Computer Science

Ravi Mukkamala, Chair
Soad Ibrahim, Chief Departmental Advisor
Ayman El Mesalami, Undergraduate Program Director

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. Students can also earn a degree of Bachelor of Science in Computer Science with Teaching Licensure, which is intended for those who wish to pursue a career in teaching computer science at the high school level and leads to teaching licensure in the Commonwealth of Virginia. 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, and 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 data 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 supports the computer technology concentration of the Engineering Technology bachelor's degree and the modeling and simulation engineering major in the Computer Engineering bachelor's degree. The CS department also supports the Bachelor of Science degree with majors in cybersecurity and in cyber operations.

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 data science, machine learning, databases, networking, web programming, systems programming, game programming, and cybersecurity.

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.

Four-Year Plan - Computer Science - BSCS (http://catalog.odu.edu/undergraduate/collegeofsciences/computerscience/computersc-bscs-fouryearplan/)

- The four-year plan is a suggested curriculum to complete this degree program in four years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.

Requirements
Lower-Division General Education

<table>
<thead>
<tr>
<th>Skills</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written Communication*</td>
<td>6</td>
</tr>
<tr>
<td>ENGL 110C English Composition</td>
<td></td>
</tr>
<tr>
<td>&amp; ENGL 231C and Introduction to Technical and Scientific Writing (preferred)</td>
<td></td>
</tr>
<tr>
<td>Mathematical Skills (satisfied in the major)</td>
<td></td>
</tr>
<tr>
<td>Oral Communication</td>
<td>3</td>
</tr>
<tr>
<td>COMM 101R Public Speaking</td>
<td></td>
</tr>
<tr>
<td>Information Literacy and Research</td>
<td>3</td>
</tr>
<tr>
<td>CS 121G Introduction to Information Literacy and Research for Scientists</td>
<td></td>
</tr>
<tr>
<td>or CS 202G Information Literacy for Cybersecurity</td>
<td></td>
</tr>
<tr>
<td>Language and Culture (competence must be at the 102 level)</td>
<td>0-6</td>
</tr>
</tbody>
</table>

Ways of Knowing

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Creativity</td>
<td>3</td>
</tr>
<tr>
<td>Literature</td>
<td>3</td>
</tr>
<tr>
<td>The Nature of Science</td>
<td>8</td>
</tr>
<tr>
<td>Human Behavior</td>
<td>3</td>
</tr>
<tr>
<td>Interpreting the Past</td>
<td>3</td>
</tr>
<tr>
<td>Philosophy and Ethics</td>
<td>3</td>
</tr>
<tr>
<td>Impact of Technology</td>
<td></td>
</tr>
</tbody>
</table>

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 for a total of eight credits from the following:

| BIOL 121N General Biology I | 4 |
| & BIOL 122N General Biology I Lab | |
| BIOL 123N General Biology II | 4 |
| & BIOL 124N General Biology II Lab | |
| BIOL 136N Honors General Biology I | 4 |
| & BIOL 137N Honors General Biology I Lab | |
| BIOL 138N Honors General Biology II | 4 |
| & BIOL 139N Honors General Biology II Lab | |
| CHEM 105N Introductory Chemistry | 4 |
| & CHEM 106N Introductory Chemistry Laboratory | |
| CHEM 107N Introductory Organic and Biochemistry | 4 |
| & CHEM 108N Introductory Organic and Biochemistry Laboratory | |
| CHEM 121N Foundations of Chemistry I Lecture | 4 |
| & CHEM 122N Foundations of Chemistry I Laboratory | |
| CHEM 123N Foundations of Chemistry II Lecture | 4 |
| & CHEM 124N Foundations of Chemistry II Laboratory | |
| OEAS 106N Introductory Oceanography | 8 |
| & OEAS 108N and Understanding Global Climate Change | |
| OEAS 106N Introductory Oceanography | 8 |
| & OEAS 250N and Natural Hazards and Disasters | |
| OEAS 126N Honors: Introductory Oceanography | 8 |
| & OEAS 108N and Understanding Global Climate Change | |
| OEAS 126N Honors: Introductory Oceanography | 8 |
| & OEAS 250N and Natural Hazards and Disasters | |
| PHYS 111N Introductory General Physics | 8 |
| & PHYS 112N and Introductory General Physics | |
| PHYS 226N Honors: University Physics I | 8 |
| & PHYS 227N and Honors: University Physics II | |
| PHYS 231N University Physics I | 8 |
| & PHYS 232N and University Physics II | |
**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. 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**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</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 270</td>
<td>Introduction to Computer Architecture II</td>
<td>3</td>
</tr>
<tr>
<td>CS 315</td>
<td>Computer Science Undergraduate Colloquium*</td>
<td>1</td>
</tr>
<tr>
<td>or CS 115</td>
<td>Introduction to Computer Science with Python</td>
<td></td>
</tr>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design</td>
<td>3</td>
</tr>
<tr>
<td>CS 350</td>
<td>Introduction to Software Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CS 355</td>
<td>Principles of Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>CS 361</td>
<td>Data Structures and Algorithms</td>
<td>3</td>
</tr>
<tr>
<td>CS 381</td>
<td>Introduction to Discrete Structures</td>
<td>3</td>
</tr>
<tr>
<td>CS 390</td>
<td>Introduction to Theoretical Computer Science</td>
<td>3</td>
</tr>
<tr>
<td>CS 410</td>
<td>Professional Workforce Development I</td>
<td>3</td>
</tr>
<tr>
<td>CS 411W</td>
<td>Professional Workforce Development II</td>
<td>3</td>
</tr>
<tr>
<td>CS 417</td>
<td>Computational Methods and Software</td>
<td>3</td>
</tr>
<tr>
<td>CS 450</td>
<td>Database Concepts (or)</td>
<td>3</td>
</tr>
<tr>
<td>or CS 418</td>
<td>Web Programming</td>
<td>3</td>
</tr>
<tr>
<td>CS 471</td>
<td>Operating Systems</td>
<td>3</td>
</tr>
</tbody>
</table>

**Total Hours** 49

* Students who complete CS 115 do not need to complete CS 315. Both may be taken.

**Elective Computer Science Courses**

Four additional CS courses (12 credits) at the 300/400 level (excluding CS 300T, CS 315 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.

Select four courses from the following: 12

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 312</td>
<td>Internet Concepts</td>
</tr>
<tr>
<td>CS 402</td>
<td>Formal Software Foundations</td>
</tr>
<tr>
<td>CS 418</td>
<td>Web Programming</td>
</tr>
<tr>
<td>CS 422</td>
<td>Introduction to Machine Learning</td>
</tr>
<tr>
<td>CS 431</td>
<td>Web Server Design</td>
</tr>
<tr>
<td>CS 432</td>
<td>Web Science</td>
</tr>
<tr>
<td>CS 441</td>
<td>App Development for Smart Devices</td>
</tr>
<tr>
<td>CS 450</td>
<td>Database Concepts</td>
</tr>
<tr>
<td>CS 454</td>
<td>Network Management</td>
</tr>
<tr>
<td>CS 455</td>
<td>Introduction to Networks and Communications</td>
</tr>
<tr>
<td>CS 458</td>
<td>Unix System Administration</td>
</tr>
<tr>
<td>CS 460</td>
<td>Computer Graphics</td>
</tr>
</tbody>
</table>

**Other Required Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</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>
</tbody>
</table>

**Technical Elective** 3-4

**Total Hours** 17-18

* Computer Science majors must complete one course not counted toward another degree requirement. These may be selected from the following biology, chemistry, ocean and earth science, and physics courses: BIOL 121N, BIOL 123N, BIOL 136N, BIOL 138N, CHEM 105N, CHEM 107N, CHEM 121N, CHEM 123N, OAES 106N, OAES 108N, OAES 110N, OAES 111N, OAES 112N, OAES 126N, OAES 250N, PHYS 111N, PHYS 112N, PHYS 226N, PHYS 227N, PHYS 231N, PHYS 232N. 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 12 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.

