elective</td>
<td>Elective</td>
<td>4</td>
</tr>
</tbody>
</table>
Courses

COMP 3200 Discrete Structures (4 Credits)
Discrete mathematical structures and non-numerical algorithms; graph theory, elements of probability, propositional calculus, Boolean algebras; emphasis on applications to computer science. Cross-listed as MATH 3200. Prerequisites: MATH 2200 or COMP 2300 and COMP 1672 or COMP 1771.

COMP 3341 Multimedia Systems (4 Credits)
This course covers fundamental issues in design and implementation of multimedia applications. This course also covers technologies in multimedia systems such as multimedia data representation, compression, coding, networking, data management, and I/O technologies. Prerequisite: COMP 3361.

COMP 3351 Programming Languages (4 Credits)
Programming language as a component of software development environment; binding, scope, lifetime, value and type of a variable; run-time structure--static, stack-based and dynamic languages; parameter passing--call by reference, value, result, value-result and name; subprogram parameters; role played by side effects, dangling pointers, aliases and garbage; garbage collection; data abstraction - study of object-oriented, functional, and logic languages. Prerequisites: COMP 2370, COMP 2691, and COMP 2355.

COMP 3353 Compiler Construction (4 Credits)
Design and implementation of a major piece of software relevant to compilers. Prerequisite: COMP 3352.

COMP 3361 Operating Systems I (4 Credits)
Operating systems functions and concepts; processes, process communication, synchronization; processor allocation, memory management in multiprogramming, time sharing systems. Prerequisites: COMP 2355, COMP 2370, and COMP 2691.

COMP 3371 Advanced Data Structures & Algorithms (4 Credits)
Design and analysis of algorithms; asymptotic complexity, recurrence equations, lower bounds; algorithm design techniques such as incremental, divide and conquer, dynamic programming, randomization, greedy algorithms, etc. Prerequisites: COMP 2370, MATH 3200.

COMP 3381 Software Engineering I (4 Credits)
An introduction to software engineering. Topics include software processes, requirements, design, development, validation and verification and project management. Cross listed with COMP 4381. Prerequisite: COMP 2370.

COMP 3382 Software Engineering II (4 Credits)
Continuation of COMP 3381. Topics include component-based software engineering, model-driven architecture, and service-oriented architecture. Prerequisite: COMP 3381.

COMP 3400 Advanced Unix Tools (4 Credits)
Design principles for tools used in a UNIX environment. Students gain experience building tools by studying the public domain versions of standard UNIX tools and tool-building facilities. Prerequisites: COMP 2400 and knowledge of C and csh (or another shell), and familiarity with UNIX.

COMP 3410 World Wide Web Programming (4 Credits)
Creating WWW pages with HTML, accessing user-written programs via CGI scripts, creating forms, imagemaps and tables, and Java programming principles and techniques. Prerequisite: COMP 2355.

COMP 3421 Database Organization & Management I (4 Credits)
An introductory class in databases explaining what a database is and how to use one. Topics include database design, ER modeling, database normalization, relational algebra, SQL, physical organization of records and clocks, heap files, sorted files, hashing, extendible hashing, linear hashing and B trees. Each student will design, load, query and update a nontrivial database using the Oracle DMBS. Prerequisite: COMP 2370.

COMP 3431 Data Mining (4 Credits)
Data Mining is the process of extracting useful information implicitly hidden in large databases. Various techniques from statistics and artificial intelligence are used here to discover hidden patterns in massive collections of data. This course is an introduction to these techniques and their underlying mathematical principles. Topics covered include: basic data analysis, frequent pattern mining, clustering, classification, and model assessment. Prerequisites: COMP 2370.

COMP 3501 Introduction to Artificial Intelligence (4 Credits)
Programming in LISP and Prolog with applications to artificial intelligence; fundamental concepts of artificial intelligence; emphasis on general problem-solving techniques including state-space representation, production systems, and search techniques. Prerequisites: MATH 2200, COMP 2370.

COMP 3621 Computer Networking (4 Credits)
An introduction to computer networks with an emphasis on Internet protocols. Topics include: network topologies, routing, Ethernet, Internet protocol, sockets, operating system impact and client/server implementations. Prerequisites: COMP 2355 and COMP 2370. Corequisite: COMP 3361.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3701</td>
<td>Topics in Computer Graphics</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3702</td>
<td>Topics in Database</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3703</td>
<td>Topics-Artificial Intelligence</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3704</td>
<td>Advanced Topics: Systems</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3705</td>
<td>Topics in Computer Science</td>
<td>1-4</td>
</tr>
<tr>
<td>COMP 3731</td>
<td>Computer Forensics</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3801</td>
<td>Introduction Computer Graphics</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3821</td>
<td>Game Programming I</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3822</td>
<td>Game Programming II</td>
<td>4</td>
</tr>
<tr>
<td>COMP 3904</td>
<td>Internship/Co-Op in Computing</td>
<td>0-10</td>
</tr>
<tr>
<td>COMP 3991</td>
<td>Independent Study</td>
<td>1-10</td>
</tr>
<tr>
<td>COMP 3992</td>
<td>Directed Study</td>
<td>1-10</td>
</tr>
<tr>
<td>COMP 4362</td>
<td>Operating Systems II</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4372</td>
<td>Theory of Algorithms</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4384</td>
<td>Secure Software Engineering</td>
<td>4</td>
</tr>
<tr>
<td>COMP 4600</td>
<td>Seminar in Computer Science</td>
<td>0-4</td>
</tr>
</tbody>
</table>

Computer Forensics involves the examination of information contained in digital media with the aim of recovering and analyzing latent evidence. This course will provide students an understanding of the basic concepts in preservation, identification, extraction and validation of forensic evidence in a computer system. The course covers many systems level concepts such as disk partitions, file systems, system artifacts in multiple operating systems, file formats, email transfers, and network layers, among others. Students work extensively on raw images of memory and disks, and in the process, build components commonly seen as features of commercial forensics tools (e.g. file system carver, memory analyzer, file carver, and steganalysis). Prerequisites: COMP 2355.

