Computer and Information Science

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Computer science, the study of computation, offers students the challenge and excitement of a dynamically evolving science whose discoveries and applications affect every aspect of modern life. Computer science is a rich intellectual field where practitioners apply a computational approach to address a wide variety of interesting and challenging problems. Computer scientists are engaged in research in core areas of theoretical computer science, computer systems design, algorithms, and programming languages, as well as more application-oriented areas such as databases, networking, and informatics.

The Department of Computer and Information Science (CIS) is committed to a strong research program and a rewarding educational experience for undergraduate and graduate students.

The department offers instruction and opportunities for research in the following areas:

- artificial intelligence
- assistive technology
- computational science
- computer security
- data science
- high-performance computing
- human-computer interaction
- internet of things
- machine learning
- networking and systems
- parallel and distributed computing
- programming languages and compilers
- scientific visualization
- smart and connected communities
- software engineering
- theoretical computer science
- universal access

The department offers bachelor’s, master’s and doctoral degrees; in addition, two undergraduate minors and a selection of service courses are offered for students who want introductory exposure to computers and computer applications. The computer science programs at the university are continually evolving as the discipline matures and as students’ needs change.

Facilities

The Department of Computer and Information Science is housed in Deschutes Hall, which holds faculty and graduate student offices and extensive laboratory space for research and instruction.

Undergraduate majors may use campus computing labs staffed by CIS undergraduate tutors and lab assistants. Undergraduate majors taking upper-division courses and graduate students share a collaborative computing lab for the exclusive use of CIS students. Graduate and undergraduate students engaged in active research also have access to the computing facilities of the associated research lab.

The cognitive modeling and eye-tracking laboratory features multiple Eyegaze eye trackers and a Tobii eye tracker, used to collect and analyze the eye movements people make during human-computer interactions, and to develop eye-controlled user interfaces for people with disabilities. The lab also features a VR Sonic SoundSim Cube spatialized audio server used to explore three-dimensional sound perception.

Research in high-performance computing and computational science is supported by resources shared among the department, the Computational Science Institute, and the Neuroinformatics Center. In addition, the University of Oregon, through a Major Research Instrumentation Program grant from the National Science Foundation, has created a large-scale computational and storage resource to support multidisciplinary scientific research. The Applied Computational Instrument for Scientific Synthesis (ACISS) is a heterogeneous platform managed as a cloud system for computational science, informatics, and data science.

The Advanced Integration and Mining Laboratory fosters research on finding useful patterns from the mountain of data on biology, health, medicine, neuroscience, physiology, and social networks and on integrating data from structurally and semantically heterogeneous resources such as databases, online social networks, and the World Wide Web.

The Oregon Network Research Group Laboratory features an array of high-end servers, experimental test beds, and mass storages for developing and testing of new network protocols, conducting large-scale network measurement and data analysis.

The Network and Security Research Laboratory features hardware and software facilities devoted to experimentation, simulation, and analysis of various computer networking techniques (such as Internet routing, software-defined networking, online social networking, and Internet of things), malicious network attacks (such as distributed denial-of-service attacks, traffic route hijacking, Internet worms, botnets, Sybil attacks), and cyberdefense technologies (such as firewalls, anti-phishing solutions, distributed denial-of-service defense, IP spoofing prevention, Internet routing security, Internet privacy protection, and Internet of things security and privacy).

The Ubiquitous Computing Laboratory uses a mix of custom-designed and commercial hardware to study the application of assistive software to everyday living. Researchers are particularly interested in the design of software for those with impairments that limit their use of commercial, off-the-shelf software.

The Research Group on Computing and Data-Understanding at Extreme Scale (CDUX) pursues problems in scientific visualization, high-performance computing, scientific computing, and computer graphics, and especially focuses on problems where these areas intersect. The group performs research for the Department of Energy, the National Science Foundation, and private companies, delivered in widely used software tools such as the VisIt visualization tool, and helps develop new tools, like VTK-m, a library for many-core visualization and analysis.
The High-Performance Computing Laboratory conducts research in several areas, including static analysis of software for building performance models and detecting security vulnerabilities, source-to-source approaches for semantics-preserving (e.g., performance optimization) and semantics-modifying (e.g., security-vulnerability fixes, automatic differentiation) transformations. The lab also performs research in modeling run-time characteristics of software, and developing and employing numerical optimization techniques for maximizing multiple run-time objectives (performance, energy efficiency, resilience).

Software engineering is applied to two emerging areas: data science and the Internet of Things. The Flare Project is exploring new tools for data scientists. The project involves working with data science frameworks (e.g., Jupyter) and the interactive development environments (with humans in the loop) that support those frameworks. The Foundry Project is exploring software frameworks to support the Internet of Things with a specific emphasis on reworking distributed algorithms that were devised in an era when cyber-security was less of a threat.

In addition, the university is a member of Internet2, a high-speed network connecting major research institutions.

Careers
The undergraduate program is designed to prepare students for professional careers or graduate study. The field of computer science, which has become increasingly interdisciplinary over the past decade, offers a rich array of opportunities in fields as disparate as medicine, manufacturing, and the media as well as the computer industry.

Graduates come away with confidence that they can specify, design, and build large software systems; analyze the effectiveness of computing techniques for a specific problem; and work effectively in problem-solving teams. The master of arts (MA) and master of science (MS) degree programs prepare students for higher-level positions in the areas described above as well as for teaching positions in community colleges. The PhD degree program trains students as scientists for advanced research in specialized areas of computer science and for teaching in universities.

Faculty


Kathleen Freeman Hennessy, senior instructor; director of undergraduate studies. BS, 1982, Bucknell; PhD, 1993, Oregon. (2011)


Joseph Sventek, professor (complex event processing, Internet of Things). BS, 1973, Rochester; PhD, 1979, California, Berkeley. (2014)

Dave Wilkins, instructor. BA, 1965, Whitman College; MS, 1971, Oregon (2010)


Emeriti


Courses in computer programming or computer technology are useful but not required. Upon arrival at the university, students should consult with a CIS advisor to determine the entry-level course best suited to the student’s background.

Transfer and Second Baccalaureate Students

Transfer and second baccalaureate students should consult the online Interactive Transfer Catalog as well as a CIS advisor to determine whether computer science, mathematics, and science courses they have taken fulfill the major requirements. Completing only general-university requirements prior to transferring to the University of Oregon will not be sufficient preparation to complete a CIS degree in two years.

