



UNIVERSITY  
*of* VIRGINIA

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SCHOOL OF ENGINEERING  
AND APPLIED SCIENCE

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## Department of Computer Science Undergraduate Handbook

Bachelor of Science in Computer Science  
Bachelor of Arts in Computer Science  
Bachelor of Science in Computer Engineering  
Minor in Computer Science

<http://www.cs.virginia.edu>  
Valid for the 2011–2012 academic year

This undergraduate handbook was last updated in the fall of 2011.

Any version of this handbook dated during or after the summer or fall of 2011 is valid for the 2011-2012 academic year.

Any updates, both errata and addendums, to this version of the handbook will be listed at <http://www.cs.virginia.edu/bscs/>.

Any updates to degree requirements to any of the three programs will be reflected both on the individual degree programs' websites shown below, as well as the above URL.

The BS CS undergraduate website is at <http://www.cs.virginia.edu/bscs/>; the BA CS website is at <http://www.cs.virginia.edu/ba/>, and the BS CpE website is at <http://www.cpe.virginia.edu/ugrads/>.

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# Chapter 1

## Introduction

### 1.1 Introduction

Through the development of sophisticated computer systems, processors, and embedded applications, computer scientists have the opportunity to change society in ways unimagined several years ago. Our goal is the education and training of a diverse body of students who can lead this information technology revolution. To this end, the computing programs orient students toward the pragmatic aspects of computing and provides the learning and practices to make them proficient computing professionals. Computational thinking is rooted in solid mathematics and science, and grounding in these fundamentals is essential. Our laboratory environment exposes students to many commercial software tools and systems, and introduces modern software development techniques. In the context of the practice of computing, this early grounding forms the basis for an education that prepares students for a computing career.

Students have opportunities to participate in cutting-edge research with department faculty members. From the senior thesis research project to independent study, students can pursue research in any conceivable area. Our former students are enrolled in top graduate programs across the country. Our undergraduates have won many research awards, including multiple CRA (Computing Research Association) research awards in the previous academic year. In fact, of all the institutions, UVa is third in overall CRA research awards won.

All graduates of our three computing programs will have the knowledge and skills to be practitioners and innovators in computing and other fields. They will be able to apply computational thinking in the analysis, design and implementation of computing solutions, whether working alone or as part of a team. The knowledge and skills acquired from our degree programs will give students the ability to make contributions after graduation in their own field as well as to society at large.

A recent Bureau of Labor Statistics Occupational Outlook Handbook states that “very favorable opportunities” (more numerous job openings compared to job seekers) can be expected for college graduates with at least a bachelors degree in computer engineering. It also projects an employment increase of over 38% by 2016 for occupations available to graduates with a bachelors degree in computer engineering<sup>1</sup>.

### 1.1.1 Diversity Statement

The members of the department envision an environment where a diversity of capable, inspired individuals congregate, interact and collaborate, to learn and advance knowledge, without barriers. We embrace this vision because:

- We wish to be leaders and role models in reaping and sharing the benefits of diversity.
- We seek to improve the intellectual environment and creative potential of our department.
- We expect to produce happier, more capable and more broadly educated computer science graduates.
- We wish to contribute to social justice and economic well being for all citizens.

## 1.2 Degrees Offered

The Department of Computer Science offers three computing degrees, as well as a minor.

- Bachelor of Science (BS in CS) in Computer Science, available to students in the School of Engineering and Applied Sciences (SEAS).
- Bachelor of Arts in Computer Science (BA in CS), available to students in the College of Liberal Arts and Sciences (CLAS).
- Bachelor of Science in Computer Engineering (BS in CpE), available to students in the School of Engineering and Applied Sciences (SEAS). This degree is shared with the Department of Electrical and Computer Engineering.
- MINOR in Computer Science, available to students in either SEAS or CLAS.

Details of the degrees are provided later in this document, but in this section we explain the differences between computer science and computer engineering. This explanation is adopted from the ACM and IEEE’s

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<sup>1</sup><http://www.bls.gov/oco>

Computing Curricula 2005: The Overview Report<sup>2</sup>. We also give a high-level overview of the difference between our BS and BA degrees in computer science.