**Computer Science Major Double Degree/Major Options**

Computer science majors may also complete the requirements for a second degree or second major in computer engineering, cybersecurity, or cyber operations. Students interested in a second degree or second major in
cybersecurity or cyber operations should contact their computer science advisor. A five-year plan for students pursuing degrees in computer science and computer engineering can be found below. Students seeking two degrees should be aware that a minimum of 150 credit hours is required.

Computer Science (BSCS) & Computer Engineering Major (BSCOME) 5-Year Plan (http://catalog.odu.edu/undergraduate/frankbattencollegeofengineeringandtechnology/electricalcomputerengineering/computereng-dualdegree-cecs-bs-fiveyearplan/)

**Bachelor of Science in Computer Science with Teaching Licensure**

This program leads to eligibility for teacher licensure in Virginia and is available only to individuals holding a baccalaureate degree or completing requirements for a Bachelor of Science in Computer Science. Due to changing University requirements, national accreditation standards, and the Virginia Board of Education licensure regulations, the teacher preparation programs in the College of Sciences are under constant revision. Any changes resulting from these factors supersede the program requirements described in this Catalog. Students are encouraged to obtain current program information from their advisors and the Office of Clinical Experiences website at https://www.odu.edu/oce (https://www.odu.edu/oce/).

**Admission**

Students must first declare computer science with teaching licensure preparation as their major with the computer science departmental advisor. All students must apply for and be admitted into the approved computer science teacher preparation program. Students must meet the required criteria for admission by earning the minimum required grade point averages (GPA).

**Virginia Board of Education Prescribed Assessments for Admission to an Approved Teacher Education Program**

Old Dominion University students seeking admission to an approved teacher education program must satisfy the Virginia Board of Education required assessment for admission into an approved teacher education program. The requirement can be satisfied by meeting a passing score in the following:

- Virginia Communication and Literacy Assessment (VCLA): Scaled passing score of 235 for the reading subtest and score of 235 for the writing subtest OR a composite score of 470 for the assessment.

**Required grade point averages (GPA)**

- A cumulative GPA of 2.75 is required.
- A major/content GPA of 2.75 is required - all computer science courses must be passed with a grade of C (2.0) or above and all other content courses must be passed with a grade of C- or higher.
- A professional education GPA of 2.75 is required – all professional education courses must be passed with a grade of C- or higher.

Although students may enroll in a limited number of education courses, students must be admitted into the approved computer science teacher preparation program prior to enrolling in any instructional strategies practicum education course. Students must also meet with an education advisor in the Office of Clinical Experiences in the Darden College of Education and Professional Studies.

**Continuance**

Students must maintain a cumulative GPA of 2.75, a major/content GPA of 2.75 and a professional education GPA of 2.75. Computer science courses must be passed with a grade of C (2.0) or higher. Courses in the professional education core must be completed with a grade of C- or higher for continuance. A professional education GPA of 2.75 is required for continuance. Students must take and pass the Praxis Subject Assessment, Computer Science content knowledge (formerly Praxis II) prior to or while enrolled in the instructional strategies course. All assessments must be passed prior to the start of the Teacher Candidate Internship Orientation session.

**Background Clearance Requirement**

Old Dominion University requires a background clearance check of candidates interested in many of the professional education programs. Professional education programs have several field experiences that are required for continuance and graduation from the program. The background clearance must be successfully completed prior to a field experience placement. Candidates will be provided a field experience placement when the background check process is completed with resolution of any issues. The process to complete the ODU clearance background check is located at: http://www.odu.edu/success/academic/teacher-education/ placement/background-checks (http://www.odu.edu/success/academic/teacher-education/placement/background-checks/). The ODU clearance process includes: an FBI fingerprint, a child protective service/social service review, and a Virginia State Police sex offender registry review. Candidates interested in the professional education programs are advised to complete this clearance process immediately upon entry into the program since the clearance process takes a minimum of eight weeks to complete.

**Virginia Board of Education Prescribed Assessments for Licensure**

Praxis Subject Assessment. Computer Science content knowledge (test code: 5652) - passing score of 142 is required.

To review more information on the Virginia Board of Education prescribed assessments visit the Office of Clinical Experiences website at https://www.odu.edu/oce (https://www.odu.edu/oce/).

