Computer Science

Ravi Mukkamala, Chair
Janet Brunelle, Chief Departmental Advisor

The Department of Computer Science (CS) offers programs leading to the Bachelor of Science in Computer Science (BSCS), Master of Science with a major in computer science, and Doctor of Philosophy with a major in computer science. A linked undergraduate to graduate option is available that leads to a Bachelor of Science in Computer Science and a Master of Science with a major in computer science. The BSCS courses are offered via traditional live lectures and distance learning options.

At the undergraduate level the Department of Computer Science jointly offers a program with the Department of Electrical and Computer Engineering in the College of Engineering and Technology leading to a Bachelor of Science in Computer Engineering. A linked undergraduate to graduate option is available that leads to Bachelor of Science in Computer Science and Master of Business Administration degrees. The CS department also supports the computer technology concentration of the Engineering Technology bachelor's degree and the Modeling, Simulation and Visualization Engineering bachelor's degree.

Computer science traces its foundation to mathematics, logic and engineering. Students in this program are exposed to the broad theoretical and practical basis of computer science in lectures and laboratory experiences. Through laboratories, students are introduced to both the experimental and the design aspects of computer science. Students may choose their electives to obtain an emphasis in databases and networking, web programming, systems programming, game programming, and cyber security.

The CS Department's curriculum applies computer science education to the real world. The Professional Workforce Development courses (CS 410 and CS 411W) expand upon the experimental and design approach of earlier courses by addressing the creativity and productivity required for business and industrial applications today. Faculty and industry representatives provide project concepts and mentor student teams in design and development of usable products.

Bachelor of Science in Computer Science

Curriculum Requirement

The Bachelor of Science in Computer Science requires the successful completion of a minimum of 120 semester credit hours of approved course work. At least 30 credit hours overall and 12 credit hours in upper-level courses in the major program must be completed at Old Dominion University. In order to gain appropriate exposure and competency in basic computer science theory and applications, students must satisfy the General Education requirements and the following departmental requirements.

Requirements

Lower-Division General Education

Skills

Written Communication * 6
ENGL 110C & ENGL 231C English Composition and Introduction to Technical Writing (preferred)

Mathematical Skills (satisfied in the major)

Oral Communication 3
COMM 101R Public Speaking (preferred)

Information Literacy and Research 3
CS 121G Introduction to Information Literacy and Research for Scientists (preferred)

Language and Culture (competence must be at the 102 level) 0-6
Ways of Knowing 3
Human Creativity 3
Literature 3

The Nature of Science ** 8
Human Behavior 3
Interpreting the Past 3
Philosophy and Ethics 3
Impact of Technology (satisfied in the major by CS 300T) 3

Total Hours 35-41

* Grade of C or better required in both courses
** Computer Science majors must complete two Nature of Science courses in sequence from the following:

BIOI 121N & BIOI 122N General Biology I and General Biology I Lab 4
BIOI 123N & BIOI 124N General Biology II and General Biology II Lab 4
BIOL 136N & BIOL 137N Honors General Biology I and Honors General Biology I Lab 4
BIOL 138N & BIOL 139N Honors General Biology II and Honors General Biology II Lab 4
CHEM 105N & CHEM 106N Introductory Chemistry and Introductory Chemistry Laboratory 4
CHEM 107N & CHEM 108N Introductory Organic and Biochemistry and Introductory Organic and Biochemistry Laboratory 4
CHEM 121N & CHEM 122N Foundations of Chemistry I Lecture and Foundations of Chemistry I Laboratory 4
CHEM 123N & CHEM 124N Foundations of Chemistry II Lecture and Foundations of Chemistry II Laboratory 4
OEAS 106N & OEAS 108N Introductory Oceanography and Understanding Global Climate Change 8
OEAS 110N Earth Science 4
OEAS 111N Physical Geology and
OEAS 112N Historical Geology 4
PHYS 101N & PHYS 102N Conceptual Physics and Conceptual Physics 8
PHYS 111N & PHYS 112N Introductory General Physics and Introductory General Physics 8
PHYS 231N & PHYS 232N University Physics I and University Physics 8

Upper-Division General Education

- Option A. Approved Disciplinary Minor (a minimum of 12 hours determined by the department), or second degree or second major.
- Option B: Interdisciplinary Minor (specifically 12 hours, 3 of which may be in the major)
- Option C. International Business and Regional Courses or an approved Certification Program such as teaching licensure
- Option D. Two Upper-Division Courses from outside the College of Sciences and not required by the major (6 hours)

In addition to completing the University's lower-division general education requirements and upper-division general education requirements, a computer science major must complete the following courses.

Required Computer Science Courses

CS 150 Problem Solving and Programming I 4
CS 170 Introduction to Computer Architecture I 3
CS 250 Problem Solving and Programming II 4
CS 252 Introduction to Unix for Programmers 1
CS 270 Introduction to Computer Architecture II 3
CS 300T Computers in Society 3
CS 330 Object-Oriented Programming and Design 3
CS 350 Introduction to Software Engineering 3
Elective Computer Science Courses

Three additional CS courses (9 credits) at the 300/400 level (excluding CS 333, CS 334 and CS 382).