### 1.2.1 What is Computer Science?

Computer science spans a wide range, from its theoretical and algorithmic foundations to cutting-edge developments in graphics, intelligent systems, cybersecurity, and other exciting areas. We can think of the work of computer scientists as falling into three categories.

- They design and implement software. Computer scientists take on challenging programming jobs. They also supervise other programmers, keeping them aware of new approaches.
- They devise new ways to use computers. Progress in the CS areas of networking, database, and human-computer-interface enabled the development of the World Wide Web. Now CS researchers are working with scientists from other fields to develop control physical sensors and devices, to use databases to create new knowledge, and to use computers to help doctors solve complex problems in medical care.
- They develop effective ways to solve computing problems. For example, computer scientists develop the best possible ways to store information in databases, send data over networks, and display complex images. Their theoretical background allows them to determine the best performance possible, and their study of algorithms helps them to develop new approaches that provide better performance.

Computer science spans the range from theory through programming. While some universities offer computing degree programs that are more specialized (such as software engineering, bioinformatics, etc.), a degree in computer science offers a comprehensive foundation that permits graduates to adapt to new technologies and new ideas.

### 1.2.2 Comparison of the BA & BS Computer Science Degrees

At the University of Virginia, we offer two different computer science degrees:

- the Bachelor of Science (BS) degree, through the School of Engineering and Applied Sciences (SEAS), and
- the Interdisciplinary Major in Computer Science, a Bachelor of Arts (BA) degree, through the College of Liberal Arts and Sciences (CLAS).

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<sup>2</sup><http://www.acm.org/education/curricula-recommendations>

The following gives a high-level comparison of these two degrees.

The BS in Computer Science degree program includes the set of core courses required of every other engineering degree in SEAS. These include an introduction to engineering, physics, chemistry, calculus, courses focused on the engineer's role in society, and at least five courses in the humanities or social sciences. Like other engineering majors, all students in our BS program complete a year-long project leading to a senior thesis in their fourth year. Students in the BS program can minor in another engineering discipline or applied math. It is also possible to minor in a subject from the College of Arts and Sciences (but it's more difficult to have a second major in a College subject). Students in the BS program must complete at least 46 credits of computer science courses. The Bachelor of Science in Computer Science is accredited by the Computing Accreditation Commission of ABET<sup>3</sup>.

The BA in Computer Science degree program includes the same general requirements (known as core and competency requirements) as all other liberal arts and science degrees in CLAS. These include courses in foreign language, writing, historical studies, social science, humanities, and non-western perspectives. These general requirements also include natural science and mathematics, but fewer courses than are required for the BSCS in engineering. Students in the BA program are in a good position to major or minor in another subject in CLAS. Students with a GPA of 3.4 or better may apply to the Distinguished Majors Program, in which students complete a thesis based on two semesters of empirical or theoretical research. Students in the BA program must complete at least 27 credits of computer science courses along with 12 additional credits of "integration electives", which are computing-related courses taught by another department other than the CS department. Students in the BA have the option of taking a version of the first two computing courses that differ from those taken by the BS students, but otherwise students from both degree programs share the same CS courses.

Graduates of both programs have been accepted to the best graduate programs, have received job offers from leading companies, etc. A few employers have shown a preference for graduates from one program or the other, but in general both degrees prepare students for excellent opportunities after graduation.

Students who apply to the University of Virginia must choose to apply for admission to either SEAS (the engineering school) or CLAS (the College of Liberal Arts and Sciences). It is possible to transfer from one unit to the other after admission, and since we offer degrees in both units a student can major in computer science in either.

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<sup>3</sup><http://www.abet.org>

### 1.2.3 What is Computer Engineering?

Computer engineering is concerned with the design and construction of computers and computer-based systems. It involves the study of hardware, software, communications, and the interaction among them. Its curriculum focuses on the theories, principles, and practices of traditional electrical engineering and mathematics and applies them to the problems of designing computers and computer-based devices.

