COMPUTER SCIENCE, BACHELOR OF SCIENCE (B.S.)

The Bachelor of Science in Computer Science is built on a rigorous, highly concentrated, accredited curriculum of computer science courses. The program provides a strong foundation in the discipline and includes advanced study in several important areas of computer science.

The degree requires a minimum of 120 credit hours and includes undergraduate requirements, general education requirements and computer science major requirements.

Learning outcomes

Upon completing this program, students will know and know how to do the following:

1. Computing and math
   An ability to apply knowledge of computing and mathematics appropriate to the program's student outcomes and to the discipline

2. Problem analysis and requirement specification
   An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution

3. Design, implement and test programs and systems
   An ability to design, implement and evaluate a computer-based system, process, component or program to meet desired needs

4. Teamwork
   An ability to function effectively on teams to accomplish a common goal

5. Ethical issues
   An understanding of professional, ethical, legal, security and social issues and responsibilities

6. Oral and written communications
   An ability to communicate effectively with a range of audiences

7. Local and global impact of computing
   An ability to analyze the local and global impact of computing on individuals, organizations and society

8. Continuing professional development
   Recognition of the need for and an ability to engage in continuing professional development

9. Current techniques, skills and tools
   An ability to use current techniques, skills and tools necessary for computing practice

10. Modeling and design of computer-based system
    An ability to apply mathematical foundations, algorithmic principles and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the trade-offs involved in design choices

11. Software construction
    An ability to apply design and development principles in the construction of software systems of varying complexity

Special requirements

Students must receive a minimum grade of C in all computer science courses in order to graduate

Degree requirements for Computer Science, Bachelor of Science (B.S.)

General Education requirements

<table>
<thead>
<tr>
<th>University Core Education Curriculum</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIV 111 Play course video for Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 112 Play course video for Focused Inquiry II</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 200 Inquiry and the Craft of Argument</td>
<td>3</td>
</tr>
<tr>
<td>Approved humanities/fine arts</td>
<td>3</td>
</tr>
<tr>
<td>Approved natural/physical sciences</td>
<td>3-4</td>
</tr>
<tr>
<td>Approved quantitative literacy</td>
<td>3-4</td>
</tr>
<tr>
<td>Approved social/behavioral sciences</td>
<td>3-4</td>
</tr>
</tbody>
</table>

General Education requirements

| Humanities electives from list below (in addition to those in University Core) | 9                |

Total Hours 30-33

Collateral requirements

Select one of the following options: 8-10

Option A:

| CHEM 101 & CHEZ 101 General Chemistry I and General Chemistry Laboratory I |                  |
| CHEM 102 & CHEZ 102 General Chemistry II and General Chemistry Laboratory II |                  |

Option B:

| PHYS 207 & PHYS 208 University Physics I and University Physics II |                  |

Option C:

| BIOL 151 & BIOZ 151 Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I |                  |
| BIOL 152 & BIOZ 152 Introduction to Biological Sciences II and Introduction to Biological Science Laboratory II |                  |
| ECON 205 The Economics of Product Development and Markets          | 3                |
| MATH 200 Calculus with Analytic Geometry (satisfies quantitative literacy) | 4                |
| MATH 201 Calculus with Analytic Geometry                             | 4                |
| Select two upper-level (300- to 400-level) MATH courses              | 6                |
| STAT 212 Concepts of Statistics                                      | 3                |
| Natural science electives (BIOL, CHEM or PHYS courses that count toward the major in that science) | 6                |

Total Hours 30-32

Major requirements

| CMSC 255 Introduction to Programming                                   | 4                |
| CMSC 256 Data Structures and Object Oriented Programming               | 4                |
| CMSC 257 Computer Systems                                             | 4                |
| CMSC 302 Introduction to Discrete Structures                           | 3                |
CMSC 303  Introduction to the Theory of Computation 3
CMSC 311  Computer Organization 3
CMSC 312  Introduction to Operating Systems 3
CMSC 355  Software Engineering: Specification and Design 3
CMSC 401  Algorithm Analysis with Advanced Data Structures 3
CMSC 403  Programming Languages 3
CMSC 451  Senior Project 6
& CMSC 452  and Senior Project (capstone courses) 6
CMSC 508  Database Theory 3
CMSC upper-level electives 9
Total Hours 51