Computer science majors may select their own electives from the CS offerings. Up to six credits of work experience (CS 367 or CS 368) may be used.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 312</td>
<td>Internet Concepts</td>
<td>3</td>
</tr>
<tr>
<td>CS 418</td>
<td>Web Programming</td>
<td>3</td>
</tr>
<tr>
<td>CS 431</td>
<td>Web Server Design</td>
<td>3</td>
</tr>
<tr>
<td>CS 441</td>
<td>App Development for Smart Devices</td>
<td>3</td>
</tr>
<tr>
<td>CS 450</td>
<td>Database Concepts</td>
<td>3</td>
</tr>
<tr>
<td>CS 451</td>
<td>Software Engineering Survey</td>
<td>3</td>
</tr>
<tr>
<td>CS 454</td>
<td>Network Management</td>
<td>3</td>
</tr>
<tr>
<td>CS 455</td>
<td>Introduction to Networks and Communications</td>
<td>3</td>
</tr>
<tr>
<td>CS 458</td>
<td>Unix System Administration</td>
<td>3</td>
</tr>
<tr>
<td>CS 460</td>
<td>Computer Graphics</td>
<td>3</td>
</tr>
<tr>
<td>CS 462</td>
<td>Cybersecurity Fundamentals</td>
<td>3</td>
</tr>
<tr>
<td>CS 463</td>
<td>Cryptography for Cybersecurity</td>
<td>3</td>
</tr>
<tr>
<td>CS 464</td>
<td>Networked Systems Security</td>
<td>3</td>
</tr>
<tr>
<td>CS 465</td>
<td>Information Assurance</td>
<td>3</td>
</tr>
<tr>
<td>CS 472</td>
<td>Network and Systems Security</td>
<td>3</td>
</tr>
<tr>
<td>CS 475</td>
<td>Introduction to Computer Simulation</td>
<td>3</td>
</tr>
<tr>
<td>CS 476</td>
<td>Systems Programming</td>
<td>3</td>
</tr>
<tr>
<td>CS 480</td>
<td>Introduction to Artificial Intelligence</td>
<td>3</td>
</tr>
<tr>
<td>CS 486</td>
<td>Introduction to Parallel Computing</td>
<td>3</td>
</tr>
<tr>
<td>CS 487</td>
<td>Applied Parallel Computing</td>
<td>3</td>
</tr>
<tr>
<td>CS 488</td>
<td>Principles of Compiler Construction</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours: 48

Other Required Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 211</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MATH 212</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MATH 316</td>
<td>Introductory Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>STAT 330</td>
<td>An Introduction to Probability and Statistics</td>
<td>3</td>
</tr>
<tr>
<td>Technical Electives *</td>
<td></td>
<td>6-8</td>
</tr>
</tbody>
</table>

Total Hours: 20-22

* Computer science majors must complete two courses not counted toward another degree requirement. These may be selected from biology, chemistry, ocean, earth and atmospheric sciences, and physics (excluding BIOL 105N-BIOL 106N, BIOL 110N, BIOL 111N, BIOL 112N, BIOL 113N, BIOL 117N, BIOL 118N, and PHYS 103N-PHY 104N). With the approval of a computer science advisor, other technically oriented courses may be used to meet this requirement.

Computer science majors must earn a grade of C or better in all (non-elective) computer science courses required for the major and in all computer science prerequisite courses. A minimum of 9 credits of upper-level (300/400) computer science elective courses must be completed in addition to the required courses.

Requirements for Graduation

Requirements for graduation include a minimum cumulative grade point average of 2.00 overall and in the major, 120 credit hours, which must include both a minimum of 30 credit hours overall and 12 credit hours in upper-level courses in the major program from Old Dominion University, passage of the Computer Science Exit Exam, completion of ENGL 110C, ENGL 211C or ENGL 221C or ENGL 231C, and the writing intensive (W) course in the major with a grade of C or better, and completion of a Senior Assessment. Additional hours may be required to meet the foreign language requirement.

Honors Program

Students may obtain a Bachelor of Science in Computer Science with an honors designation through the completion of three junior/senior level computer science courses with honors designation and by achieving a 3.50 in-major GPA.

Advanced Placement

The Department of Computer Science awards credit for CS 133 to students who achieve a score of 3, 4, or 5 on the AP Computer Science A or AB exams or a 5, 6, or 7 on the IB Computer Science exams.

Cooperative Education

Computer science majors interested in gaining practical experience and on-the-job training while completing undergraduate degree requirements may find opportunities through participation in the Cooperative Education Program.

Those students usually start in the junior year working with an employer in a field of computer science. Students must apply through Career Development Services prior to registering for Cooperative Education credit. All work experiences must be approved by Career Development Services and the academic department concerned.

Undergraduates can earn a maximum of six semester credits through cooperative education that apply toward degree requirements. For further information, see the Career Development Services section of this Catalog.