COMP 3801 Introduction Computer Graphics (4 Credits)
Fundamentals of graphics hardware, scan conversion algorithms, 2D and 3D viewing transformations, windows, viewports, clipping algorithms, mathematics for computer graphics, graphics programming using a standard API. Prerequisites: COMP 2370, MATH 1952 or 1962, and MATH 2060.

COMP 3821 Game Programming I (4 Credits)
An introduction to computer game programming. Use of a game engine to create 3D computer games. Topics to include game scripting, simple 3D asset creation, incorporation of assets, keyboard/mouse event handling, animation, game phases and score keeping. Prerequisite: COMP 2370.

COMP 3822 Game Programming II (4 Credits)
An introduction to computer game engine programming. Major class goal is to understand how game engines are created by building subsets of a game engine. Non-exhaustive set of topics include how terrains are generated, how animations are supported, how particle systems are implemented, how physics systems are coded, and how support is provided for higher level scripting languages. All coding will be done in low-level graphics languages. Prerequisites: COMP 3801 and COMP 3821.

COMP 3904 Internship/Co-Op in Computing (0-10 Credits)
Practical experience in designing, writing and/or maintaining substantial computer programs under supervision of staff of University Computing and Information Resources Center. Prerequisites: COMP 2370 and approval of internship committee (see department office).

COMP 3991 Independent Study (1-10 Credits)
Cannot be arranged for any course that appears in the regular course schedule for that particular year.

COMP 3992 Directed Study (1-10 Credits)

COMP 4362 Operating Systems II (4 Credits)
Continuation of COMP 3361. Case studies of existing operating systems programming. Prerequisite: COMP 3621.

COMP 4372 Theory of Algorithms (4 Credits)
NP-completeness; lower bound theory; approximation algorithms; amortized complexity and data structures, randomized algorithms. Assorted topics such as string algorithms, graph algorithms, linear programming, computational geometry. Prerequisite: COMP 3371.

COMP 4384 Secure Software Engineering (4 Credits)
This course is concerned with systematic approaches for the design and implementation of secure software. While topics such as cryptography, networking, network protocols and large scale software development are touched upon, this is not a course on those topics. Instead, this course is on identification of potential threats and vulnerabilities early in the design cycle. The emphasis in this course is on methodologies and paradigms for identifying and avoiding security vulnerabilities, formally establishing the absence of vulnerabilities, and ways to avoid security holes in new software. There are programming assignments designed to make students practice and experience secure software design and development. Prerequisites: COMP 3381 & COMP 4555. COMP 3621 is highly recommended. Students must be able to implement complex programs in C, C++ and Java.

COMP 4600 Seminar in Computer Science (0-4 Credits)
Preparation and presentation of lectures on some aspect of current research in computer science; topics not generally encountered in formal courses, may include robotics, pattern recognition, parallel processing, computer applications. 10- to 15- page paper with bibliography required.
COMP 4621 Computer Networking (1-4 Credits)
COMP 4701 Special Topics-Computer Graphics (1-4 Credits)
COMP 4702 Advanced Topics-Database (3 Credits)
COMP 4703 Adv Topics-Artificial Intell (1-4 Credits)
COMP 4704 Advanced Topics-Systems (3-4 Credits)
COMP 4705 Advanced Topics-Programming (1-4 Credits)
COMP 4708 Special Topics-VLSI (3 Credits)
COMP 4709 Special Topics-Computer Security (3 Credits)
COMP 4720 Applied Cryptography (4 Credits)
Block ciphers, one-way hashes, symmetric and asymmetric encryption, public-key infrastructure, digital signatures, security protocols, anonymity, and digital cash.

COMP 4721 Computer Security (4 Credits)
This course gives students an overview of computer and system security along with some cryptography. Some network security concepts are also included. Other concepts include coverage of risks and vulnerabilities, policy formation, controls and protection methods, role-based access controls, database security, authentication technologies, host-based and network-based security issues. Prerequisite: COMP 3361.

COMP 4722 Network Security (4 Credits)
Authentication and key establishment, web security, Internet worms, viruses, spyware, spam, phishing, botnets, distributed denial of service, TCP/IP and DNS security, firewalls and intrusion detection systems, and wireless security. Prerequisites: COMP 4621 and COMP 4721.

COMP 4723 Ethical Hacking (4 Credits)
Penetration testing, denial of service, social engineering, buffer overflow, hacking of sessions, bluetooth, smartphone, and wireless protocols. Web security including SQL injection and cross-site scripting is included as well. Prerequisites: COMP 4621 and COMP 4721.

COMP 4991 Independent Study (1-10 Credits)
Cannot be arranged for any course that appears in regular course schedule for that particular year.

COMP 4992 Directed Study (1-10 Credits)

COMP 4995 Independent Research (1-17 Credits)
Research projects undertaken in conjunction with a faculty member.

COMP 5991 Independent Study (1-17 Credits)

COMP 5995 Independent Research (1-17 Credits)