Students attending community college in Oregon are encouraged to obtain the associate of arts Oregon transfer degree or the associate of science Oregon transfer degree in computer science before entering the University of Oregon. While earning this degree, community college transfer students should take discrete mathematics and computer science. In addition, calculus and laboratory science are recommended.

Bachelor of Arts Degree Requirements

To earn a BA in computer and information science, majors must complete the requirements for a BS in addition to demonstrating proficiency in a second language. Computer and information science majors must complete at least 60 credits of CIS courses, of which 24 must be earned in residence at the University of Oregon. In addition, majors must complete 28 credits in mathematics, 12 credits in the sciences, and 4 credits of technical or business writing. The specific requirements for the CIS major fall into five categories: core courses, track and elective requirements, mathematics, writing, and science.

Computer Science I (CIS 210), Computer Science II (CIS 211), Computer Science III (CIS 212), Elements of Discrete Mathematics I (MATH 231), and Elements of Discrete Mathematics II (MATH 232) must be passed with grades of B– or better before students can take the upper-division core courses. Courses required for the major must be taken for a letter grade; upper-division electives in CIS courses numbered 410 or higher (12 credits) must also be taken for a letter grade. Upper-division courses must be passed with a grade of C– or better.

Undergraduate Studies

The Department of Computer and Information Science offers a major and a minor in computer and information science, a major in mathematics and computer science, and a minor in computer information technology.

The computer and information science major is intended for students who want to study computers and computation with strong mathematical and scientific foundations. The mathematics and computer science major emphasizes formal and abstract problem solving complemented by computational methods and computer technologies. This program, administered jointly with the Department of Mathematics, is described in the Mathematics and Computer Science section of this catalog. Both of these majors lead to the bachelor of arts (BA) or bachelor of science (BS) degrees.

Students majoring in computer and information science may choose to focus their studies in one of several areas of specialization, or tracks, which build on the standard CIS core requirements. Each track specifies a set of coordinated choices for fulfilling upper-division computer science and other elective requirements. Students interested in specializing in a track should contact their advisor as early as possible. Current computer science tracks include foundations, software development, computer networks, database and informatics, multimedia, business information systems, computational science, and security.

Preparation

High school students who plan to major in computer and information science should pursue a strong academic program, including substantial work in mathematics, the sciences, and writing. Courses in algebra, geometry, trigonometry, and more advanced topics should be included.
To support interdisciplinary study, students on any track are encouraged to complete a minor (typically 24–32 credits) or major in a computing-related field. Students who complete a minor (other than computer information technology or mathematics) or another major (including mathematics) in a computing-related field may, with the approval of the Undergraduate Education Committee, replace the CIS laboratory science requirement with the completed minor or major.

2 Students are encouraged to complete the accompanying lab courses.

3 Physics is recommended for networks track students.

4 If Experimental Course: [Topic] (CIS 410) courses are applied, they must have different topic subtitles to satisfy this requirement.

5 A maximum of 8 credits in courses numbered 399–409. Courses numbered 400–499 may be taken for a maximum of 4 credits when used to satisfy this requirement. Special Studies: [Topic] (CIS 399), Seminar: [Topic] (CIS 407), and Experimental Course: [Topic] (CIS 410) courses must have different topic subtitles to satisfy this requirement.

6 The mathematics elective is selected from upper-division mathematics courses with a prerequisite of Calculus II (MATH 252) or higher, or from theoretical computer science courses. A list of theoretical computer science courses is available in the computer science office or the department website.

Bachelor of Science Degree Requirements

To earn a BS in computer and information science, majors must complete at least 60 credits of CIS courses, of which 24 must be earned in residence at the University of Oregon. In addition, majors must complete 28 credits in mathematics, 12 credits in the sciences, and 4 credits of technical or business writing. The specific requirements for the CIS major fall into five categories: core courses, track and elective courses, mathematics, writing, and science.

Computer Science I (CIS 210), Computer Science II (CIS 211), Computer Science III (CIS 212), Elements of Discrete Mathematics I (MATH 231), and Elements of Discrete Mathematics II (MATH 232) must be passed with a grade of B– or better before students can take the upper-division core courses. Courses required for the major must be taken for a letter grade; upper-division electives in CIS courses numbered 410 or higher (12 credits) must also be taken for a letter grade. Upper-division courses must be passed with a grade of C– or better.
Select 12 credits from the following:

**Core Courses: Mathematics**
Select one of the following:
- MATH 251–252 Calculus I–II
- MATH 261–262 Calculus with Theory I–II
- MATH 246–247 Calculus for the Biological Sciences I–II

Select two of the following:
- MATH 347 Fundamentals of Number Theory I
  or MATH 35:Elementary Numerical Analysis II
  or MATH 39 Fundamentals of Abstract Algebra I
- MATH 253 Calculus III
  or MATH 263:Calculus with Theory III
- MATH 341 Elementary Linear Algebra
- MATH 343 Statistical Models and Methods
  or MATH 42:Statistical Methods I

**Core Courses: Science**
Select 12 credits from the following:

**Biology** 2
- CH 111 Introduction to Chemical Principles
  or CH 113 The Chemistry of Sustainability
  or CH 221 General Chemistry I
  or CH 224H Advanced General Chemistry I
- BI 211,213 General Biology I,III
  or BI 211–212 General Biology I–II

**Chemistry** 2
- CH 221–223 General Chemistry
  or CH 224H-Honors General Chemistry 226H

**Earth Sciences**
- ERTH 201 Dynamic Planet Earth
- ERTH 202 Earth's Surface and Environment
- ERTH 203 History of Life

**Geography**
- GEOG 141 The Natural Environment
  Select two of the following:
  - GEOG 321 Climatology
  - GEOG 322 Geomorphology
  - GEOG 323 Biogeography

**Physics** 2,3
- PHYS 201–203 General Physics
  or PHYS 25:Foundations of Physics I
  or PHYS 25:Foundations of Physics II

**Psychology**
- PSY 201 Mind and Brain
  Select two of the following:
  - PSY 301 Scientific Thinking in Psychology
  - PSY 304 Biopsychology

**Core Course: Writing**
- WR 320 Scientific and Technical Writing
  or WR 321 Business Communications

**Electives: Upper Division**
Upper-division CIS courses in student's chosen track (track information below)
Upper-division CIS courses in student's chosen track, honors thesis, capstone project, or other upper-division courses 4,5
Upper-division mathematics or theoretical computer science course 6

Total Credits 104

1. To support interdisciplinary study, students on any track are encouraged to complete a minor (typically 24–32 credits) or major in a computing-related field. Students who complete a minor (other than computer information technology or mathematics) or another major (including mathematics) in a computing-related field may, with the approval of the Undergraduate Education Committee, replace the CIS laboratory science requirement with the completed minor or major.