Open electives
Select seven to nine open elective credits 7-9

Total minimum requirement 120 credits
CMSC upper-level electives
CMSC 409  Artificial Intelligence 3
CMSC 411  Computer Graphics 3
CMSC 412  Social Network Analysis and Cybersecurity Risks 3
CMSC 413  Introduction to Cybersecurity 3
CMSC 414  Computer and Network Security 3
CMSC 415  Introduction to Cryptography 3
CMSC 416  Introduction to Natural Language Processing 3
CMSC 420  Software Engineering: Project Management 3
CMSC 428  Mobile Programming: iOS 3
CMSC 435  Introduction to Data Science 3
CMSC 491  Topics in Computer Science 1-3
CMSC 492  Independent Study 2-4
CMSC 506  Computer Networks and Communications 3
Approved humanities electives
Select nine credits from the following programs or subject areas: 9

Some courses in other programs (including most honors modules and other courses that focus on human behavior, communication and/or social interaction) may be counted toward this requirement with departmental approval.

What follows is a sample plan that meets the prescribed requirements within a four-year course of study at VCU. Please contact your adviser before beginning course work toward a degree.

Freshman year
Fall semester Hours
CMSC 255  Introduction to Programming 4
UNIV 111  Focused Inquiry I 3
CMSC 302  Introduction to Discrete Structures 3
ECON 205  The Economics of Product Development and Markets 3
MATH 200  Calculus with Analytic Geometry 4
UNIV 112  Focused Inquiry II 3
Term Hours: 16

Spring semester
CMSC 256  Data Structures and Object Oriented Programming 4
CMSC 355  Software Engineering: Specification and Design 3
MATH 201  Calculus with Analytic Geometry 4
UNIV 200  Inquiry and the Craft of Argument 3
Approved humanities/fine arts 3
Term Hours: 17

Sophomore year
Fall semester
CMSC 257  Computer Systems 4
CMSC 492  Independent Study 2-4
MATH 201  Calculus with Analytic Geometry 4
UNIV 200  Inquiry and the Craft of Argument 3
Approved humanities/fine arts 3
Term Hours: 17

Spring semester
CMSC 303  Introduction to the Theory of Computation 3
CMSC 311  Computer Organization 3
STAT 212  Concepts of Statistics 3
Approved humanities elective 4
Approved social/behavioral sciences 3
Term Hours: 16

Junior year
Fall semester
CMSC 312  Introduction to Operating Systems 3
CMSC 401  Algorithm Analysis with Advanced Data Structures 3
Approved natural science elective (BIOL, CHEM or PHYS course that count toward the major in that science) 3
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 101</td>
<td>General Chemistry I</td>
<td>4</td>
</tr>
<tr>
<td>&amp; CHEZ 101</td>
<td>and General Chemistry Laboratory I</td>
<td></td>
</tr>
<tr>
<td>PHYS 207</td>
<td>University Physics I</td>
<td>5</td>
</tr>
<tr>
<td>BIOL 151</td>
<td>Introduction to Biological Sciences I</td>
<td>4</td>
</tr>
<tr>
<td>&amp; BIOZ 151</td>
<td>and Introduction to Biological Science Laboratory I</td>
<td></td>
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</table>

Term Hours: 13-14

**Spring semester**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSC 403</td>
<td>Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 508</td>
<td>Database Theory</td>
<td>3</td>
</tr>
<tr>
<td>MATH upper-level (300- to 400-)</td>
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<tr>
<td>Select one of the following:</td>
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</tr>
<tr>
<td>CHEM 102</td>
<td>General Chemistry II</td>
<td>4</td>
</tr>
<tr>
<td>&amp; CHEZ 102</td>
<td>and General Chemistry Laboratory II</td>
<td></td>
</tr>
<tr>
<td>PHYS 208</td>
<td>University Physics II</td>
<td>5</td>
</tr>
<tr>
<td>BIOL 152</td>
<td>Introduction to Biological Sciences II</td>
<td>4</td>
</tr>
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<td>&amp; BIOZ 152</td>
<td>and Introduction to Biological Science Laboratory II</td>
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Term Hours: 13-14