Computer Science Add-on Endorsement for Professional Education Licensure

A person licensed by the Commonwealth of Virginia to teach in secondary schools may add an endorsement for computer science by completing this program. The required courses are:

<table>
<thead>
<tr>
<th>Course</th>
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<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>CS 150</td>
<td>Problem Solving and Programming I</td>
<td>4</td>
</tr>
<tr>
<td>CS 170</td>
<td>Introduction to Computer Architecture I</td>
<td>3</td>
</tr>
<tr>
<td>CS 250</td>
<td>Problem Solving and Programming II</td>
<td>4</td>
</tr>
<tr>
<td>CS 252</td>
<td>Introduction to Unix for Programmers</td>
<td>1</td>
</tr>
<tr>
<td>CS 312</td>
<td>Internet Concepts</td>
<td>3</td>
</tr>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design</td>
<td>3</td>
</tr>
<tr>
<td>CS 355</td>
<td>Principles of Programming Languages</td>
<td></td>
</tr>
<tr>
<td>CS 361</td>
<td>Advanced Data Structures and Algorithms</td>
<td>3</td>
</tr>
<tr>
<td>CS 381</td>
<td>Introduction to Discrete Structures</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours: 24

For more information, refer to the Darden College of Education section of this Catalog.

Bachelor of Science in Computer Engineering

The computer engineering undergraduate degree program is designed to provide both a broad engineering background and comprehensive foundation in the technical principles underlying the computer area. Students develop
a background through course work in mathematics, the basic sciences, and general engineering. The technical core consists of courses from electrical and computer engineering to address hardware aspects of computer engineering and course work from computer science to address software aspects. A grade of C or better must be earned in computer science required courses. In addition, course work in General Education perspectives and communication skills is required to assure a well rounded program of study. Specific degree requirements can be found listed under the Department of Electrical and Computer Engineering.

Due to limited laboratory facilities, admission to the computer engineering program is on a competitive basis. Students should apply to the Department of Electrical and Computer Engineering.

**Bachelor of Science in Engineering Technology with a Concentration in Computer Engineering Technology**

The goal of the computer engineering technology program is to prepare students for employment in areas defined by the rapidly expanding opportunities of computer applications. With new hardware and software products being introduced monthly, students who wish to succeed in this field should develop a background in both software and hardware. This program provides such a background by combining a grounding in basic theory with hands-on, application courses selected from the disciplines of Computer Science and Electrical Engineering Technology. The curriculum emphasizes practical design and the utilization of systems and hardware. Areas of concentration include network design and management, modern communication systems, microcomputer systems and applications, and application program development. A grade of C or better must be earned in computer science required courses. Specific degree requirements can be found listed under the Department of Engineering Technology.

**Minor in Computer Science**

Students may minor in computer science by taking the following courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 150</td>
<td>Problem Solving and Programming I</td>
<td>4</td>
</tr>
<tr>
<td>CS 250</td>
<td>Problem Solving and Programming II</td>
<td>4</td>
</tr>
<tr>
<td>CS 252</td>
<td>Introduction to Unix for Programmers</td>
<td>1</td>
</tr>
<tr>
<td>CS 361</td>
<td>Advanced Data Structures and Algorithms</td>
<td>3</td>
</tr>
<tr>
<td>or CS 330</td>
<td>Object-Oriented Programming and Design</td>
<td></td>
</tr>
</tbody>
</table>

Select two CS Electives at the 400-level or from the following: 6

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 312</td>
<td>Internet Concepts</td>
<td></td>
</tr>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design</td>
<td></td>
</tr>
<tr>
<td>CS 355</td>
<td>Principles of Programming Languages</td>
<td></td>
</tr>
<tr>
<td>CS 361</td>
<td>Advanced Data Structures and Algorithms</td>
<td></td>
</tr>
<tr>
<td>CS 350</td>
<td>Introduction to Software Engineering</td>
<td></td>
</tr>
<tr>
<td>CS 381</td>
<td>Introduction to Discrete Structures</td>
<td></td>
</tr>
<tr>
<td>CS 390</td>
<td>Introduction to Theoretical Computer Science</td>
<td></td>
</tr>
</tbody>
</table>

Total Hours 18

A grade of C or better is required in each course. Students must also meet the University’s requirements for a minor as described under Requirements for Undergraduate Degrees.

The curriculum for the Bachelor of Science in Engineering Technology with an emphasis in computer engineering technology and the Bachelor of Science in Computer Engineering contain a built-in minor in computer science.

