

# COMPUTER SCIENCE, DOCTOR OF PHILOSOPHY (PH.D.)

The Ph.D. in Computer Science will educate and train students in core areas of computer science. Students will explore the advanced concepts of computer science theory, systems and research. They will learn how to identify problems, set a research agenda, clearly identify and isolate good ideas, solve programming challenges creatively, and communicate in a clear and concise manner. Graduates will possess the necessary analytical, technical and research skills of complex computer science topics in order to respond directly to the needs of industry, research laboratories, the public sector, academia and government for effective, innovative and productive engineers, professors and researchers.

Students in the Ph.D. in Computer Science program will be immersed in a curriculum that exposes them to computer science theory, computer systems, machine learning, data sciences and cybersecurity. The program prepares students with the ability to formulate and analyze new algorithmic solutions and to turn them into usable programs that efficiently exploit distributed, multi-core architectures dominating current computer hardware.

## Student learning outcomes

Students will be able to:

1. Apply knowledge of the foundations of computer science
2. Apply knowledge of a specialized research area
3. Use principles of scientific inquiry and software design to evaluate scientific literature and formulate research hypotheses
4. Solve computational problems and discover or generate new ideas, concepts, techniques and/or products in general and specialized areas of computer science
5. Write technical reports and scholarly papers in computer science
6. Present problems and solutions in computer science

## VCU Graduate Bulletin, VCU Graduate School and general academic policies and regulations for all graduate students in all graduate programs

The VCU Graduate Bulletin website documents the official admission and academic rules and regulations that govern graduate education for all graduate programs at the university. These policies are established by the graduate faculty of the university through their elected representatives to the University Graduate Council.

It is the responsibility of all graduate students, both on- and off-campus, to be familiar with the VCU Graduate Bulletin as well as the **Graduate School website** and academic regulations in individual school and department publications and on program websites. However, in all cases, the official policies and procedures of the University Graduate Council, as published on the VCU Graduate Bulletin and Graduate School websites, take precedence over individual program policies and guidelines.

**Visit the academic regulations section for additional information on academic regulations for graduate students.**

## Degree candidacy requirements

A graduate student admitted to a program or concentration requiring a final research project, work of art, thesis or dissertation, must qualify for continuing master's or doctoral status according to the degree candidacy requirements of the student's graduate program. Admission to degree candidacy, if applicable, is a formal statement by the graduate student's faculty regarding the student's academic achievements and the student's readiness to proceed to the final research phase of the degree program.

Graduate students and program directors should refer to the following degree candidacy policy as published in the VCU Graduate Bulletin for complete information and instructions.

**Visit the academic regulations section for additional information on degree candidacy requirements.**

## Graduation requirements

As graduate students approach the end of their academic programs and the final semester of matriculation, they must make formal application to graduate. No degrees will be conferred until the application to graduate has been finalized.

Graduate students and program directors should refer to the following graduation requirements as published in the Graduate Bulletin for a complete list of instructions and a graduation checklist.

**Visit the academic regulations section for additional information on graduation requirements.**

## Admission requirements

Degree:	Semester(s) of entry:	Deadline dates:	Test requirements:
Ph.D.	Fall	Jun 1 (Feb 15 for financial assistance)	GRE-General; TOEFL for international students
	Spring	Nov 15	

Applications for matriculation to the Ph.D. program are evaluated by the departmental admissions committee, under the direction of the graduate program director, on a rolling basis. Successful applicants typically have a GPA of 3.3 or greater and a combined score of 320 or greater (verbal and quantitative) on the GRE; however, admission is selective and the admissions committee makes admission recommendations based on a holistic assessment of the applicant's potential for success in the program. In addition to the Graduate School requirements, the following are required for consideration for admissions into the Computer Science PhD program:

1. Letter of intent clearly outlining research interests and relevant experience.
2. GRE (fewer than five years old).
3. Three letters of recommendation from instructors or professional references in the applicant's intended field of study. Two may be waived subject to adviser approval. Letters should address the applicant's academic and professional abilities and preparation for graduate study.

Requests for more information should be directed to [csgrad@vcu.edu](mailto:csgrad@vcu.edu).