2. Students are encouraged to complete the accompanying lab courses.

3. Physics is recommended for networks track students.

4. If Experimental Course: [Topic] (CIS 410) courses are applied, they must have different topic subtitles to satisfy this requirement.

5. A maximum of 8 credits in courses numbered 399–409. Courses numbered 400–499 may be taken for a maximum of 4 credits when used to satisfy this requirement. Special Studies: [Topic] (CIS 399), Seminar: [Topic] (CIS 407), and Experimental Course: [Topic] (CIS 410) courses must have different topic subtitles to satisfy this requirement.

6. The mathematics elective is selected from upper-division mathematics courses with a prerequisite of Calculus II (MATH 252) or higher, or from theoretical computer science courses. A list of theoretical computer science courses is available in the computer science office or the department website.

**Upper-Division Electives**
In addition to the core CIS, mathematics, science, and writing courses, and computer and information science majors must complete 20 credits of upper-division computer science and 4 credits of upper-division mathematics or theoretical computer science. Students complete at least 12 of their upper-division CIS credits with courses from their selected track; the 8 remaining upper-division credits may be additional track courses, an honors thesis, capstone project, or upper-division electives.

A maximum of 8 credits in CIS courses, numbered 399–409, may be applied to the upper-division electives requirement. Courses numbered 400–409 may be taken for a maximum of 4 credits when used to satisfy this requirement. (Courses numbered 399, 407, or 410 may be repeated with different course subtitles.) Special Studies: [Topic] (CIS 399) and Experimental Course: [Topic] (CIS 410) courses used as upper-division electives must have a prerequisite of CIS 313 and have regular weekly class meetings and homework assignments.

The mathematics elective is selected from upper-division mathematics courses with a prerequisite of MATH 252 or higher, or from theoretical...
computer science courses. A list of courses is available in the computer science office or the department website.

**Tracks**

Tracks highlight areas of specialization within the department and guide student elective choices. Each track has an approved list of CIS courses, available from the computer science office or the department website. Tracks may also include recommended science or mathematics courses or a recommended minor in another field.

**Foundations Track**

The foundations track is the most general track, allowing a student to choose a set of electives tailored to his or her interests and intended choice of career.

**Software Development Track**

The software development track prepares students for careers in software engineering, software project management, software quality assurance, and other areas involving the creation of software. Course work focuses on solving problems related to the cost of development as well as the quality of the software delivered in complex software projects.

**Computer Networks Track**

The computer networks track prepares students for careers as network systems administrators, network protocol developer-programmers, or network security specialists in a wide range of environments, including educational institutions, business enterprises, and government agencies, as well as for advanced graduate studies and research in the field of computer networks. Course work encompasses most aspects of network theory and practice.

**Database and Informatics Track**

The database and informatics track prepares students for careers in database application programming, database design, doctoral work in business administration, and graduate work in informatics and database theory. Course work includes data structures, data architecture, and data mining.

**Business Information Systems Track**

Graduates in the business information systems track are qualified to work as analysts, managers, developers, or consultants, and to enter leadership-development programs. Completion of this track, combined with professional work experience and economics courses, prepares students to enter the Lundquist College of Business MBA program at the University of Oregon, and MBA programs at other universities.

**Computational Science Track**

The computational science track prepares students to apply computational and mathematical techniques to the analysis and management of biological data. Course work in this track combines depth in applied and formal aspects of computer science with rigorous training in biology.

**Security Track**

The security track provides a foundation in topics and concepts relating to the security of computer systems and networks. It prepares students to work as security analysts and provides a highly desirable skill set for all employers, ranging from software engineers to administrators, in both the private and government sectors. It also provides a foundation for further graduate study and research in security. Course work encompasses a strong understanding of computer systems and networks and their security, and can be tailored to a more theoretical or more applied focus.

**Preparation for the Major**

Students who take Computer Science I (CIS 210) are expected to have completed Elementary Functions (MATH 112) or the equivalent and to have prior programming experience from a high school course, through employment, or in a course such as Introduction to Programming and Problem Solving (CIS 122). Students who are unsure about their level of programming preparation should meet with a CIS advisor.

**Sequence of Courses for Students with Programming Experience and Mathematical Background**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 231–232</td>
<td>Elements of Discrete Mathematics I-II 8</td>
</tr>
<tr>
<td>CIS 210–212</td>
<td>Computer Science I-III 12</td>
</tr>
<tr>
<td><strong>Total Credits:</strong></td>
<td>20</td>
</tr>
</tbody>
</table>

**Sequence of Courses for Students without Programming Experience and Mathematical Background**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>MATH 112</td>
<td>Elementary Functions 4</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td>4</td>
</tr>
<tr>
<td>CIS 122</td>
<td>Introduction to Programming and Problem Solving 4</td>
</tr>
<tr>
<td>CIS 111</td>
<td>Introduction to Web Programming 4</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
</tr>
<tr>
<td>MATH 231–232</td>
<td>Elements of Discrete Mathematics I-II 2 8</td>
</tr>
<tr>
<td>CIS 210–212</td>
<td>Computer Science I-III 2 12</td>
</tr>
<tr>
<td><strong>Total Credits:</strong></td>
<td>28</td>
</tr>
</tbody>
</table>

1. Taken either in first term or first year. Students are encouraged to take more than one course. CIS 122 strongly recommended.
2. Taken in either second term or second year.

**Major Progress Review and Major in Good Standing**

Each major must meet with a computer science advisor and file the Major Progress Review form while taking Intermediate Data Structures (CIS 313) or Computer Organization (CIS 314), Mathematics and CIS core courses and at least 12 credits of CIS upper division elective courses numbered 410 or higher must be taken for letter grades and passed with grades of C– or better. Other courses used to satisfy the major requirements may be taken for letter grades or pass/no pass. Grades of C– or better or P must be earned in these courses. At least 12 of the CIS upper-division credits applied to the degree must be taken in residence at the university. A student who receives two grades below C– in the upper-division core, or three grades below C– in any CIS upper-division courses, will be removed from the major.
Mathematics and Computer Science

The Department of Computer and Information Science and the Department of Mathematics jointly offer an undergraduate major in mathematics and computer science, leading to a bachelor of arts or a bachelor of science degree. This program is described in the Mathematics and Computer Science section of this catalog. This major prepares students for a wide range of careers in the high tech industry, for advanced graduate study, and for careers as middle school and high school teachers.