**Minor in Web Programming**

Students may minor in Web Programming by taking the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design</td>
<td>3</td>
</tr>
<tr>
<td>CS 418</td>
<td>Web Programming</td>
<td>3</td>
</tr>
</tbody>
</table>

Select two of the following: 6

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 321</td>
<td>Internet Concepts</td>
<td></td>
</tr>
<tr>
<td>CS 431</td>
<td>Web Server Design</td>
<td></td>
</tr>
<tr>
<td>CS 432</td>
<td>Web Science</td>
<td></td>
</tr>
<tr>
<td>CS 441</td>
<td>App Development for Smart Devices</td>
<td></td>
</tr>
<tr>
<td>CS 462</td>
<td>Cybersecurity Fundamentals</td>
<td></td>
</tr>
<tr>
<td>CS 465</td>
<td>Information Assurance</td>
<td></td>
</tr>
</tbody>
</table>

Total Hours 12

* CS 252 and CS 333 are prerequisites and are not included in the calculation of the grade point average for the minor.

A grade of C or better is required in any of these courses if they are used as a prerequisite to any other CS course. Students must also meet the University’s requirements for a minor as described under Requirements for Undergraduate Degrees.

**Linked Bachelor of Science in Computer Science and Master of Business Administration**

This program allows students to earn a Bachelor of Science in Computer Science and a Master of Business Administration. After students have satisfactorily completed their undergraduate requirements, they must complete the remaining requirements in the MBA program.

Additional information can be found in the section on B.S./M.B.A. Linked Program listed at the beginning of the College of Sciences section of this Catalog. Students interested in this program should contact the MBA Program as early as possible. The MBA Program manager will act as an advisor to the student in addition to the Computer Science advisor.

**Linked Bachelor of Science in Computer Science and Master of Science in Computer Science**

This program allows exceptionally successful students to earn both a bachelor's and master's degree in computer science. Up to 12 credits of graduate coursework may be counted toward both their undergraduate and master's degrees in computer science. Students must earn a minimum of 150 credit hours (120 for the undergraduate degree and 30 for the graduate degree).

**Admission**

To be admitted to the linked program, students must have completed at least 60 undergraduate credit hours with at least 24 credit hours from ODU. Students must have completed CS 361, CS 381, MATH 212 and all prerequisites for those courses. At the time of admission, they must have an overall GPA of 3.00 or better, and an overall GPA of 3.00 or better in CS and MATH courses.

Interested students who meet the admission requirements should apply to the graduate program director, after consulting with the undergraduate chief departmental advisor, as soon as possible upon completing the required courses and 60 credit hours. In consultation with the graduate program director, a student will:

1. Officially declare an undergraduate Computer Science major with the undergraduate chief departmental advisor.
2. Draft a schedule of graduate courses to be taken as an undergraduate to be presented to the undergraduate chief departmental advisor.
3. Apply, during their senior year, to the Office of Graduate Admissions for admission to the master's in computer science program.

Students who have completed at least six hours of graduate courses upon attaining senior standing (completion of 90 credit hours) and who have earned a GPA of 3.00 or better in those courses will not be required to take the Graduate Record Exam (GRE) for admission to the master's program. Otherwise, in keeping with normal admission requirements for the M.S. in
computer science, students will take the GRE as an undergraduate and will subsequently be reevaluated for continuation into the master's program.

Once students have been awarded their bachelor's degree and fulfilled all regular admission requirements for the M.S. in computer science, they will be officially admitted into the M.S. program.

Program Requirements

Students in the program will fulfill all normal admission and curricular requirements for both a Bachelor of Science in Computer Science and an M.S. in computer science with the following exceptions:

1. Students in the program may count up to 12 hours of graduate courses, at the 500 or 600 level, excluding independent study, taken as an undergraduate toward both the bachelor's and master's degrees in computer science.
   a. Students in the program may substitute computer science graduate courses for undergraduate courses according to the following schema. All students must complete an undergraduate writing intensive course in the major.
   b. Students will not receive credit for both the 400 and 500 level version of the same course.
   c. Students in the program may make a written petition for other substitutions to the graduate program director, who will consider them in consultation with the chief departmental advisor and the instructor(s) of the courses involved.

NOTES:

1. In accordance with University policy, up to 21 hours of graduate courses taken as an undergraduate may be counted toward the bachelor's degree in computer science. However, only 12 hours of graduate courses taken as an undergraduate may also be counted toward the M.S. degree in computer science. This will limit students' scheduling flexibility subsequently.

2. Like students in the regular M.S. in computer science program, students in the linked B.S.C.S./M.S. computer science degree may count no more than 12 hours at the 500-level toward their M.S. degree. Students are advised against taking all 12 of those 500-level credits as an undergraduate, since doing so will limit their scheduling flexibility subsequently.

Computing Facilities

The Computer Science Department at Old Dominion University offers a wide array of facilities, resources, and services to our faculty, staff, students and guests. Assets are distributed between Dragas Hall and the Engineering and Computational Sciences Building (E&CS). This system architecture enables our services to be configured in a redundant/highly-available manner. This stability and resiliency is essential to maintaining a high level of service to over 2,300 users.

The E&CS building is home to our primary data-center and main administrative office. It also houses several of our research labs, a multimedia conference room, and our network operations center. Dragas Hall contains several instructional and research labs, our satellite administrative office, secondary conference room, redundant data-center, extended network operations center, and support staff offices.