**Graduation**

Requirements for graduation include 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, completion of the Senior Assessment, a minimum cumulative 2.75 GPA, in the major area, and in the professional education core, with no grade less than a C in the major and C- in the professional education core; successful completion of the Teacher Candidate Internship and a minimum of 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. Note that a C (2.0) must be earned in all computer science courses used to satisfy departmental requirements.

Additional hours may be required to meet the foreign language requirement. The professional education core satisfies the Upper-Division General Education requirement.

**Four-Year Plan - Computer Science Teaching Licensure - BSCS (http://catalog.odu.edu/undergraduate/collegeofsciences/computerscience/cs-teachinglicensure-bscs-fouryearplan/)**

- The four-year plan is a suggested curriculum to complete this degree program in four years. It is just one of several plans that will work and is presented only as broad guidance to students. Each student is strongly encouraged to develop a customized plan in consultation with their academic advisor. Additional information can also be found in Degree Works.

**Lower-Division General Education**

**Skills**

<table>
<thead>
<tr>
<th>Written Communication*</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGL 110C &amp; ENGL 231C</td>
<td>English Composition and Introduction to Technical and Scientific Writing (preferred)</td>
</tr>
</tbody>
</table>

**Mathematical Skills (satisfied in the major)**

| Oral Communication | 3 |

| COMM 101R | Public Speaking |

| Information Literacy and Research | 3 |
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

or CS 202G  Information Literacy for Cybersecurity

Language and Culture (competence must be at the 102 level)  0-6

Ways of Knowing

- 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)

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 for a total of eight credits from the following:

- BIOL 121N  General Biology I  4
  & BIOL 122N  General Biology I Lab  4
- BIOL 123N  General Biology II  4
  & BIOL 124N  General Biology II Lab  4
- BIOL 136N  Honors General Biology I  4
  & BIOL 137N  Honors General Biology I Lab  4
- BIOL 138N  Honors General Biology II  4
  & BIOL 139N  Honors General Biology II Lab  4
- CHEM 105N  Introductory Chemistry  4
  & CHEM 106N  Introductory Chemistry Laboratory  4
- CHEM 107N  Introductory Organic and Biochemistry  4
  & CHEM 108N  Introductory Organic and Biochemistry Laboratory  4
- CHEM 121N  Foundations of Chemistry I Lecture  4
  & CHEM 122N  Foundations of Chemistry I Laboratory  4
- CHEM 123N  Foundations of Chemistry II Lecture  4
  & CHEM 124N  Foundations of Chemistry II Laboratory  4
- OEAS 106N  Introductory Oceanography  8
  & OEAS 108N  Understanding Global Climate Change  8
- OEAS 106N  Introductory Oceanography  8
  & OEAS 250N  Natural Hazards and Disasters  8
- OEAS 126N  Honors: Introductory Oceanography  8
  & OEAS 120N  Honors: Understanding Global Climate Change  8
- OEAS 126N  Honors: Introductory Oceanography  8
  & OEAS 250N  Natural Hazards and Disasters  8
- OEAS 110N  Earth Science  4
  or OEAS 111N  Physical Geology  4

and

- OEAS 112N  Historical Geology  4
- PHYS 111N  Introductory General Physics  8
  & PHYS 112N  Introductory General Physics  8
- PHYS 226N  Honors: University Physics I  8
  & PHYS 227N  Honors: University Physics II  8
- PHYS 231N  University Physics I  8
  & PHYS 232N  University Physics II  8

Required Computer Science Courses

- CS 330  Object-Oriented Programming and Design  3
- CS 350  Introduction to Software Engineering  3
- CS 355  Principles of Programming Languages  3
- CS 361  Data Structures and Algorithms  3
- CS 381  Introduction to Discrete Structures  3
- CS 432  Web Science  3
- CS 462  Cybersecurity Fundamentals  3
- CS 471  Operating Systems  3

One CS Upper-Level Elective  3

Total Hours  45

Other Required Courses

- MATH 211  Calculus I  4
- MATH 212  Calculus II  4
- MATH 316  Introductory Linear Algebra  3
- STAT 330  An Introduction to Probability and Statistics  3

Total Hours  14

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.