Honors Program

Students with a GPA of 3.50 or higher in computer and information science and a cumulative GPA of 3.50 or higher are encouraged to apply to the department honors program after completing Intermediate Data Structures (CIS 313), Computer Organization (CIS 314), Intermediate Algorithms (CIS 315), and C/C++ and Unix (CIS 330). The application form is available in the department office. To graduate with departmental honors, a student must write a thesis under the supervision of a faculty member.

Internships

Practical work experience in the software industry is seen as a valuable complement to academic course work. The department works with students to place them in internship positions in the summer and throughout the academic year. Students may also use the services of the University Career Center and other agencies to identify internship opportunities. Majors may receive academic credit for internships. To earn upper-division elective credit for an internship, the work experience must be at a technical level beyond Intermediate Data Structures (CIS 313) and be sponsored by a CIS faculty member. A contract signed by the faculty sponsor, internship supervisor, and the student must be filed with the department before the internship begins.

Research

Faculty members in the computer and information science department receive grants from government, industry, and private sources to conduct research in their areas of expertise. Undergraduate majors are encouraged to take part in the various research groups in the department. Most students begin approaching faculty members for such opportunities while taking the 300-level courses. Research can be used to fulfill upper-division electives, as part of an honors thesis, or in some cases as a paid internship.

Awards and Honor Societies

The Erwin and Gertrude Juilfs Scholarship in Computer and Information Science, in honor of Erwin and Gertrude Juilfs, is awarded to one or more students who show exceptional promise for achievement as evidenced by grade point average, originality of research, or other creative activities.

The Geoffrey Eric Wright Outstanding Junior Award, in honor of CIS student Geoffrey Wright, is a scholarship for students displaying high-quality academic performance, commitment to learning, and a promise of further outstanding achievement in computer and information science and its applications.

The J. Donald Hubbard Scholarship in Computer and Information Science, in honor of J. Donald Hubbard, recognizes an undergraduate or graduate student who shows outstanding promise in the fields of computer-human interaction, computer graphics, or multimedia.

The Phillip Seeley Scholarship in Computer and Information Science has been established as a permanent endowment to provide a source of income supporting a scholarship for outstanding undergraduate CIS students. This scholarship is based on overall quality of academic work, commitment to learning, and potential for further academic achievement. Preference is given to resident Oregon students with financial need, as determined by the UO Office of Student Financial Aid and Scholarships.

Students with outstanding academic accomplishments may be invited to become members of Upsilon Pi Epsilon, the international honor society in computer science.

Minor Requirements

Computer and Information Science Minor

The minor in computer and information science introduces the theories and techniques of computer science and develops programming skills that are applicable to the student’s major. It is a strong complement to a major in any of the sciences and in related fields such as multimedia arts. Students from all majors have found their career opportunities enhanced through the CIS minor.

Before enrolling in upper-division courses, students planning a minor in computer and information science must file an application form with the department. Each student should consult with a CIS faculty advisor to plan the minor program.

Courses applied to the CIS minor must be completed with grades of C– or better.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIS 210–212</td>
<td>Computer Science I-II</td>
<td>12</td>
</tr>
<tr>
<td>MATH 231–232</td>
<td>Elements of Discrete Mathematics I-II</td>
<td>8</td>
</tr>
</tbody>
</table>

Intermediate Data Structures | 4

Electives 1 | 8

Total Credits 32

1 Classes number CIS 399-409 with departmental permission only

Computer Information Technology Minor

The minor in computer information technology (CIT) prepares students to work with evolving technologies for work environments that require development and management of web applications, databases, computer networks, open-source platforms, and cloud computing. It provides practical experience in understanding the tools and technologies of the computing field. It goes well with majors in the professional schools such as business and journalism and is an excellent match with almost any major on campus.

Before enrolling in CIT upper-division courses, students planning a minor in computer information technology must file an application form with the department. Each student should consult with an assigned CIT faculty advisor to plan the minor program.

Lower-division courses must be completed with grades of B– or better.

Upper-division courses must be taken in sequence and are offered only once a year. Upper-division courses must be completed with grades of C– or better.

Lower-Division Courses

Option 1:
- CIS 110: Fluency with Information Technology
- CIS 111: Introduction to Web Programming
- CIT 281: Web Applications Development I

Option 2:
- CIS 111: Introduction to Web Programming
- CIS 115: Multimedia Web Programming
- CIT 281: Web Applications Development I

Upper-Division Courses
- CIT 381: Database Systems
- CIT 382: Web Applications Development II
- CIT 383: Networking Fundamentals

Total Credits: 24

Four-Year Degree Plan

The degree plan shown is only a sample of how students may complete their degrees in four years. There are alternative ways. Students should consult their advisor to determine the best path for them. Additional information may be found at the department website (https://cs.uoregon.edu).

Bachelor of Arts in Computer and Information Science

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Year</strong></td>
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<td></td>
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<tr>
<td><strong>Fall</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIS 122</td>
<td>Introduction to Programming and Problem Solving</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>MATH 112</td>
<td>Elementary Functions</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>First term of second-language sequence</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>General-education course in social science</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Credits</td>
<td></td>
<td>17</td>
<td></td>
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<tr>
<td><strong>Winter</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CIS 210</td>
<td>Computer Science I</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>MATH 231</td>
<td>Elements of Discrete Mathematics I</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>WR 121</td>
<td>College Composition I</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Second term of second-language sequence</td>
<td></td>
<td>5</td>
<td></td>
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<tr>
<td>Credits</td>
<td></td>
<td>17</td>
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<tr>
<td><strong>Spring</strong></td>
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<tr>
<td>CIS 211</td>
<td>Computer Science II</td>
<td>4</td>
<td></td>
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<tr>
<td>MATH 232</td>
<td>Elements of Discrete Mathematics II</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>WR 122</td>
<td>College Composition II or WR 123</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>College Composition III</td>
<td></td>
<td>5</td>
<td></td>
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<tr>
<td>Third term of second-language sequence</td>
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<td>5</td>
<td></td>
</tr>
<tr>
<td>Credits</td>
<td></td>
<td>17</td>
<td></td>
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<tr>
<td><strong>Third Year</strong></td>
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<tr>
<td><strong>Fall</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CIS 415</td>
<td>Operating Systems</td>
<td>4</td>
<td></td>
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<tr>
<td>Upper-division elective course with CIS subject code</td>
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<tr>
<td>First course of additional science sequence</td>
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</tr>
<tr>
<td>General-education course in arts and letters</td>
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<td>4</td>
<td></td>
</tr>
<tr>
<td>Credits</td>
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<td>16</td>
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<tr>
<td><strong>Winter</strong></td>
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<td>Credits</td>
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<td>16</td>
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<td>Principles of Programming Languages</td>
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General-education course in arts and letters that also meets multicultural requirement | 4
Credits | 16
Total Credits | 48