Computer engineering students study the design of digital hardware systems including communications systems, computers, and devices that contain computers. They study software development, focusing on software for digital devices and their interfaces with users and other devices. At the University of Virginia, the CpE degree has a balanced emphasis on hardware and software.

At the University of Virginia, computer engineering degrees are jointly designed and administered by the Department of Computer Science and the Department of Electrical and Computer Engineering. The degree program is composed of courses from both departments.

### 1.2.4 ABET accreditation

The Bachelor of Science in Computer Science is accredited by the Computing Accreditation Commission of ABET<sup>4</sup>. The Bachelor of Science in Computer Engineering is accredited by the Engineering Accreditation Commission of ABET<sup>4</sup>.

## 1.3 Course Numbering

Starting with the fall 2009 semester, the University of Virginia changed all course numbers to 4-digit numbers from the old 3-digit number system. Whenever possible, the course numbers in this version of the handbook will use both the 3-digit number and the four digit number, in the form of "CS 1110 (101)" to allow people to transition from the old numbers to the new numbers.

The table below lists the mapping of the old course numbers to the new course numbers; it is sorted by the old course numbers.

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<sup>4</sup><http://www.abet.org>

<b>Old</b>	<b>New</b>	<b>Title</b>
CS 100T	CS 1000T	Non-UVa Transfer/Test Credit
CS 101	CS 1110	Introduction to Computer Science
CS 101E	CS 1111	Introduction to Computer Science
CS 101X	CS 1112	Introduction to Computer Science
CS 110	CS 1010	Introduction to Information Technology
CS 120	CS 1020	Introduction to Business Computing
CS 150	CS 1120	Introduction to Computing: Language, Logic, and Machines
CS 200T	CS 2000T	Non-UVa Transfer/Test Credit
CS 201	CS 2110	Software Development Methods
CS 202	CS 2102	Discrete Mathematics I
CS 205	CS 2220	Engineering Software
CS 216	CS 2150	Program and Data Representation
CS 230	CS 2330	Digital Logic Design
CS 290	CS 2190	Computer Science Seminar I
CS 300T	CS 3000T	Non-UVa Transfer/Test Credit
CS 302	CS 3102	Theory of Computation
CS 305	CS 3205	HCI in Software Development
CS 333	CS 3330	Computer Architecture
CS 340	CS 3240	Advanced Software Development Techniques
CS 400T	CS 4000T	Non-UVa Transfer/Test Credit
CS 414	CS 4414	Operating Systems
CS 415	CS 4610	Programming Languages
CS 416	CS 4710	Artificial Intelligence
CS 425	CS 4630	Defense against the Dark Arts
CS 432	CS 4102	Algorithms
CS 433	CS 4330	Advanced Computer Architecture
CS 434	CS 4434	Fault-tolerant Computing
CS 441	CS 4240	Principles of Software Design
CS 444	CS 4444	Introduction to Parallel Computing
CS 445	CS 4810	Introduction to Computer Graphics
CS 453	CS 4753	Electronic Commerce Technologies
CS 457	CS 4457	Computer Networks
CS 458	CS 4458	Internet Engineering
CS 462	CS 4750	Database Systems
CS 471	CS 4620	Compilers
CS 493	CS 4993	Independent Study
CS 494	CS 4501	Special Topics in Computer Science
CS 495	CS 4998	Distinguished BA Majors Research

The registrar provides an online course renumbering website<sup>5</sup> to help

<sup>5</sup><http://www.virginia.edu/registrar/search.php>

determine the mapping between old 3-digit and new 4-digit course numbers.

Courses that have been created since the change from 3-digit to 4-digit course numbers, such as CS 4720 (Web and Mobile Systems) and CS 4730 (Computer Game Design), are not listed in the table.