Professional Education Core

- STEM 101  Step 1 – Inquiry Approaches to Teaching STEM  1
- STEM 102  Step 2 - Inquiry Based STEM Lesson Design  1
- STEM 201  Knowing and Learning in STEM Education  3
- STEM 202  Classroom Interactions in STEM Education  3
- STEM 401  Project Based Instruction in STEM Education  3
- STEM 402  Perspectives on STEM  3
- STEM 485  Apprentice Teaching  9
- CS 468W  Research Methods in Mathematics and Sciences  3

Total Hours  26

Advanced Placement

Advanced placement credit is awarded to students who earn qualifying scores on AP and IB subject examinations. See the equivalency charts on the Office of Undergraduate Admissions website at https://www.odu.edu/admission/undergraduate/credit (https://www.odu.edu/admission/undergraduate/credit/).

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.

Honors Program in Computer Science

Undergraduate computer science majors maintaining an overall GPA of at least 3.25 and of 3.50 in the major have the opportunity to participate in the Honors Program in Computer Science (program coordinator: Dr. Jing He). Students who complete the program and also meet the University’s standards for graduation with honors (see description in this Catalog) may
earn the designation of departmental honors on their diplomas. Students must complete one of three options.

A. Departmental Honors in Computer Science

Students maintaining an overall GPA of at least 3.25 and of 3.50 in computer science can receive a "Bachelor's Degree with Honors in Computer Science" subject to satisfaction of the minimum University standards for the departmental honors and completion of one of the following three options:

1. Successful completion of two semesters of honors research taken as either CS 491 and CS 492 or CS 491 and CS 499W.

2. Successful completion of four upper-division courses in Computer Science as "Contract Honors Courses" and achievement of the "Honors" designation in each.

3. Successful completion of one semester of honors research taken as CS 491 and two "Contract Honors Courses" in Computer Science and achievement of the Contract Honors designation in each.

Note: Completion of at least 60 credit hours at Old Dominion University, 54 of which must be in grade-point graded courses, is also required. Candidates who have used grade forgiveness or adjusted resident credit should be aware that the enhanced grade point average determined by use of these procedures does not determine eligibility for departmental honors. To determine eligibility for departmental honors, the student's complete record, including grades and hours for courses that have been forgiven or adjusted, will be evaluated to calculate the final grade point average.

B. Honors Research Scholars

Undergraduates with junior or senior standing and a minimum of 3.0 GPA (or with approval by Honors Program Coordinator) are eligible to participate in Honors Research. After consultation with the Honors Program Coordinator, students select a faculty member who agrees to oversee the research project. The research project, time commitment, and the basis for grading are mutually determined by the student and the mentor. An outline is to be submitted and approved by the Honors Program Coordinator before registration of the course. Students are expected to perform mentored research. Faculty mentors encourage students to present/publish results at scientific conferences or journals. Students are encouraged to apply for funds to support undergraduate research. The following honors research courses are provided:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 491</td>
<td>Honors Research I in Computer Science</td>
<td>3</td>
</tr>
<tr>
<td>CS 492</td>
<td>Honors Research II in Computer Science</td>
<td>3</td>
</tr>
<tr>
<td>CS 499W</td>
<td>Honors Thesis in Computer Science</td>
<td>3</td>
</tr>
</tbody>
</table>

C. Contract Honors Designation for Upper-Division Computer Science courses

Students with a grade point average of at least 3.25 may convert any upper-division computer science course into an Honors course on an individual basis. No grade below B is accepted for Honors designation. An Honors designation of a course requires successful completion of honors-level tasks to be agreed upon by the student and the instructor. Students who plan to apply for the honors designation of a course are required to communicate with the instructor before registration. Students are required to submit an outline of honors work to Honors Program Coordinator and obtain an approval before the start of the semester in which the course is taken.