International students seeking admission to the program must also satisfy requirements related to timeline, visa or immigration status, proof

of English proficiency, and other items as specified by VCU's Graduate School and VCU's Global Education Office.

Degree requirements

In addition to the VCU Graduate School graduation requirements, students must meet the following requirements.

Students can earn the Ph.D. in Computer Science through two routes: post-baccalaureate study and post-master's study.

The Ph.D. curriculum requires completion of a minimum of 72 credit hours for students entering with a baccalaureate degree and a minimum of 54 credits for students entering with a master's degree.

Only graduate credit hours count for the doctoral degree. At least half of the minimum required course work credit hours must be at the 600-level or higher.

To graduate, degree applicants must achieve an overall minimum grade point average of 3.0 on a 4.0 scale. The GPA for graduation will be based on all the graduate courses attempted after acceptance into the program. Graduates must also achieve a passing performance on their qualifying and comprehensive examination.

Curriculum requirements

Total graduate credit hours required for post-baccalaureate students is 72 (minimum). Total graduate credit hours required for post-M.S. students is 54 (minimum).

The Ph.D. curriculum will prepare the program graduates for research and teaching careers in computer science, with emphasis on areas of cybersecurity and data science. The program will allow students to ascertain breadth in computer science education and depth relevant to the selected research topics.

The program consists of the following components:

Computer science core

This component is common to all students in the Ph.D. program.

Electives

Elective courses allow students to expand their education in areas related to their dissertation research. The choice of courses is based on the recommendation of the student's dissertation adviser. The program will include courses related to algorithms, computer systems, networking, security, privacy and reliability of information processing. The program will also include elective courses focused on numerical and scientific computing, computer architecture, artificial intelligence and machine learning, bioinformatics, and methods for efficient and accurate processing of data and extracting knowledge from data. Students may also take courses outside of the computer science department, however these courses (not labeled CMSC) must show relevance to the student's research and be pre-approved by the dissertation adviser.

Directed research requirement

Students are required to complete at least 36 (B.S. to Ph.D. students) or 24 (M.S. to Ph.D. students) credit hours of combined dissertation course work (CMSC 697 and CMSC 702). This part of the program exposes students to current developments in the field of computer science and emphasizes research directed toward solving a challenging problem of computer science under the guidance of the dissertation adviser and

dissertation committee. Topics pursued as directed research credit hours (CMSC 697) are devoted to open-ended projects in computer science. Students must enroll in the seminar course (CMSC 702) each semester of enrollment.

B.S. to Ph.D. curriculum for students entering with a baccalaureate degree

Course	Title	Hours
Computer science core		
CMSC 501	Advanced Algorithms	3
CMSC 603	High Performance Distributed Systems	3
CMSC 702	Computer Science Seminar (one-credit course repeated for four semesters)	4
Seminar course		
CMSC 702	Computer Science Seminar (one-credit course repeated for two additional credits)	2
Electives		
Students will work with their research adviser to select the elective courses appropriate for their research focus area. Elective courses will be selected from graduate-level courses including:		18
CMSC 502	Parallel Algorithms	
CMSC 506	Computer Networks and Communications	
CMSC 510	Regularization Methods for Machine Learning	
CMSC 512	Advanced Social Network Analysis and Security	
CMSC 516	Advanced Natural Language Processing	
CMSC 525	Introduction to Software Analysis, Testing and Verification	
CMSC 531	3D Computer Vision for Robot Navigation	
CMSC 601	Convex Optimization	
CMSC 605	Advanced Computer Architecture	
CMSC 608	Advanced Database	
CMSC 610	Algorithmic Foundations of Bioinformatics	
CMSC 612	Game Theory and Security	
CMSC 615	Cryptocurrency and Blockchain Techniques	
CMSC 618	Database and Application Security	
CMSC 620	Applied Cryptography	
CMSC 622	Network and System Security	
CMSC 623	Cloud Computing	
CMSC 628	Mobile Networks: Applications, Modeling and Analysis	
CMSC 630	Image Analysis	
CMSC 635	Knowledge Discovery and Data Mining	
CMSC 636	Artificial Neural Networks and Deep Learning	
CMSC 678	Statistical Learning and Fuzzy Logic Algorithms	

**Dissertation research requirement**

Complete a minimum of 42 hours of combined dissertation course work.	42
CMSC 697 Directed Research	
<b>Total Hours</b>	<b>72</b>

The minimum number of graduate credit hours required for this degree is 72.