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**Bachelor of Science in Computer and Information Science**

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<td>College Composition I</td>
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<td>Elective course</td>
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<tr>
<td>Credits</td>
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<tr>
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<td>CIS 422</td>
<td>Software Methodology I</td>
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Second course of additional science sequence 4
Elective course 4

Credits 16

Spring
CIS 425 Principles of Programming Languages 4
Upper-division elective course with CIS subject code 4
Third course of additional science sequence 4
Elective course 4

Credits 16

Total Credits 48

Course Title Credits Milestones

Fourth Year

Fall
Upper-division elective course with CIS subject code 4
Upper-division mathematics elective 4
Elective course 4

Credits 12

Winter
Upper-division elective course with CIS subject code 4
Upper-division mathematics elective 4
Elective course 4

Credits 12

Spring
WR 320 or WR 321 Scientific and Technical Writing 4
Elective courses 8

Credits 12

Total Credits 36

- Master of Science
- Doctor of Philosophy

Graduate Studies
The department offers programs leading to the master of arts (MA), master of science (MS), and doctor of philosophy (PhD).

Master’s Degree Program

Admission
Admission to the master’s degree program in computer and information science is competitive. It is based on prior academic performance, Graduate Record Examinations (GRE) scores, and computer science background. Minimum requirements for admission with graduate master’s status are as follows:

1. Documented knowledge of
   a. Principles of computer organization and operating systems
   b. Programming languages
   c. Program development and analysis
   d. Data structures and algorithm analysis
2. GRE scores on the general test. The computer science test is optional.
3. A score of at least 100 on the Internet-based option of the Test of English as a Foreign Language (TOEFL iBT) or a score of 7.0 on the International English Language Testing System (IELTS) for applicants who have no justification for a waiver. Applicants may be required to study one or more terms at the university’s American English Institute or elsewhere before taking any graduate work in the department. International applicants for teaching assistantships who score at least 26 on the speaking section of the TOEFL iBT will not have to take the Speaking Proficiency English Assessment Kit (SPEAK) test upon arrival at the university.
4. Three letters of recommendation, a statement of purpose, and unofficial transcripts (via online application). Note that official transcripts are sent to the UO Office of Admissions.

Grades from previous course work should indicate the ability to maintain at least a 3.00 grade point average in graduate-level courses.

Application materials should be submitted by February 1 for admission, via GradWeb (http://gradweb.uoregon.edu), for the following fall term.

Admission to the master’s degree program requires the substantive equivalent of an undergraduate degree in computer science. A second bachelor’s degree program can be used to gain the required level of computer science background. Students without this background may be admitted conditionally and required to complete remedial course work before achieving unconditional standing in the program.

Master of Science Degree Requirements

<table>
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<tr>
<th>Code</th>
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<tr>
<td>CIS 621</td>
<td>Algorithms and Complexity</td>
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<td>CIS 670</td>
<td>Data Science</td>
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<td>And one of the following:</td>
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<tr>
<td>CIS 630</td>
<td>Distributed Systems 2</td>
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<tr>
<td>CIS 631</td>
<td>Parallel Processing 3</td>
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<td>Depth Requirement: Choose one, 12 credits total 1</td>
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<tr>
<td>Each Depth requires three courses, at least one at 600-level</td>
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<td>Foundations Depth</td>
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<td>Introduction to Logic</td>
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<tr>
<td>CIS 543</td>
<td>User Interfaces</td>
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<td>CIS 545</td>
<td>Modeling and Simulation</td>
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<tr>
<td>CIS 561</td>
<td>Introduction to Compilers</td>
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<tr>
<td>CIS 624</td>
<td>Structure of Programming Languages</td>
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<td>CIS 573</td>
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<td>CIS 531</td>
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<td>CIS 532</td>
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<tr>
<td>CIS 533</td>
<td>Computer and Network Security</td>
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Master's Project

The project option requires a minimum of 9 credits, and as many as 12, in Final Project Final Project (CIS 609).

Under the supervision of a faculty member, the project may entail a group effort involving several master's degree students.

Accelerated Master’s Degree Program

This program is open to students who earn a BS or BA degree in computer and information science at the University of Oregon and who want to enter the master's degree program.

If a UO undergraduate takes one or two 400-level electives that also are offered as 500-level courses, the student can petition the department to have 4 or 8 credits deducted from the total number of elective credits required for the master's degree. The student must earn an A– or better in the 400-level course and have an overall GPA of 3.50 in upper-division CIS courses to participate in this accelerated master’s program. Note that all admission procedures, as outlined in the Master’s Degree Program (p. 10) section, are also applicable. Applications are available in the department office.

Awards and Honor Societies

The Erwin and Gertrude Juilfs Scholarship in Computer and Information Science, in honor of Erwin and Gertrude Juilfs, is awarded to one or more students who show exceptional promise for achievement as evidenced by grade point average, originality of research, or other creative activities.

The J. Donald Hubbard Scholarship in Computer and Information Science, in honor of J. Donald Hubbard, recognizes an undergraduate or graduate student who shows outstanding promise in the fields of computer-human interaction, computer graphics, or multimedia.

The Gurdeep Pall Scholarship in Computer and Information Science, in honor of Gurdeep Pall, is awarded to a student based on the overall quality of their academic work, their commitment to learning, and their potential for further academic achievement.

Students with outstanding academic accomplishments may be invited to become members of Upsilon Pi Epsilon, the international honor society in computer science.

Doctoral Degree Program

The doctor of philosophy in computer and information science is, above all, a high-quality degree that is not conferred simply for the successful completion of a specified number of courses or years of study. It is a degree reserved for students who demonstrate a comprehensive understanding of computer science and an ability to do creative research. Each PhD student produces a significant piece of original research, presented in a written dissertation and defended in an oral examination.

The PhD program is structured to facilitate the process of learning how to do research. Students begin by taking required courses to build a foundation of knowledge that is essential for advanced research. Early in the program the student gains research experience by undertaking a directed research project under the close supervision of a faculty member and the scrutiny of a faculty committee. In the later stages of the program, students take fewer courses and spend most of their time exploring their dissertation area to learn how to identify and solve open problems. The final steps are to propose an independent research project, do the research, and write and defend a dissertation.
Admission

Application materials should be submitted by December 15 for the following fall term. Materials include everything required for admission to the master’s program as well as a discussion of the anticipated research area.