**Senior year**

**Fall semester**

<table>
<thead>
<tr>
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<th>Credits</th>
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<tbody>
<tr>
<td>CMSC 451</td>
<td>Senior Project (capstone)</td>
<td>3</td>
</tr>
<tr>
<td>CMSC upper-level electives</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>MATH upper-level (300- to 400-)</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Approved natural science elective (BIOL, CHEM or PHYS) course that count toward the major in that science</td>
<td></td>
<td>3</td>
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Term Hours: 15

**Spring semester**

<table>
<thead>
<tr>
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<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>CMSC 452</td>
<td>Senior Project (capstone)</td>
<td>3</td>
</tr>
<tr>
<td>CMSC upper-level elective</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Open electives</td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

Term Hours: 13

Total Hours: 120-122

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**Total minimum requirement 120 credits**

**CMSC 101. Introduction to Computer Science. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 141 or the equivalent with a minimum grade of C. An introduction to the work of computer scientists, including an overview of current research and application areas as well as career opportunities. Topics include problem-solving, the basics of computer organization, the software engineering life cycle, research resources and social and ethical aspects of technology. Additional topics also include binary, hexadecimal, two's complement, floating point representation, ASCII and Unicode.

**CMSC 191. Topics in Computer Science. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. May be repeated for credit. Prerequisite: permission of the instructor. This course will teach selected topics in computer science. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

**CMSC 245. Introduction to Programming Using C++. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 151 or satisfactory score on the Mathematical Placement Test. Students registering for CMSC 245 must have taken the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. An exception to this policy is made in the case in which the stated alternative prerequisite course has been completed at VCU. Students are expected to have fundamental computer skills. Introduction to the concepts and practice of structured programming using C++. Problem-solving, top-down design of algorithms, objects, basic C++ syntax, control structures, functions and arrays. This course is intended for engineering majors.

**CMSC 246. Advanced Programming Using C++. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 245. Advanced programming in C++. Topics include program design, objects, classes, inheritance, files, strings, linked lists, stacks, queues, binary trees, recursion, and basic searching and sorting techniques. This course is intended for engineering majors.

**CMSC 255. Introduction to Programming. 4 Hours.**
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisite: calculus-level placement on the VCU Mathematics Placement Test within the one-year period immediately preceding enrollment in the course, or MATH 151 or equivalent. Students are expected to have fundamental computer skills. Introduction to object-oriented programming using Java. Topics include problem-solving, top-down design of algorithms using control structures, methods, arrays, basic I/O, basic concepts of objects and classes in Java, Java classes for manipulating strings, and introduction to program testing. UML notation and integrated development environments. Students may not receive credit for both CMSC 255 and INFO 250.

**CMSC 256. Data Structures and Object Oriented Programming. 4 Hours.**
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisite: CMSC 255 with a minimum grade of C; corequisite: CMSC 302. Advanced programming using Java. Topics include introduction to object-oriented design, inheritance, polymorphism, exceptions, interfaces, linked lists, stacks, queues, binary trees, recursion, and basic searching and sorting techniques. Continued focus on program testing and UML notation. Students may not receive credit for both CMSC 256 and INFO 350.

**CMSC 257. Computer Systems. 4 Hours.**
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisite: CMSC 256 with a minimum grade of C. Topics include UNIX essentials; system programming in C; machine-level representation and organization of programs/data, arrays and pointers; types, structs and unions; strings; bit/byte operations; memory management; shell programming; input/output, including file handling; debugging; signals; network programming using sockets; program concurrency using forks and threads; experiments on program performance and optimization techniques.