### 1.3.1 Course Numbering Methodology

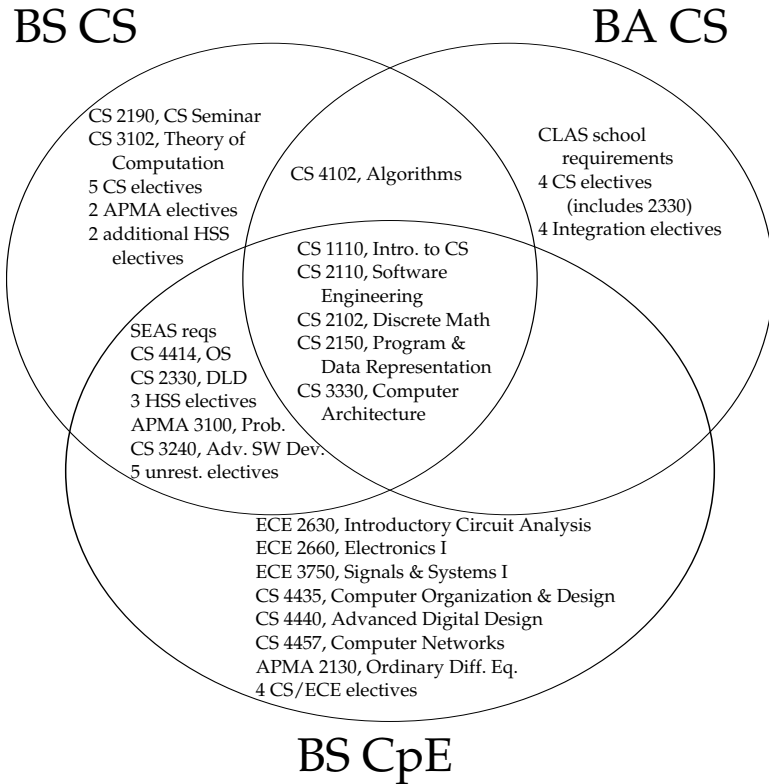
The new 4-digit course numbers follow a system developed by the department. The first digit is the year that the course is expected to be taken. The second digit specifies the type of course, as shown below. The third and fourth digits attempted to keep the previous last two digits of the 3-digit course number, although that was not always possible.

The 2nd digit numbering scheme is:

- x000 service courses, courses for non-majors, general interest
- x100 core, fundamentals, theoretical (a broad category)
- x200 SW development-oriented courses (note in ECE, this will be for electronics courses)
- x300 hardware, architecture, etc.
- x400 computer systems
- x500 by University rule: “special-topics and variable one-time offerings”
- x600 languages, compilation, etc.
- x700 application areas including AI, databases, etc.
- x800 computer graphics
- x900 by University rule: thesis, dissertation, independent study, capstone, etc.

Note that currently cross-listed courses with ECE fall in the x300 and x400 categories.

## 1.4 Major Course Requirements Comparison



The SEAS school requirements consist of:

- APMA 1110 & 2120
- CHEM 1610 & 1611
- ENGR 1620
- PHYS 1425 & 1429
- PHYS 2415 & 2419
- Science elective
- STS 1500
- STS 2xxx/3xxx elective
- STS 4500 & 4600

The CLAS school requirements consist of:

- First & second writing requirements
- Foreign language requirement
- 6 credits of social sciences
- 6 credits of humanities
- 3 credits of historical studies
- 3 credits of non-western perspectives
- 12 credits of natural science and math

# Chapter 2

## Bachelors of Science in Computer Science

### 2.1 Introduction

The Bachelor of Science degree in Computer Science is a wide-ranging program, encompassing both the theoretical and the practical. The BS program builds upon the engineering and mathematical principles introduced in the Engineering school's core curriculum. Our students are taught to apply computing to the world around them by building faster, smaller, and more secure software systems, exploring emerging technologies, and working on real-world problems. Our courses focus on teaching students how to recognize computational challenges, create elegant and efficient algorithms, and then use rigorous development methodologies to build systems that can solve pressing problems. Graduates of the BS program find successful careers with traditional software companies, government agencies, consulting firms, academia, and companies in other fields that have software needs. Computing professions are often ranked near the top in "Best Job" lists put together by news organizations for job availability, pay, and satisfactions.