Students who enter the UO with a master’s degree may petition the Graduate Education Committee for credit toward the course requirements listed below, indicating how their prior graduate work corresponds to these courses. See the graduate coordinator for the petition.

PhD Course Requirements

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<td>CIS 630</td>
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Depth Requirement: Choose one, 12 credits total

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Data Science Depth

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Systems Depth

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<td>Distributed Systems</td>
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</tr>
<tr>
<td>CIS 631</td>
<td>Parallel Processing</td>
<td>2</td>
</tr>
<tr>
<td>CIS 632</td>
<td>Computer Networks</td>
<td></td>
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<tr>
<td>CIS 633</td>
<td>Advanced Network Security</td>
<td></td>
</tr>
<tr>
<td>CIS 650</td>
<td>Software Engineering</td>
<td></td>
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Writing Requirement

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CIS 640</td>
<td>Writing in Computer Research</td>
<td>2</td>
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Elective Options: 24 credits total

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Total Credits

<table>
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<tbody>
<tr>
<td></td>
<td></td>
<td>50</td>
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</tbody>
</table>

1 A grade of B- or better is required
2 Cannot duplicate Depth course used
3 Cannot duplicate Breadth course used
4 A grade of C or better is required in graded elective credits

PhD Degree Requirements

PhD candidates who enter the program without a master’s degree in computer science must take 48 credits in graduate course work including the core and cluster courses required for the MS program. Doctoral students must earn a minimum grade of B- and an overall GPA of 3.50 in the six courses they use to satisfy the breadth and depth requirements.

Minimum Annual Enrollment

PhD students are expected to enroll in at least 6 credits of 600-level course work each year until their advancement to candidacy. Research: [Topic] (CIS 601), Dissertation (CIS 603), and Reading Conference: [Topic] (CIS 605) do not satisfy this requirement. After candidacy, PhD students are encouraged to continue participation in 600-level courses

Directed Research Project

Complete a directed research project, which is supervised by a faculty member and evaluated by a faculty committee. The research project comprises the following:

1. The definition and expected results of the project in the form of a Directed Research Project Contract
2. Delivery of the materials constituting the results of the project and oral presentation of the results
3. A private oral examination by the committee members

Status Change

PhD candidates are admitted conditionally. Successful completion of the directed research project leads to a change in the student’s doctoral status from conditional to unconditional.

Dissertation Advisory Committee

After successfully completing the directed research project, PhD students form a Dissertation Advisory Committee chaired by their research advisor. The main role of the committee is to advise the student between completion of the research project and mounting the dissertation defense. The committee takes primary responsibility for evaluating student progress. In addition, it approves the plan for the area examination, which in turn is approved by the graduate education committee. See the graduate coordinator for further instructions.

Area Examination

The student chooses an area of research and works closely with an advisor to learn the area in depth by surveying the current research and learning research methods, significant achievements, and how to pose and solve problems. The student gradually assumes a more independent role and prepares for the area examination, which tests depth of knowledge in the research area. The examination contains the following:

1. A survey of the area in the form of a position paper and an annotated bibliography
2. A public presentation of the position paper
3. A private oral examination by committee members
Advancement to Candidacy
After the area examination, the committee decides whether the student is ready for independent research work; if so, the student is advanced to candidacy.

Dissertation and Defense
Identify a significant unsolved research problem and submit a written dissertation proposal to the dissertation committee. The dissertation committee, comprising three department members and one member from an outside department, is approved by the graduate education committee. In addition to these four, the dissertation committee often includes a fifth examiner. This outside examiner should be a leading researcher in the candidate’s field who is not at the University of Oregon. The outside member should be selected a year before the candidate’s dissertation defense, and no later than six months before.

The student submits a written dissertation proposal to the committee for approval, and the proposal is then submitted to the graduate education committee. The proposal presents the research problems to be tackled, related research, methodology, anticipated results, and work plan. The committee may request an oral presentation, similar to the area exam, which allows the student to explain and answer questions about the proposed research. The student then carries out the research.

The final stage is writing a dissertation and defending it in a public forum by presenting the research and answering questions about the methods and results. The dissertation committee may accept the dissertation, request small changes, or require the student to make substantial changes and schedule another defense.

Graduate School Requirements
PhD students must meet the requirements set by the Graduate School as listed in that section of this catalog.

Research Areas
It is important that a PhD student be able to work effectively with at least one dissertation advisor. Hence the student should identify, at an early stage, one or more areas of research to pursue. The student should also find a faculty member with similar interests to supervise the dissertation.

Computer and Information Science Courses
CIS 110. Fluency with Information Technology. 4 Credits.
Introduction to information technology (IT), the study of computer-based information systems. Basics of the Internet and World Wide Web. Students create websites using XHTML and CSS.

CIS 111. Introduction to Web Programming. 4 Credits.
Project-based approach to learning computer programming by building interactive web pages using JavaScript and XHTML. Programming concepts including structured and object-oriented program design. CIS 110 recommended preparation.
Prereq: MATH 101 or equivalent.

CIS 115. Multimedia Web Programming. 4 Credits.
Intermediate web programming with an emphasis on HTML5 multimedia: two-dimensional graphics, image processing, animation, video, user interaction, geolocation. Continuing JavaScript, DOM, Ajax, and JSON use, programming fundamentals, and debugging techniques.
Prereq: CIS 111.

CIS 122. Introduction to Programming and Problem Solving. 4 Credits.
Computational problem solving, algorithm design, data structures, and programming using a multi-paradigm programming language. Introduces techniques for program design, testing, and debugging.
Prereq: MATH 101 or equivalent.

CIS 196. Field Studies: [Topic]. 1-2 Credits.
Repeatable.

CIS 198. Workshop: [Topic]. 1-2 Credits.
Repeatable.

CIS 199. Special Studies in Computer Science: [Topic]. 1-5 Credits.
Repeatable.

CIS 210. Computer Science I. 4 Credits.
Basic concepts and practices of computer science. Topics include algorithmic problem solving, levels of abstraction, object-oriented design and programming, software organization, analysis of algorithm and data structures. Sequence.
Prereq: MATH 112. Prior programming experience strongly encouraged.

CIS 211. Computer Science II. 4 Credits.
Basic concepts and practices of computer science. Topics include algorithmic problem solving, levels of abstraction, object-oriented design and programming, software organization, analysis of algorithm and data structures. Sequence.
Prereq: CIS 210.

CIS 212. Computer Science III. 4 Credits.
Basic concepts and practices of computer science. Topics include algorithmic problem solving, levels of abstraction, object-oriented design and programming, software organization, analysis of algorithm and data structures. Sequence.
Prereq: CIS 211.