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 ways of knowing 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>Hours</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>Data Structures and Algorithms</td>
<td>3</td>
</tr>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design</td>
<td>3</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>
</tr>
</thead>
<tbody>
<tr>
<td>CS 312</td>
<td>Internet Concepts</td>
</tr>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design</td>
</tr>
<tr>
<td>CS 355</td>
<td>Principles of Programming Languages</td>
</tr>
<tr>
<td>CS 361</td>
<td>Data Structures and Algorithms</td>
</tr>
<tr>
<td>CS 350</td>
<td>Introduction to Software Engineering</td>
</tr>
<tr>
<td>CS 381</td>
<td>Introduction to Discrete Structures</td>
</tr>
<tr>
<td>CS 390</td>
<td>Introduction to Theoretical Computer Science</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 a concentration 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>
</tr>
</thead>
<tbody>
<tr>
<td>CS 330</td>
<td>Object-Oriented Programming and Design*</td>
</tr>
<tr>
<td>CS 418</td>
<td>Web Programming</td>
</tr>
</tbody>
</table>

Select two of the following: 6

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 312</td>
<td>Internet Concepts</td>
</tr>
<tr>
<td>CS 431</td>
<td>Web Server Design</td>
</tr>
<tr>
<td>CS 432</td>
<td>Web Science</td>
</tr>
<tr>
<td>CS 441</td>
<td>App Development for Smart Devices</td>
</tr>
<tr>
<td>CS 462</td>
<td>Cybersecurity Fundamentals</td>
</tr>
</tbody>
</table>
Officially admitted into the MS program. Once students have been awarded their bachelor's degree and fulfilled all subsequent requirements, they will subsequently be reevaluated for continuation into the master's program. Otherwise, in keeping with normal admission requirements for the MS in computer science, students will take the GRE as an undergraduate and will earn 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. Attaining senior standing (completion of 90 credit hours) and who have completed at least six hours of graduate courses upon admission, 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 MS 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 MS in computer science, they will be officially admitted into the MS 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 MS 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. Students may substitute 500- and 600-level courses for the upper-level CS electives in the undergraduate program so long as they have the prerequisites for those courses. 700- or 800-level courses may not be used.
   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.
   d. To maximize the accelerated benefit one or more of the following required courses should be selected: CS 517, CS 518, CS 550, or CS 571.

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 master's degree in computer science. This will limit students' scheduling flexibility subsequently.
2. Like students in the regular MS in computer science program, students in the linked BSCS/MS computer science degree may count no more than 12 hours at the 500-level toward their MS 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.

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 BS/MBA Linked Program at the beginning of the College of Sciences section of this Catalog and the Strome College of Business section in the Graduate Catalog (http://catalog.odu.edu/graduate/stromecollegeofbusiness/).

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

This program allows for exceptionally successful students to earn both a BSCS and an MS in Computer Science by allowing up to 12 credits of graduate coursework to count toward both their bachelor's and master's degree in Computer Science. All options available under the MS degree are available under this program. Students must earn a minimum of 150 credit hours (120 discrete credit hours for the undergraduate degree and 30 discrete credit hours 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 MS 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 MS in computer science, they will be officially admitted into the MS program.

NOTES:

1. 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 master's degree in computer science. This will limit students' scheduling flexibility subsequently.
2. Like students in the regular MS in computer science program, students in the linked BSCS/MS computer science degree may count no more than 12 hours at the 500-level toward their MS 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.

Linked Bachelor of Science in Computer Science and Master of Science in Data Science and Analytics

This program allows for exceptionally successful students to earn both a BSCS and an MS in Data Science and Analytics by allowing up to 12 credits of graduate coursework to count toward both their bachelor’s degree in Computer Science and master’s degree in Data Science and Analytics. All options available under the MS degree are available under this program. Students must earn a minimum of 150 credit hours (120 discrete credit hours for the undergraduate degree and 30 discrete credit hours 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 MS 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 MS in computer science, they will be officially admitted into the MS program.
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 Data Science and Analytics 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 MS in Data Science and Analytics, 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 MS in data science and analytics, they will be officially admitted into the MS 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 MS in Data Science and Analytics 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.
   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. Students may substitute 500- and 600-level courses for the upper-level CS electives in the undergraduate program so long as they have the prerequisites for those courses. 700- or 800-level courses may not be used.
   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.