**CMSC 302. Introduction to Discrete Structures. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 255 with minimum grade of C. Combinatorial and sequential circuits, algorithms and algorithm analysis, recursion, recurrence relations, graphs, trees.

**CMSC 303. Introduction to the Theory of Computation. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 302 or the equivalent with a grade of C or better. Complexity classes, grammars, automata, formal languages, Turing machines, computability.
CMSC 311. Computer Organization. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 302 with a minimum grade of C; corequisite: CMSC 257. Introduction to the basic organization of computers including elementary digital logic design, processor and arithmetic/logic unit design, data paths, memory hierarchy, I/O devices, instruction set architecture and addressing modes.

CMSC 312. Introduction to Operating Systems. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 311 or EGRE 246, either with a minimum grade of C. Provides an overview of the software engineering process and software life-cycle models. Gives a detailed study of the analysis, specification and design phases. Students will work in teams to gain experience in software development methodology, developing specification and design documents and developing an operating system simulation.

CMSC 355. Software Engineering: Specification and Design. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 256 or EGRE 246, either with a minimum grade of C. Provides an overview of the software engineering process and software life-cycle models. This course will teach selected topics in computer science. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

CMSC 391. Topics in Computer Science. 3 Hours.
Semester course; 3 lecture hours. 3 credits. May be repeated for credit. Prerequisite: permission of the instructor. This course will teach selected topics in computer science. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

CMSC 401. Algorithm Analysis with Advanced Data Structures. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 256 with a grade of C or better and CMSC 302 with a grade of C or better. Introduction to algorithm analysis and complexity classes. Advanced data structures topics including multiple linked lists, height-balanced trees, B-trees, hashing and graph representation; incorporating data structures into object-oriented design. Analysis of various searching and sorting algorithms. Algorithm design topics include divide-and-conquer, dynamic programming and greedy methods.

CMSC 403. Programming Languages. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 256 with a grade of C or better and CMSC 303. Survey of representative modern programming languages. Formal definition of programming languages including specifications of syntax and semantics. Precedence, infix, prefix and postfix notation. Global properties of algorithmic languages. Sub-routines, co-routines and tasks. List processing, string manipulation, data description and simulation languages. Run-time representation of program and data structures.

CMSC 404. Compiler Construction. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 401 and 403. A first course in compiler theory and construction. Formal description of languages, underlying theory and design techniques for compilers, lexical analysis, syntax analysis, syntax-directed translation, intermediate languages, run-time system management, code generation, code optimization, compiler-building tools.

CMSC 409. Artificial Intelligence. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 401 with a minimum grade of C and MATH 310. Covers problem spaces, problem-solving methods, game playing, knowledge representatives, expert systems, natural language understanding.

CMSC 411. Computer Graphics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 355 and MATH 310. Presents mathematical techniques for graphic development and transformation, curve and surface approximation and projections, graphical languages and data structures and their implementation, graphic modeling.

CMSC 412. Social Network Analysis and Cybersecurity Risks. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 401 with a minimum grade of C. Covers network models, link prediction and analysis, centrality measures, random networks, power-laws and preferential attachment, small world phenomenon and decentralized search, community structure, information propagation in networks, and security and privacy issues in OSNs.

CMSC 413. Introduction to Cryptography. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 401 with a minimum grade of C. This course provides an introduction and basic concepts of computer security, cyber attacks, cyber defense, cyber forensics and cyber ethics.

CMSC 414. Computer and Network Security. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 401 with a minimum grade of C. Corequisite: CMSC 312. This course covers the best practices of computer systems and network security. Key topics include security architecture, cryptographic systems and security management tools.

CMSC 415. Introduction to Cryptography. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 401 with a minimum grade of C. This course provides an introduction and basic concepts of computer security, cyber attacks, cyber defense, cyber forensics and cyber ethics.