The department offers a heterogeneous computing environment that primarily consists of Windows and *nix based workstations and servers. On the Windows domain, users are offered network logons, Exchange email, terminal services via our Virtual Computing Lab (VCLab) where users can have access to our software remotely, roaming profiles, MSSQL database access for research, and Hyper-V virtualization for research/faculty projects. For Unix and Linux users we support Solaris, Ubuntu and Red Hat Enterprise Linux (RHEL) distributions. Our *nix services include DNS, NIS, Unix mail, access to personal MySQL databases, class and research project Oracle databases, and both Linux and Unix servers for secure shell sessions.

COMPUTER SCIENCE Courses

CS 112. Information Literacy for Former Engineering Majors. 1 Credit.
The objective of this course is to enhance the ability of students to locate, manage, critically evaluate, and use information for problem solving, research, and decision making in a complex digital world. Emphasis in this course will be on information security, laws, regulations, institutional policies and ethical issues surrounding the access and use of information. Prerequisites: CEE 111 or ECE 111 or ENGT 111 or MAE 111 or MSIM 111.

CS 120G. Introduction to Information Literacy and Research. 3 Credits.
Students will learn to locate, manage, critically evaluate and use information for problem solving, research and decision making. Includes collaborative tools for document development and office productivity tools for presentation. Information security, laws and etiquette related to use and access of information are covered.

CS 121G. Introduction to Information Literacy and Research for Scientists. 3 Credits.
Students will learn to locate, manage, critically evaluate and use information for scientific problem solving and research. Includes mathematical tools for data analysis and presentation and office and collaborative tools, as well. Information security, laws and etiquette related to use and access of information are covered.

CS 126G. Honors: Introduction to Information Literacy and Research. 3 Credits.
Open only to students in the Honors College. A special honors version of CS 120G.

CS 133. Introduction to Programming in Java. 4 Credits.
Laboratory work required. Introduction to computer-based problem solving and programming in Java. Topics include problem solving methodologies, program design, algorithm development, and testing. Java language concepts include variables, data types and expressions, assignment, control-flow statements, functions, arrays, and classes. Algorithms covered include sorting, searching, and linked list manipulations. Prerequisite: MATH 102M or MATH 103M.

CS 150. Problem Solving and Programming I. 4 Credits.
Laboratory work required. Introduction to computer-based problem solving and programming in C++. Topics include problem solving methodologies, program design, algorithm development, and testing. C++ language concepts include variables, data types and expressions, assignment, control-flow statements, functions, arrays, pointers, structs, and classes. Prerequisite: MATH 102M or MATH 103M or equivalent.

CS 170. Introduction to Computer Architecture I. 3 Credits.
Fundamentals of the architecture and operation of modern computers. Basic computer logic: logic equations; gates; combinatorial logic. Basic computer arithmetic: binary numbers; floating point representation. System hierarchy, overview of a computer; integrated circuit technology. Performance: metrics; choosing benchmarks; Amdahl's law. Instruction Sets and Operations: assembly language; machine language; examples of other instruction sets. Prerequisite: MATH 102M or MATH 103M and a grade of C or better in CS 150.

CS 195. Topics. 1-3 Credits.
Special topics in computer science that are not part of the current curriculum at the freshman/sophomore level.

CS 250. Problem Solving and Programming II. 4 Credits.
Laboratory work required. Design issues arising in software systems and C++ programming techniques aiding in their solution. Topics include the software life cycle, methods of functional decomposition, design documentation, abstract data types and classes, common data structures, dynamic data structures, algorithmic patterns, and testing and debugging techniques. Term project required. Prerequisites: MATH 162M and a grade of C or better in CS 150. Corequisite: CS 252.
CS 252. Introduction to Unix for Programmers. 1 Credit.
Laboratory work required. Available for pass/fail grading only. An introduction to Unix with emphasis on the skills necessary to be a productive programmer in Unix, Linux, and related environments. Topics include command line shells, files and directories, editing, compiling and common command line utilities. Prerequisites: A grade of C or better in CS 150, CS 333, or IT 205.

CS 270. Introduction to Computer Architecture II. 3 Credits.
Fundamentals of the architecture and operation of modern computers. Building an ALU. The cache-Ram interaction. The virtual memory system. The Fetch/Execute cycle. Implementing a set of the ALU. Load/Store and Branch instructions in a single cycle implementation. Basics of microprogramming. Design of the control unit. A pipelined implementation. Multicores, multiprocessors and clusters. Prerequisites: A grade of C or better in CS 170 and in either CS 150 or CS 333.

CS 295. Topics in Computer Science. 1-3 Credits.
Special topics in computer science which are not part of the current curriculum at the freshman/sophomore level.

CS 300T. Computers in Society. 3 Credits.
Covers changes in the world's society due to continuing implementation of computing technologies. Evaluation of technological expansions in areas of governments, business/industry, education, medicine, transportation, communication and entertainment. Topics include: intellectual property, software piracy, computer crimes and ethics. Students must research a societal topic and present in written and oral forms. Prerequisites: ENGL 110C.