Course work in the BS CS program starts with several courses that introduce the basic principles of software creation, from learning programming languages to advanced development techniques. Once students have mastered the basics, the bulk of our program opens up, offering electives in several exciting fields, including networking, security, game design, web programming, e-commerce, parallel computing, and much more. Students have the opportunity to take several electives each semester, as our department offers more electives than the other departments in the Engineering school.

## 2.2 Curriculum

### 2.2.1 Recommended Course of Study

Below is the recommended course of study for the bachelor's degree. If you have already completed some of these classes (through AP credit, for example), then your course of study would deviate from what is shown below – consult your academic advisor for details.

There are a total of 8 electives that the student can choose from. These electives are indicated by the footnotes below, and are described in detail beginning on page 10. Note that some of these requirements are for all SEAS students, while others are required for the CS bachelor's degree. Please be aware of when the classes are offered! Some are only offered once per year, or in a particular semester. See page 44 for details as to when courses are offered.

The recommended schedule shown below has changed slightly each year as the degree requirements have evolved. As discussed in the Degree Requirement Revisions (page 51), a student can graduate using any set of requirements that were in effect when they became a declared computer science major. Thus, as long as all the major requirements are met, students can follow any version of the recommended course schedule.

Academic requirements are managed by SIS (the Student Information System, UVas system for handling academic requirements and registration) A sample of the BS CS requirement listing can be found online<sup>1</sup>; your individual one can be found via SIS. You may also want to see the FAQ question about how HSS requirements list in the SIS report (see page 43).

### 2.2.2 Elective Information

The numbers in the list below correspond to the footnote numbers from the sample course schedule shown starting on page 14.

1. Science elective (1 required): Students must choose one of BIOL 2010 (201) (Introduction to Biology: Cell Biology and Genetics), BIOL 2020 (202) (Introduction to Biology: Organismal and Evolutionary Biology), CHEM 1620 (152) (Introductory Chemistry for Engineers), ECE 2066 (200) (Science of Information), ENGR 2500 (Introduction to Nanoscience and Technology), MSE 2090 (209) (Introduction to the Science and Engineering of Materials), or PHYS 2620 (252) (Introductory Physics IV: Quantum Physics). Additional courses in this list can count as an unrestricted elective.
2. HSS electives (5 required): Studies in the humanities and social sciences serve not only to meet the objectives of a broad education, but

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<sup>1</sup><http://www.cs.virginia.edu/bscs/bscs-reqs-in-sis.pdf>

also to meet the objectives of the engineering profession. Such course work must meet the generally accepted definitions that the humanities are the branches of knowledge concerned with humankind and its culture, while the social sciences are the studies of society. See the full list of allowed courses in the SEAS Undergraduate Handbook. This list can be found online<sup>2</sup>. Note that there are a number of courses that do not count as HSS electives, but would count as an unrestricted elective. See that URL for details.

3. Unrestricted elective (5 required): Any graded course in the University, with a few exceptions. From the SEAS Undergraduate Student Handbook<sup>3</sup>: All Unrestricted Electives may be chosen from any graded course in the University except mathematics courses below MATH 1310 (131), including STAT 1100 (110) and 1120 (112), and courses that substantially duplicate any others offered for the degree, including PHYS 2010 (201), PHYS 2020 (202), CS 1010 (110), or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should obtain the approval of their advisor and the dean's office, Thornton Hall, Room A122. APMA 1090 (109) counts as a three credit unrestricted elective for students. Band classes (such as marching band) and ROTC classes can count for the unrestricted elective.
4. APMA elective (2 required): Must choose two from: APMA 2130 (213) (Ordinary Differential Equations), APMA 3080 (308) (Linear Algebra) or APMA 3120 (312) (Statistics). Note that APMA 3100 (310) (Probability) is a required course in addition to the two APMA electives.
5. CS electives (5 required): Any 3 credit CS class at the 3000 level or above. A course that is fulfilling another requirement can not also count as a CS elective. If you take more than five CS electives, you can count additional CS elective course(s) as unrestricted electives. ECE 4435 (435) (Computer Organization & Design) and ECE 4440 (436) (Advanced Digital Design) also count as a CS electives (this is not the case for CpE majors, as they are both required courses for CpE). Note, however, that those two courses only count as *one* CS elective each; those 9 credits (each is worth 4.5 credits) do not count as 3 CS electives. And in order for them to be counted, a SIS exception must be entered – see section 7.2.8 on page 43 for details. CS 4993 (493) (Independent Study) can be used at most once for a CS elective (i.e. no more than 3 credits); additional CS 4993 (493) credits can be used as unrestricted electives. Note that for a class that does