CMSC 416. Introduction to Natural Language Processing. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 401 with a minimum grade of C. Covers rule-based and statistical methods for analyzing and understanding human language. Topics include regular expressions and automata, context-free grammars, probabilistic classifiers, and machine learning. Word-level, syntactic and semantic processing are all considered. Application to real-world problems such as spell-checking, Web search, automatic question answering, authorship identification and developing conversational interfaces.

CMSC 420. Software Engineering: Project Management. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 355 with a minimum grade of C. This course provides an introduction and basic concepts of computer security, cyber attacks, cyber defense, cyber forensics and cyber ethics.

CMSC 428. Mobile Programming: iOS. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 355, with a minimum grade of C. This course covers the fundamentals of Swift, Xcode and iOS for programming and design of iOS applications. Background in object-oriented programming and access to a computer with Xcode platform is required.
CMSC 435. Introduction to Data Science. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: CMSC 401 with a minimum grade of C. This course covers understanding, representation, storage, retrieval, preprocessing and analysis of data. Specific topics include data quality and preprocessing, database management systems, data warehouses, selected methods for scalable unsupervised and supervised data analysis, and assessment of results generated by these methods. Students will be engaged in analysis of real-life data from data preprocessing, through data analysis, to the assessment of a knowledge product.

CMSC 451. Senior Project. 3 Hours.
Semester course; 3 laboratory hours. 3 credits. Prerequisites: senior standing in the computer science department; 24 credits in computer science, including CMSC 355 and CMSC 508, both with minimum grades of C; UNIV 200 or HONR 200 or equivalent. Capstone project or experience for the computer science major; research and presentation methods in computer science. Each student will participate, either individually or as part of a team, in a project or other experience approved by the course coordinator or sponsored by another computer science faculty member. Each student will write and revise a research paper on a technical topic associated with his or her project or experience. Students will submit a detailed written description of their proposed project or experience and will present orally some aspect of what they have learned and/or done during the semester. (This course cannot be counted as upper-level CMSC electives for students graduating under bulletins prior to 2008-09.).

CMSC 452. Senior Project. 3 Hours.
Semester course; 1 lecture and 2 laboratory hours. 3 credits. Prerequisites: senior standing in the computer science department; CMSC 451 with a minimum grade of C. Capstone project or experience for the computer science major; research and presentation methods in computer science; ethical, legal and social issues in computing; and professional responsibilities of computer scientists. Each student will participate, either individually or as part of a team, in a project or other experience approved by the course coordinator or sponsored by another computer science faculty member. Each student will write and revise a research paper on a technical topic associated with his or her project or experience. Students must continue on the same project that was started in CMSC 451. A final project report and presentation, which will include a discussion of associated legal, social and/or ethical issues, are due at the conclusion of the two-semester project or experience. (This course cannot be counted as upper-level CMSC electives for students graduating under bulletins prior to 2008-09.).

CMSC 491. Topics in Computer Science. 1-3 Hours.
Semester course; variable hours. 1-3 credits. May be repeated for credit with different content. Prerequisite: permission of instructor. This course will cover selected topics in computer science. See the Schedule of Classes for specific topics to be offered each semester.

CMSC 492. Independent Study. 2-4 Hours.
Semester course; variable hours. 2, 3 or 4 credits per semester. Maximum 4 credits per semester; maximum total of 6 credits. Generally open only to students of junior or senior standing who have acquired at least 12 credits in the departmental discipline. Determination of the amount of credit and permission of instructor and department chair must be procured prior to registration of the course. The student must submit a proposal for investigating some area or problem not contained in the regular curriculum. The results of the student's study will be presented in a report.

CMSC 493. Computer Science Internship. 1-3 Hours.
Semester course; variable hours. 1-3 credits. May be repeated for up to 3 credits. Prerequisites: CMSC 401 and CMSC 403. Approval of Computer Science Undergraduate Credentials Committee is required prior to registration. A minimum of 30 clock hours per credit in an information technology environment. The internship is designed to provide practical experience in the computing industry. Student must present a written report reflecting upon internship experience. Graded as pass/fail. Not applicable toward the computer science major.