CS 312. Internet Concepts. 3 Credits.
Laboratory work required. An in-depth introduction to the Internet and the World Wide Web for CS or similar majors as a basis for more advanced studies in Web programming. Topics include: historical and current development of the Internet Web document publishing. Internet design, communication, and application protocols and the tools that use them. Internet search tools and their design. Internet issues such as netiquette, copyright, spam, computer viruses, cookies, security, and future of the Internet. Prerequisites: CS 252.

CS 330. Object-Oriented Programming and Design. 3 Credits.
Laboratory work required. The techniques and idioms of object-oriented programming in C++ and Java. Methods of object-oriented analysis and design with the Unified Modeling Language. Multi-thread programs and synchronization. Prerequisites: MATH 163, CS 252 and a grade of C or better in CS 250 or CS 333.

CS 333. Programming and Problem Solving in C++. 4 Credits.
Laboratory work required. Topics include C++ syntax and semantics, principles of design and basic software engineering skills. This course satisfies the requirements of both CS 150 and 250. It is intended for the student who has already been introduced to programming, possibly in another language. This web-based course requires considerable maturity and independent responsibility on the part of the student. Prerequisites: MATH 163 and a grade of C or better in CS 150 or IT 210 (or an equivalent course in a high level language). Corequisite: CS 252.

CS 334. Computer Architecture Fundamentals. 4 Credits.
Topics include: number representation, base conversion, Boolean algebra, combinatorial circuits, arithmetic units, registers, memory, hardwired and microprogrammed control units, architecture of typical microcomputers, and the development of systems from basic components. The performance of competing architectures will be a major concern. This course satisfies the requirements of both CS 170 and CS 270. This web-based course requires considerable maturity and independent responsibility on the part of the student. Prerequisites: MATH 163 and a grade of C or better in CS 150 (or an equivalent course in a high level language).

CS 350. Introduction to Software Engineering. 3 Credits.
Laboratory work required. An exploration of the software development process, with an emphasis on the tools and techniques that support project teams. Topics include: software development process models, requirements, automated testing, documentation, build, version and configuration management, issue tracking, and agile methods. The course requires each student to participate as a member of a project team and to demonstrate proficiency with a variety of development tools. Prerequisites: CS 252 and a grade of C or better in CS 330 or CS 361.

CS 355. Principles of Programming Languages. 3 Credits.
Survey of significant features of programming languages. Language types including imperative, functional, logical, and object-oriented are covered. Concepts include lexical and syntactic analysis, type systems, flow control, modularity, and parallel programming. Small programs in several languages required. Laboratory work required. Prerequisites: CS 252 and a grade of C or better in CS 250 or CS 333.

CS 361. Advanced Data Structures and Algorithms. 3 Credits.
Laboratory work required. Common abstract data types, including vectors, lists, stacks, queues, sets, maps, heaps, and graphs. Standard C++ interfaces for these ADTs. Generic programming via iterators and templates. Choosing data structures and algorithms to implement ADTs, via analysis of their time and space complexity. Prerequisites: MATH 163, CS 252 and a grade of C or better in CS 250 or CS 333.

CS 367. Cooperative Education. 1-3 Credits.
Available for pass/fail grading only. Student participation for credit based on the academic relevance of the work experience, criteria, and evaluative procedures as formally determined by the department and Career Development Services prior to the semester in which the work experience is to take place. Written report required. (qualifies as a CAP experience) Prerequisites: approval by the CS Department and Career Development Services in accordance with the policy for granting credit for Cooperative Education programs.

CS 386. Computer Science Internship. 1-3 Credits.
Available for pass/fail grading only. Academic requirements will be established by the department and will vary with the amount of credit desired. Allows students to gain short duration career-related experience. An academic project may be required by the department to enhance the value of the educational experience. Written report required. (qualifies as a CAP experience) Prerequisites: approval by CS Department and Career Development Services.

CS 381. Introduction to Discrete Structures. 3 Credits.
Topics include propositional and predicate logic, rules of inference, methods of proof, set operations, functions, complexity of algorithms, growth of functions, induction, counting, relations, equivalence relations and graphs. Prerequisites: MATH 163 and a grade of C or better in CS 150 or CS 333.

CS 382. Introduction to JAVA. 1 Credit.
Laboratory work required. An introduction to the Java programming language for students who are familiar with programming in C++. Topics include basic language syntax, data structures, control flow, classes, exception handling, and basic elements of the Java API. This web-based class requires independent responsibility and online communication skills on the part of the student. Prerequisites: A grade of C or better in CS 250 or CS 333.

CS 390. Introduction to Theoretical Computer Science. 3 Credits.
Elementary study of theoretical aspects of computer science. Topics in formal languages and automata theory are covered including regular languages, regular expressions, finite automata, context-free languages, pushdown automata, grammars, Turing machines, and unsolvable problems. Prerequisites: A grade of C or better in CS 381 and CS 250 or CS 333.