The graduate courses taken must be from the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 550</td>
<td>Database Concepts</td>
<td>3</td>
</tr>
<tr>
<td>CS 522</td>
<td>Introduction to Machine Learning</td>
<td></td>
</tr>
<tr>
<td>CS 532</td>
<td>Web Science</td>
<td></td>
</tr>
<tr>
<td>CS 569</td>
<td>Data Analytics for Cybersecurity</td>
<td></td>
</tr>
<tr>
<td>CS 580</td>
<td>Introduction to Artificial Intelligence</td>
<td></td>
</tr>
</tbody>
</table>

Choose three from the following:* 9

* Substitutions of other computer science courses may be made with approval of the graduate program director.

**NOTE:**

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 MS degree in Data Science and Analytics. This will limit students' 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 115. Introduction to Computer Science with Python. 1 Credit.**

An overview of computer science as a problem-solving discipline and as a career path. Topics include fundamentals of software, hardware computing fundamentals, and an introduction to the development of software to solve problems. Software development is introduced using the Python programming language. Intended for prospective CS majors. Laboratory work required.

**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 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. Pre- or corequisite: MATH 163.

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. Prerequisites: A grade of C or better in CS 150 or ENGN 150. Pre- or corequisite: MATH 163.

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 197. Undergraduate Research Experience in Computer Science. 0 Credits.
Student participation in a supervised, undergraduate research experience for which credit will not apply to the degree. Experience must be related to the student's major, minor or career area of interest. Prerequisites: permission of the instructor.

CS 202G. Information Literacy for Cybersecurity. 3 Credits.
This course provides an in-depth introduction to information literacy from library and information science, information ethics, and computer science perspectives along with applications to cybersecurity research and professional activity. This course is aligned with Old Dominion University's general education learning outcomes for information literacy. Prerequisites: ENGL 110C.

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: CS 150 or ENGN 150 with a grade of C or better. Pre- or corequisite: CS 252 and MATH 211.

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, ENGN 150 or IT 205.

CS 270. Introduction to Computer Architecture II. 3 Credits.

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 315. Computer Science Undergraduate Colloquium. 1 Credit.
This course consists of talks by invited speakers, including Old Dominion University faculty and guests from different research and industry communities. The colloquium introduces the possibilities of future research and career opportunities in the various areas of the computer science field. Additionally, students will learn about available scholarships and how to apply for them. Prerequisites: CS 150 or ENGN 150, and junior/senior standing as a computer science major.

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, synchronization, and graphic user interfaces. Prerequisites: CS 252 and a grade of C or better in CS 250. Pre- or corequisite: MATH 211.

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.

CS 361. 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: CS 252 and a grade of C or better in CS 250. Pre- or corequisite: MATH 212.

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. Prerequisites: approval by the CS Department and Career Development Services in accordance with the policy for granting credit for Cooperative Education programs.
CS 368, 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. 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 ENGN 150.

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.

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.

CS 395. Topics in Computer Science. 1-3 Credits. Special topics in computer science that are not part of the current curriculum at the junior/senior level. Prerequisite: permission of the instructor.

CS 402/502. Formal Software Foundations. 3 Credits. Laboratory work required. Foundational principles and techniques for building correct-by-construction software systems with provable guarantees. Includes functional programming, algebraic and polymorphic data types, pattern matching, computer-assisted theorem proving, proof automation, extraction of certified executable code, examples of verified algorithms. Prerequisite: CS 381.

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. Pre-corequisite: CS 350.

CS 411W/511. Professional Workforce Development II. 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. Pre-corequisite: CS 350.

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.

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 422/522. Introduction to Machine Learning. 3 Credits. Laboratory work required. An introduction to machine learning with a focus on practical aspects of various learning techniques. Topics include supervised learning (linear models, probabilistic models, support vector machine, decision trees, neural networks, etc.), unsupervised learning (scaling, dimension reduction, clustering, etc.), reinforcement learning, and model evaluation. The course will also discuss applications on image analysis, text processing, and biomedical informatics. Prerequisites: MATH 316 and CS 150 (or equivalent programming experience).