## M.S. to Ph.D. curriculum for students entering with a master's degree

Course	Title	Hours
<b>Core courses</b>		
CMSC 501	Advanced Algorithms	3
CMSC 603	High Performance Distributed Systems	3
CMSC 702	Computer Science Seminar (one-credit course repeated for four semesters)	4
<b>Electives</b>		
Students will work with their research adviser to select the elective courses appropriate for their research focus area. Elective courses will be selected from graduate-level courses including:		6
CMSC 502	Parallel Algorithms	
CMSC 506	Computer Networks and Communications	
CMSC 510	Regularization Methods for Machine Learning	
CMSC 512	Advanced Social Network Analysis and Security	
CMSC 516	Advanced Natural Language Processing	
CMSC 525	Introduction to Software Analysis, Testing and Verification	
CMSC 531	3D Computer Vision for Robot Navigation	
CMSC 601	Convex Optimization	
CMSC 605	Advanced Computer Architecture	
CMSC 608	Advanced Database	
CMSC 610	Algorithmic Foundations of Bioinformatics	
CMSC 612	Game Theory and Security	
CMSC 615	Cryptocurrency and Blockchain Techniques	
CMSC 618	Database and Application Security	
CMSC 620	Applied Cryptography	
CMSC 622	Network and System Security	
CMSC 623	Cloud Computing	
CMSC 628	Mobile Networks: Applications, Modeling and Analysis	
CMSC 630	Image Analysis	
CMSC 635	Knowledge Discovery and Data Mining	
CMSC 636	Artificial Neural Networks and Deep Learning	
CMSC 678	Statistical Learning and Fuzzy Logic Algorithms	

**Directed research requirement**

Complete a minimum of 38 hours of combined dissertation course work.	38
CMSC 697 Directed Research	
<b>Total Hours</b>	<b>54</b>

The minimum number of graduate credit hours required for this degree is 54.

## Doctoral requirements and procedures

### Research adviser and dissertation committee

Students select a research adviser before they can be admitted into the graduate program, and a dissertation committee within 24 months of enrollment. The selection of the research adviser and the dissertation committee has to be approved by the CS graduate program director. The dissertation committee consists of five faculty members, including the primary research adviser. Three committee members must be from the CS graduate program and two from outside; whenever possible, one of the committee members should be from outside of VCU. This committee votes to approve or not the student's dissertation proposal and the final Ph.D. dissertation defense and makes the recommendation to award or not the Ph.D. degree. All members of the committee must be members of the VCU graduate faculty.

### Qualifying examination

The Ph.D. qualifying examination focuses on the knowledge fundamental to computer science and on problem-solving skills critical to the student's research area. The QE is an oral exam typically lasting at least an hour. It is conducted by the exam committee composed of the student's research adviser and the CS department members of the student's dissertation advisory committee; the research adviser may also choose to invite the outside members of the student's advisory committee to participate in the exam. The exam has to take place prior to the proposal defense or can be scheduled as an additional element of the proposal defense. Typically, the student will take the qualifying exam within 24 months of starting in the doctoral program. Students cannot take the qualifying exam if they are not in good standing.

### Dissertation proposal and proposal defense

The dissertation proposal consists of the research plan and initial results. It includes a thorough literature review of the topic and enough information to judge the feasibility, scope and potential impact of the research. The student will submit one copy of the dissertation research proposal to each member of the dissertation committee two weeks before the proposal defense. The defense typically happens during the time allotted for departmental seminars. All faculty and students can ask questions during an open part of the defense, followed by more questions by the dissertation committee during the closed session of the defense. This constitutes an oral comprehensive exam.

The purpose of the dissertation proposal is to display comprehensive knowledge of the chosen research area, defend the chosen research hypothesis and show a well-reasoned plan for exploring the hypothesis through additional research. The OCE should be taken within 36 months from enrollment.