CS 395. Topics in Computer Science. 1-3 Credits.
Special topics. Prerequisites: permission of the instructor.
CS 410/510. Professional Workforce Development I, 3 Credits.
Laboratory work required. Provides students with challenges of business environments in developing a technology based project. Students identify a societal problem, identify solutions, define project solutions, develop project objectives, conduct feasibility analysis, establish organizational group structure to meet project objectives and develop formal specifications. Students make formal technical project presentations and develop web documentation. Students prepare a draft grant proposal. Prerequisites: A grade of C or better in CS 300T and CS 350.

CS 411W/511. Professional Workforce Development II, 3 Credits.
Laboratory work required. Students write professional and non-technical documents and continue the development of the project defined in CS 410. Written work is reviewed and returned for corrective rewriting. Students will design and develop a project prototype, and demonstrate the prototype to a formal panel along with delivering the formal product specifications and a draft formal grant proposal. (qualifies as a CAP experience) (This is a writing intensive course.) Prerequisites: A grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C and a grade of C or better in CS 330 and CS 410.

CS 417/517. Computational Methods and Software, 3 Credits.
Laboratory work required. Algorithms and software for fundamental problems in scientific computing. Topics: properties of floating point arithmetic, linear systems of equations, matrix factorizations, stability of algorithms, conditioning of problems, least-squares problems, eigenvalue computations, numerical integration and differentiation, nonlinear equations, iterative solution of linear systems. Prerequisites: MATH 316 and a grade of C or better in CS 250 or CS 333.

CS 418/518. Web Programming, 3 Credits.
Laboratory work required. Overview of Internet and World Wide Web; web servers and security, HTTP protocol; web application and design; server side scripts and database integration, and programming for the Web. Prerequisites: A grade of C or better in CS 312 and CS 330.

CS 431/531. Web Server Design, 3 Credits.
Laboratory work required. Extensive coverage of the hypertext transfer protocol (HTTP), specifications and commentary (IETF RFCs), and implications for servers and clients. Students will develop a web server providing common HTTP functionality and implementing all HTTP (including unsafe and conditional) methods, content negotiation, transfer and content encoding, basic & digest authentication, and server-side execution of programs (i.e., dynamic resources). Frequent in-class demonstrations of progress and protocol conformance will be required. Prerequisites: CS 150, familiarity with Internet and network (including socket) programming.

CS 432/532. Web Science, 3 Credits.
Provides an overview of the World Wide Web and associated decentralized information structures, focusing mainly on the computing aspects of the Web: how it works, how it is used, and how it can be analyzed. Students will examine a number of topics including: web architecture, web characterization and analysis, web archiving, Web 2.0, social networks, collective intelligence, search engines, web mining, information diffusion on the web, and the Semantic Web. Prerequisites: A grade of C or better in CS 361 and CS 330.

CS 441/541. App Development for Smart Devices, 3 Credits.
Laboratory work required. Project-oriented coverage of the principles of application design and development for Android platform smart devices. Topics include user interface; input methods; data handling; network techniques; localization and sensing. Students are required to produce a professional-quality mobile application. Prerequisite: CS 330 or CS 382.

CS 450/550. Database Concepts, 3 Credits.
Laboratory work required. Three level database architecture. The relational database model and relational algebra. SQL and its use in database procedures and with conventional programming languages. Entity relationship modeling. Functional dependencies and normalization. Transactions, concurrency and recovery. Prerequisites: CS 252 and a grade of C or better in CS 381 and either CS 330 or CS 361.

CS 451/551. Software Engineering Survey, 3 Credits.
Laboratory work required. Evaluation of software development methodologies. Topics include: software life cycle models, software specification and design methodologies, informal specification techniques, formal specifications, design tools, software analysis, quality assurance, life cycle management, software costing models and complexity. Prerequisites: A grade of C or better in CS 330 or CS 361.

CS 454/554. Network Management, 3 Credits.
Laboratory work required. The administration of computer networks and their interaction with wide area networks: network topologies for local and wide area networks, common protocols and services, management of distributed file services, routing and configuration, security, monitoring and trouble-shooting. Prerequisites: A grade of C or better in CS 455.

CS 455/555. Introduction to Networks and Communications, 3 Credits.
Internet and the 5-layered protocol architecture for the Internet, applications built on top of data networks, specifically the Internet, the web, the transport layer, TCP and UDP protocols, the network layer, the data link layer, also some of the technologies for the physical layer. Prerequisites: CS 250 or CS 333, CS 252, CS 270.

CS 458/558. Unix System Administration, 3 Credits.
Laboratory work required. Aspects of administering a SOLARIS/UNIX operating system in a networked environment are covered. Topics covered include installation, file system management, backup procedures, process control, user administration, device management, Network File Systems (NFS), Network Information Systems (NIS), UNIX security, Domain Name Services (DNS), and integration with other operating systems. Prerequisites: experience with UNIX.