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 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, 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 for Cybersecurity. 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 466/566. Principles and Practice of Cyber Defense. 3 Credits.
This course is designed to help students gain a thorough understanding of vulnerabilities and attacks in systems and networks and learn cyber defense best practices. It covers fundamental security design principles and defense strategies and security tools used to mitigate various cyber attacks. The topics may include identification of Recon Ops, intrusion detection, identification of C2 Ops, data exfiltration detection, identifying malicious codes, network security techniques, cryptography, malicious activity detection, system security architectures, defense in depth, distributed/cloud and virtualization. Laboratory work required. Prerequisites: CS 250, CS 270 and CS 455; no prior knowledge of computer security is necessary.

CS 467/567. Introduction to Reverse Software Engineering. 3 Credits.
Laboratory work required. Covers all the major components such as static analysis, dynamic analysis, Windows x86/64 Assembly, APIs, DLL/process injection, covert launching methods, behaviors, anti-disassembly, anti-VM, packing/unpacking, shell code, C++, buffer overflow attacks and various kinds of networking attacks; includes a final project that analyzes a piece of real malware. Prerequisites: CS 250 and CS 270.

CS 468W. Research Methods in Mathematics and Sciences. 3 Credits.
Emphasizes the tools and techniques used to solve scientific problems. Topics include use and design of experiments, use of statistics to interpret experimental results, mathematical modeling of scientific phenomena, and oral and written presentation of scientific results. Students will perform four independent inquiries, combining skills from mathematics and science to solve research problems. Required for Physics teaching licensure track; not available as upper-division elective in content area. This is a writing intensive course. Prerequisites: Admission to the Monarch Teach Program; CS 361 or MATH 212; and a grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C.

CS 469/569. Data Analytics for Cybersecurity. 3 Credits.
The course introduces classical and advanced models and techniques in machine learning and deep learning. It applies these techniques in the cybersecurity domain including anomaly detection, network security, and malware detection and classification. Advanced applications such as self-driving cars and IoT systems are also discussed. In addition, cyber-attacks on machine learning techniques and AI systems and the possible consequences are also discussed. Prerequisites: CS 462 or CS 455 or experience in cybersecurity.

CS 471/571. 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: ECE 346 or ECE 443 or a grade of C or better in CS 361 and CS 270.

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, Delaunaytriangulations, binary space partitions, quadtrees, 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.

CS 488/588. Principles of Compiler Construction. 3 Credits.
Laboratory work required. Theoretical and practical aspects of compiler design and implementation. Topics will include lexical analysis, parsing, translation, code generation, optimization, and error handling. Prerequisites: A grade of C or better in CS 361.

CS 491. Honors Research I in Computer Science. 3 Credits.
Laboratory work required. Students perform mentored research in a group environment to develop computational approaches in addressing computer science challenges. The project needs approval by the Computer Science Honors Program director, and registration requires approval of the mentor. A GPA of 3.00 or better is required, or approval by the director of the Computer Science Honors Program. Prerequisites: grade of C or better in CS 350.

CS 492. Honors Research II in Computer Science. 3 Credits.
Laboratory work required. Students continue mentored research using the project defined in CS 491. Students will present the work and findings to the public. The project needs approval by the Computer Science Honors Program director, and registration requires approval of the mentor. Prerequisites: A grade of B or better in CS 491.

CS 495/595. Topics in Computer Science. 1-3 Credits.
Special topics. Prerequisite: permission of the instructor.

CS 497/597. Independent Study in Computer Science. 1-3 Credits.
Independent study under the direction of an instructor. Prerequisites: permission of the instructor.

CS 499W. Honors Thesis in Computer Science. 3 Credits.
Laboratory work required. Each student writes a thesis and continues the development of the project defined in CS 491. Written work is reviewed and returned for corrective rewriting. Students will present the work and findings to the public. The project needs approval by the Computer Science Honors Program director, and registration requires approval of the mentor. This is a writing intensive class. Prerequisites: A grade of C or better in CS 491.