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<sup>2</sup><http://www.seas.virginia.edu/advising/undergradhandbook.php#hss>

<sup>3</sup><http://www.seas.virginia.edu/advising/undergradhandbook.php>

not meet these requirements to count as a CS elective requires approval by the CS undergraduate curriculum committee (NOT by the student's academic advisor). Due to substantial overlap, one cannot get credit for both ECE 4435 (435) and CS 4330 (433). Thus, if a student takes both of those classes, the other one can ONLY count as a unrestricted elective.

6. STS 2xxx/3xxx elective (1 required): Any STS course at the 2000-level or 3000-level.

Note that classes that receive no grade (including classes that are audited) do not count toward your degree requirements.

## 2.2.3 Degree Requirements Checklist

Required computing & math courses	Grade	Semester	Comments?
CS 1110: Intro. to Computer Science			
CS 2110: Software Development Methods			
CS 2102: Discrete Mathematics I			
CS 2150: Program & Data Representation			
CS/ECE 2330: Digital Logic			
CS 2190: CS Seminar I			
CS 3102: Theory of Computation			
CS/ECE 3330: Computer Architecture			
CS 3240: Advanced SW Devel. Tech.			
CS 4414: Operating Systems			
CS 4102: Analysis of Algorithms			
APMA 3100: Probability			
APMA 2130 or 3080 or 3120 (circle one)			
APMA 2130 or 3080 or 3120 (circle one)			

### SEAS required courses

Course	Grade	Semester
APMA 1110		
APMA 2120		
CHEM 1610		
CHEM 1611		
ENGR 1620		
PHYS 1425		
PHYS 1429		
PHYS 2415		
PHYS 2419		

### Science elective

Course	Grade	Semester

### HSS electives (5)

	Course	Grade	Semester
1)			
2)			
3)			
4)			
5)			

### STS courses

Course	Grade	Semester
STS 1010/1500		
STS 2xxx/3xxx		
STS 4010/4500		
STS 4020/4600		

### CS Electives (5)

	Course	Grade	Semester
1)			
2)			
3)			
4)			
5)			

### Unrestricted electives (5)

	Course	Grade	Semester
1)			
2)			
3)			
4)			
5)			

## 2.2.4 Sample BS CS Course Schedule

<u>First semester</u>		<u>15</u>
APMA 1110 (111)	Single Variable Calculus	4
CHEM 1610 (151)	Chemistry for Engineers	3
CHEM 1611 (151L)	Chemistry Lab	1
ENGR 1620 (162)	Introduction to Engineering	4
STS 1010/1500 (101)	Engineering, Technology & Society	3
<u>Second semester</u>		<u>17</u>
APMA 2120 (212)	Multivariate Calculus	4
PHYS 1425 (142E)	Physics I	3
PHYS 1429 (142W)	Physics I Workshop	1
CS 1110 (101)	Intro to Computer Science	3
SCI	Science elective <sup>1</sup>	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
<u>Third semester</u>		<u>16</u>
APMA	APMA elective <sup>4</sup> or APMA 3100 (310)	3
CS 2110 (201)	Software Development Methods	3
CS 2102 (202)	Discrete Mathematics	3
PHYS 2415 (241E)	General Physics II	3
PHYS 2419 (241W)	General Physics Lab I	1
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
<u>Fourth semester</u>		<u>16</u>
CS 2150 (216)	Program and Data Representation	3
CS/ECE 2330 (230)	Digital Logic Design	3
CS 3102 (302)	Theory of Computation	3
CS 2190 (290)	CS Seminar	1
STS STS	2xx/3xx elective <sup>6</sup>	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
<u>Fifth semester</u>		<u>15</u>
CS/ECE 3330 (333)	Computer Architecture	3
CS 4102 (432)	Algorithms	3
APMA	APMA elective <sup>4</sup> or APMA 3100 (310)	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3