### Admission to candidacy

Admission to doctoral degree candidacy is a formal statement regarding the student's academic achievements and their readiness to proceed to the final research phase of the doctoral program. Before admission

to candidacy for the doctorate, students must have: (1) completed core courses in the program, (2) completed at least 75 percent of all the required didactic course work and (3) successfully completed the qualifying examination and the oral comprehensive examination. To be admitted to candidacy, the student must be in good standing.

## Dissertation research

The student must complete at least 38 (students entering with M.S. degree) or at least 42 (students entering with B.S. degree) research and seminar credit hours conducting an original investigation under the guidance of the adviser and prepare a dissertation reporting the results of this research and comparing its significance in relation to existing scientific knowledge. Once the research is close to completion, no later than three months prior to the planned dissertation defense, the student should meet with their dissertation committee members. In order for the student to proceed toward dissertation defense, all committee members must certify that the student is ready to write the dissertation.

## Dissertation defense

In drafting the dissertation, the doctoral candidate is expected to follow all style and format guidelines outlined by VCU. The doctoral candidate will submit individual copies of the complete dissertation to the dissertation committee. If the committee accepts the dissertation for defense, the candidate appears before them for a final oral examination: the dissertation defense. This examination is open to all members of the faculty and students. There shall be an announcement of the candidate's name, department and title of dissertation, specifying day, place and time of the final oral examination at least 14 days in advance.

The final oral examination is normally limited to the subject of the candidate's dissertation and related matters. All committee members are required to vote, and a favorable decision by the dissertation committee with no more than one negative vote is required for passing the examination. The committee can approve the final oral examination conditionally, subject to corrections required by the committee, to the satisfaction of either the adviser or the entire dissertation committee.

All members of the committee should be present at the dissertation defense; in exceptional cases, the defense may go forward if no more than one committee member is absent but the absent committee member has to provide the student an opportunity to present and discuss the dissertation before voting. The dissertation adviser must be physically present at the final dissertation defense.

## Publication requirement

Since the Ph.D. is awarded for completion of work on an original research problem, peer-reviewed evidence of the quality of this work, in terms of at least one accepted journal paper or published high-quality conference paper in a student's research area and a second manuscript submitted for review to a journal or a high-quality conference must be approved by the dissertation committee and the CS graduate committee before the final oral examination can be scheduled.

## Optional training

Students enrolled in the program have an option to participate in additional non-technical training that will prepare them for future careers. Within the School of Engineering, students will be encouraged to take a course on career and professional development that will be focused on the process for making meaningful career choices, preparing and connecting these decisions and career goals, and gaining confidence in career development. Students will also be encouraged to participate in career training outside of School of Engineering, including the Preparing

Future Faculty Program and the Leaders and Entrepreneurs Academy for Professional Development offered by the VCU Academic Learning Transformation Lab and VCU Graduate School. PFFP is designed for graduate students interested in pursuing careers in higher education. It introduces students to the roles and responsibilities of higher education and addresses teaching and learning issues in the college classroom. The LEAPD program targets students seeking careers in industry, nonprofit organizations, health care, public service and government. Areas of study include how to start your own business, building networking skills, leadership, enhancing communication skills, resume writing, negotiation skills and opportunities for discovering alternative career paths. Both programs consist of a series of short one- or two-credit-hour courses that students can easily add into their schedules. These credits do not count toward the Ph.D. in Computer Science degree.

## Time to degree

Students in the Ph.D. program will be able to enroll on a full-time or part-time basis.

The time to degree will vary based on the entrance pathway. The typical time to degree for full-time post-bachelor's students in the program is four years. Students are required to attend during the fall and spring each year. Students with a B.S. degree are required to enroll full-time and are not permitted to attend on a part-time basis.

The typical time to degree for full-time post-master's students in the program is three years. Full-time students are required to attend during the fall and spring each year. Students entering with a master's degree may enroll on a part-time basis. The typical time to degree for part-time post-master's students in the proposed degree program is six years.

All requirements for the Ph.D. degree must be completed within eight years from the date of admission to the degree program.

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