CS 460/560. Computer Graphics, 3 Credits.
Laboratory work required. An introduction to graphical systems and methods. Topics include basic primitives, windowing, transformations, hardware, interaction devices, 3-D graphics, curved surfaces, solids, and realism techniques such as visible surface, lighting, shadows, and surface detail. Requires project involving OpenGL programming. Prerequisites: A grade of C or better in CS 361.

CS 462/562. Cybersecurity Fundamentals, 3 Credits.
Introduction to networking and the Internet protocol stack; Vulnerable protocols such as HTTP, DNS, and BGP; Overview of wireless communications, vulnerabilities, and security protocols; Introduction to cryptography; Discussion of cyber threats and defenses; Firewalls and IDS/IPS; Kerberos; Transport Layer Security, including certificates; Network Layer Security. Prerequisites: MATH 162M.

CS 463/563. Cryptography for Cybersecurity, 3 Credits.
This course covers mathematical foundations, including information theory, number theory, factoring, and prime number generation; cryptographic protocols, including basic building blocks and protocols; cryptographic techniques, including key generation and key management, and applications; and cryptographic algorithms—DES, AES, stream ciphers, hash functions, digital signatures, etc. Prerequisites: MATH 162M.

CS 464/564. Networked Systems Security, 3 Credits.
Authentication in cyber systems including password-based, address-based, biometrics-based, and SSO systems; Authorization and accounting in cyber systems; Securing wired and wireless networks; Secured applications including secure e-mail services, secure web services, and secure e-commerce applications; Security and privacy in cloud environments. Prerequisites: MATH 162M.

CS 465/565. Information Assurance, 3 Credits.
Introduction to information assurance. Topics to be covered include metrics, planning and deployment; identity and trust technologies; verification and evaluation, and incident response; human factors; regulation, policy languages, and enforcement; legal, ethical, and social implications; privacy and security trade-offs; system survivability; intrusion detection; and fault and security management. Prerequisites: MATH 162M and familiarity with computer security area.
CS 471. Operating Systems. 3 Credits.
Laboratory work required. Operating system structures. Multiprogramming and multiprocessing. Process management. Memory and other resource management. Storage management. I/O systems, distributed systems. Protection and security. The concepts will be illustrated through example systems such as Unix and Windows. Prerequisites: A grade of C or better in CS 270 and CS 361.

CS 472. Network and Systems Security. 3 Credits.
Laboratory work required. Basic protocols, techniques and programming issues to secure network and computer systems. Topics include: cryptographic algorithms and concepts (Secret Key Cryptography, Hashes and Message Digests, Public Key and Authentication); Security Standards (Kerberos, Public Key Infrastructure, IPsec, SSL/TLS); Security applications (PEM, S/MIME, PGP, HTTP, Firewalls); Hands-on programming using OpenSSL. Prerequisites: A grade of C or better in CS 361.

CS 475/575. Introduction to Computer Simulation. 3 Credits.
Laboratory work required. Efficient implementation methods. Time management. Planning and design of simulation experiments. Statistical issues in simulation. Generation of random numbers and stochastic variates. Programming with graphically- and text-based simulation languages. Verification and validation of simulation models. Distributed simulation. Special topics such as HLA will be discussed. Prerequisites: STAT 330 and a grade of C or better in CS 330 or CS 361.

CS 476/576. Systems Programming. 3 Credits.
Laboratory work required. This course is to help students fully understand and utilize the internal workings and capabilities provided by modern computing, networking and programming environments. Topics include: Shell Script Programming, X Windows (Xlib and Motif), UNIX internals (I/O, Processes, Threads, IPC and Signals), Network Programming (UDP/TCP Sockets and Multicasting) and Java Systems Programming (SWING, Multithreading and Networking). Prerequisites: A grade of C or better in CS 330 and CS 361.

CS 478/578. Computational Geometry, Methods and Applications. 3 Credits.
The discipline of Computational Geometry is devoted to the study of algorithms which are formulated in terms of spatially embedded arrangements of objects, such as points, lines, surfaces, and solids. This course covers fundamental algorithms including convex hulls, polygon triangulations, point location, Voronoi diagrams, Delaunay triangulations, binary space partitions, quad trees, and other topics. Prerequisites: CS 361 and MATH 211.

CS 480/580. Introduction to Artificial Intelligence. 3 Credits.
Laboratory work required. Introduction to concepts, principles, challenges, and research in major areas of AI. Areas of discussion include: natural language and vision processing, machine learning, machine logic and reasoning, robotics, expert and mundane systems. Prerequisites: A grade of C or better in CS 361.

CS 486/586. Introduction to Parallel Computing. 3 Credits.

CS 487. Applied Parallel Computing. 3 Credits.
Laboratory work required. Fundamental concepts of parallel computing: Machine models, architectures, parallel topologies and languages, parallel algorithm design and parallel programming, architecture independent message passing interface (MPI) communication library, and scaled-speedup. Group project required. Prerequisites: A grade of C or better in CS 270 and either CS 361 or CS 330; CS 417 or linear algebra is recommended.