CIS 313. Intermediate Data Structures. 4 Credits.
Design and analysis of data structures as means of engineering efficient software; attention to data abstraction and encapsulation. Lists, trees, heaps, stacks, queues, dictionaries, priority queues.
Prereq: CIS 210, CIS 211, CIS 212, MATH 231, MATH 232 with grades of B- or better.

CIS 314. Computer Organization. 4 Credits.
Introduction to computer organization and instruction-set architecture--digital logic design, binary arithmetic, design of central processing unit and memory, machine-level programming.
Prereq: CIS 210, CIS 211, CIS 212, MATH 231, MATH 232 with grades of B- or better.

CIS 315. Intermediate Algorithms. 4 Credits.
Algorithm design, worst-case and average-behavior analysis, correctness, computational complexity.
Prereq: CIS 313.

CIS 322. Introduction to Software Engineering. 4 Credits.
A project-intensive introduction to software engineering intended to build skills, knowledge, and habits of mind that prepare students for 400-level computer science courses, internships, and other software.
Prereq: CIS 210, CIS 211, CIS 212 with grades of B- or better.

CIS 330. C/C++ and Unix. 4 Credits.
Practical software design and programming activities in a C/C++ and Unix environment, with emphasis on the details of C/C++ and good programming style and practices.
Prereq: CIS 314.
CIS 372M. Machine Learning for Data Science. 4 Credits.
Introduction to Machine Learning, with an emphasis on topics relevant for data science. Multilisted with DSCI 372M.
Prereq: CIS 212, DSCI 345M, MATH 342

CIS 399. Special Studies: [Topic]. 1-5 Credits.
Repeatable when the topic changes.

CIS 401. Research: [Topic]. 1-21 Credits.
Repeatable.
Prereq: CIS 313

CIS 403. Thesis. 1-12 Credits.
Repeatable.
Prereq: CIS 313

CIS 404. Internship: [Topic]. 1-4 Credits.
Repeatable.
Prereq: CIS 313

CIS 405. Reading and Conference: [Topic]. 1-12 Credits.
Repeatable up to five times.
Prereq: CIS 313

CIS 406. Field Studies: [Topic]. 1-21 Credits.
Repeatable.
Prereq: CIS 313

CIS 407. Seminar: [Topic]. 1-5 Credits.
Repeatable when the topic changes. Opportunity to study in greater depth specific topics arising out of other courses.
Prereq: CIS 313

CIS 408. Workshop: [Topic]. 1-21 Credits.
Repeatable.
Prereq: CIS 313

CIS 409. Practicum: [Topic]. 1-2 Credits.
The student assists other students who are enrolled in introductory programming classes. For each four hours of scheduled weekly consulting, the student is awarded 1 credit. Repeatable for maximum of 4 credits.
Prereq: CIS 313

CIS 410. Experimental Course: [Topic]. 1-5 Credits.
Repeatable when the topic changes.

CIS 413. Advanced Data Structures. 4 Credits.
Complex structures, storage management, sorting and searching, hashing, storage of texts, and information compression.
Prereq: CIS 315

CIS 415. Operating Systems. 4 Credits.
Principles of operating system design. Process and memory management, concurrency, scheduling, input-output and file systems, security.
Prereq: CIS 313, CIS 330.

CIS 420. Automata Theory. 4 Credits.
Provides a mathematical basis for computability and complexity. Models of computation, formal languages, Turing machines, solvability. Nondeterminism and complexity classes.
Prereq: CIS 315.

CIS 422. Software Methodology I. 4 Credits.
Technical and nontechnical aspects of software development, including specification, planning, design, development, management and maintenance of software projects. Student teams complete projects.
Prereq: CIS 313.

CIS 423. Software Methodology II. 4 Credits.
Application of concepts and methodologies covered in CIS 422/522. Student teams complete a large system design and programming project. Final system specification, test plan, user documentation, and system walk throughs.
Prereq: CIS 422 with a B- or better.

CIS 425. Principles of Programming Languages. 4 Credits.
Prereq: CIS 315.

CIS 427. Introduction to Logic. 4 Credits.
Prereq: CIS 315; CIS 425 recommended pre or co-req.

CIS 429. Computer Architecture. 4 Credits.
RISC (reduced instruction-set computer) and CISC (complex instruction-set computer) design, storage hierarchies, high-performance processor design, pipelining, vector processing, networks, performance analysis.
Prereq: CIS 330.

CIS 431. Introduction to Parallel Computing. 4 Credits.
Parallel architecture, theory, algorithms, and programming with emphasis on parallel programming, focusing on models, languages, libraries, and runtime systems.
Prereq: CIS 330.

CIS 432. Introduction to Networks. 4 Credits.
Principles of computer network design. Link technologies, packet switching, routing, inter-networking, reliability. Internet protocols. Programming assignments focus on protocol design.
Prereq: CIS 330. CIS 415 recommended.

CIS 433. Computer and Network Security. 4 Credits.
Prereq: CIS 415.

CIS 441. Introduction to Computer Graphics. 4 Credits.
Introduction to the hardware, geometrical transforms, interaction techniques, and shape representation schemes that are important in interactive computer graphics. Programming assignments using contemporary graphics hardware and software systems.
Prereq: CIS 330.

CIS 443. User Interfaces. 4 Credits.
Introduction to user interface software engineering. Emphasis on theory of interface design, understanding the behavior of the user, and implementing programs on advanced systems.
Prereq: CIS 313.

CIS 445. Modeling and Simulation. 4 Credits.
Theoretical foundations and practical problems for the modeling and computer simulation of discrete and continuous systems. Simulation languages, empirical validation, applications in computer science.
Prereq: CIS 315, 330.
CIS 451. Database Processing. 4 Credits.
Fundamental concepts of DBMS. Data modeling, relational models and normal forms. File organization and index structures. SQL, embedded SQL, and concurrency control.
Prereq: CIS 313, 314.

CIS 453. Data Mining. 4 Credits.
Databases, machine learning, artificial intelligence, statistics, and data visualization. Examines data warehouses, data preprocessing, association and classification rule mining, and cluster analysis.
Prereq: CIS 451/551.

CIS 451/551. Introduction to Parallel Computing. 4 Credits.
Parallel architecture, theory, algorithms, and programming with emphasis on parallel programming, focusing on models, languages, libraries, and runtime systems.

CIS 453. Data Mining. 4 Credits.
Introduction to the hardware, geometrical transforms, interaction techniques, and shape representation schemes that are important in interactive computer graphics. Programming assignments using contemporary graphics hardware and software systems.

CIS 454. Data Mining. 4 Credits.
Introduction to machine learning and its established algorithms. Topics include concept learning, decision trees, neural network.
Prereq: CIS 315.

CIS 471. Introduction to Artificial Intelligence. 4 Credits.
Basic themes, issues, and techniques of artificial intelligence, including agent architecture, knowledge representation and reasoning, problem solving and planning, game playing, and learning.
Prereq: CIS 315.

CIS 472. Machine Learning. 4 Credits.
A broad introduction to machine learning and its established algorithms. Topics include concept learning, decision trees, neural network.
Prereq: CIS 315.

CIS 473. Probabilistic Methods for Artificial Intelligence. 4 Credits.
Fundamental techniques for representing problems as probability distributions, performing inference, and learning from data. Topics include Bayesian and Markov networks, variable elimination, loopy belief propagation, and parameter.
Prereq: CIS 315.

CIS 477. Introduction to Logic. 4 Credits.

CIS 527. Introduction to Logic. 4 Credits.

CIS 529. Computer Architecture. 4 Credits.
RISC (reduced instruction-set computer) and CISC (complex instruction-set computer) design, storage hierarchies, high-performance processor design, pipelining, vector processing, networks, performance analysis.

CIS 531. Introduction to Artificial Intelligence. 4 Credits.
Basic themes, issues, and techniques of artificial intelligence, including agent architecture, knowledge representation and reasoning, problem solving and planning, game playing, and learning.
Prereq: CIS 314 or equivalent, 624. CIS 420/520 strongly recommended.

CIS 532. Introduction to Networks. 4 Credits.
Principles of computer network design. Link technologies, packet switching, routing, inter-networking, reliability. Internet protocols. Programming assignments focus on protocol design.

CIS 533. Computer and Network Security. 4 Credits.

CIS 551. Database Processing. 4 Credits.
Fundamental concepts of DBMS. Data modeling, relational models and normal forms. File organization and index structures. SQL, embedded SQL, and concurrency control.

CIS 553. Data Mining. 4 Credits.
Databases, machine learning, artificial intelligence, statistics, and data visualization. Examines data warehouses, data preprocessing, association and classification rule mining, and cluster analysis.
Prereq: CIS 451/551.

CIS 554. Data Mining. 4 Credits.
Introduction to the hardware, geometrical transforms, interaction techniques, and shape representation schemes that are important in interactive computer graphics. Programming assignments using contemporary graphics hardware and software systems.

CIS 555. Data Mining. 4 Credits.
Introduction to machine learning and its established algorithms. Topics include concept learning, decision trees, neural network.
CIS 573. Probabilistic Methods for Artificial Intelligence. 4 Credits.
Fundamental techniques for representing problems as probability distributions, performing inference, and learning from data. Topics include Bayesian and Markov networks, variable elimination, loopy belief propagation, and parameter.

CIS 601. Research: [Topic]. 1-16 Credits.
Repeatable.

CIS 602. Supervised College Teaching. 1-5 Credits.
Repeatable.

CIS 603. Dissertation. 1-16 Credits.
Repeatable.

CIS 604. Internship: [Topic]. 1-4 Credits.
Repeatable.

CIS 605. Reading and Conference: [Topic]. 1-16 Credits.
Repeatable.

CIS 606. Field Studies: [Topic]. 1-16 Credits.
Repeatable.

CIS 607. Seminar: [Topic]. 1-5 Credits.
Repeatable. Research topics are presented.

CIS 608. Colloquium: [Topic]. 1 Credit.
Repeatable.

CIS 609. Final Project. 1-16 Credits.
Repeatable. Final project for master's degree without thesis.

CIS 610. Experimental Course: [Topic]. 1-5 Credits.
Repeatable.

CIS 621. Algorithms and Complexity. 4 Credits.
Design and analysis of algorithms, strategies for efficient algorithms, introduction to complexity theory including NP-completeness. Prereq: CIS 420/520 strongly recommended.

CIS 622. Structure of Programming Languages. 4 Credits.
Introduction to axiomatic, operational, and denotational semantics. Environments, stores, and continuations. Type theory, subtypes, polymorphism, and inheritance. Functional and logic programming.

CIS 630. Distributed Systems. 4 Credits.
Principles of distributed computer systems: interprocess communication, distributed file systems, distributed timing and synchronization, distributed programming, transactions, process scheduling, distributed shared memory. Prereq: CIS 415 or equivalent, CIS 429/529.

CIS 631. Parallel Processing. 4 Credits.
Advanced topics in parallel processing including massively parallel computer architecture, supercomputers, parallelizing compiler technology, performance evaluation, parallel programming languages, parallel applications. Prereq: CIS 529, CIS 531.

CIS 632. Computer Networks. 4 Credits.
Advanced issues in computer networks, focusing on research to extend the services offered by the Internet. Prereq: CIS 432/532.

CIS 633. Advanced Network Security. 4 Credits.
Classic and state-of-the-art research topics in network security; threats and attacks, defense algorithms and mechanisms, measurement and evaluation of both security problems and solutions. Offered alternate years. Prereq: CIS 533.

CIS 640. Writing in Computer Research. 2 Credits.
Students learn to provide and accept constructive criticism of writing samples in a workshop format.

CIS 650. Software Engineering. 4 Credits.
Examines recent models and tools in software engineering including modifications to the traditional software life-cycle model, development environments, and speculative view of the future role of artificial intelligence.

CIS 670. Data Science. 4 Credits.
Data science is the development of methods to study large and complex data sets. Methods that scale to very large data sets are of particular interest. This course introduces state-of-the-art data science methods focused on processing very large data sets of real-world data. Prereq: CIS 451/CIS 551 Database Processing

Computer Information Technology Courses

CIT 281. Web Applications Development I. 4 Credits.
Fundamentals of web application development using open-source software tools and technologies (Unix, Git), client-side frameworks, server-side programming (Node.js, PHP), model-view-controller pattern, data storage and APIs, cloud hosting. Prereq: CIS 111 with a B- or higher.

CIT 381. Database Systems. 4 Credits.
Introduction to database systems, emphasis on database design and access. Database concepts, data modeling, SQL, connecting database to web. Prereq: B- or better in CIT 281, and CIS 110 or 115.

CIT 382. Web Applications Development II. 4 Credits.

CIT 383. Networking Fundamentals. 4 Credits.

CIT 405. Reading and Conference: [Topic]. 1-4 Credits.
Repeatable.