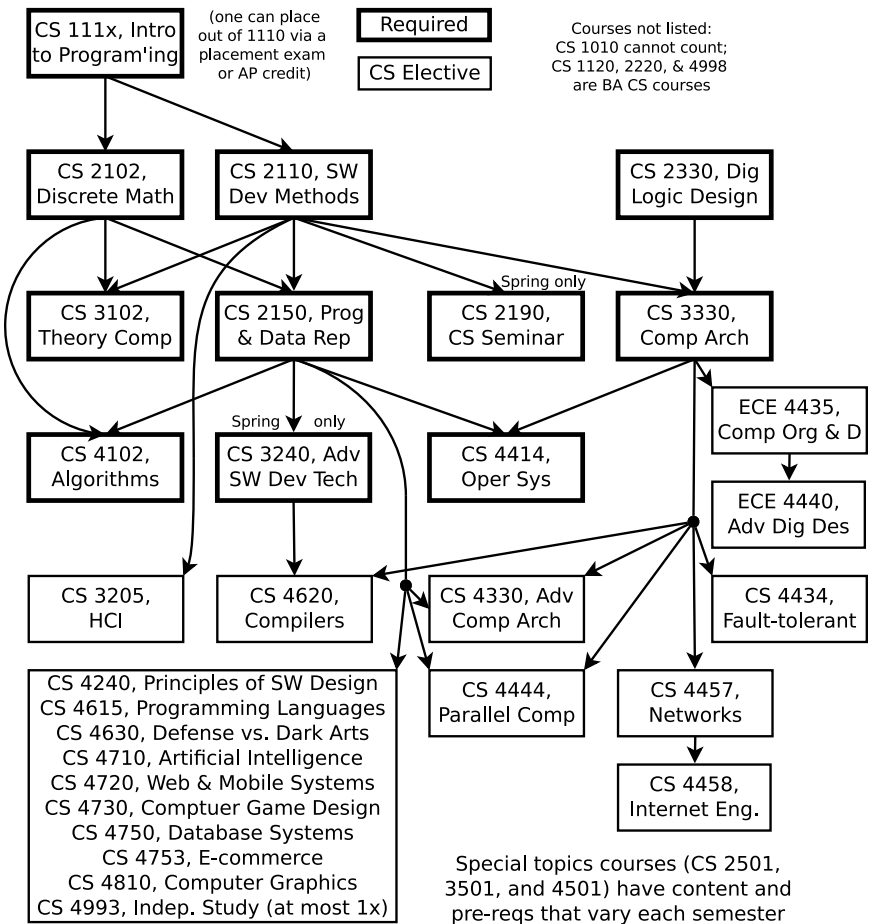
<u>Sixth semester</u>		<u>15</u>
CS 3240 (340)	Advanced Software Development	3
CS	CS elective <sup>5</sup>	3
APMA	APMA elective <sup>4</sup> or APMA 3100 (310)	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
<u>Seventh semester</u>		<u>15</u>
STS 4010/4500 (401)	Western Tech and Culture	3
CS	CS elective <sup>5</sup>	3
CS	CS elective <sup>5</sup>	3
CS 4414 (414)	Operating Systems	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
<u>Eighth semester</u>		<u>15</u>
STS 4020/4600 (402)	Engineer in Society	3
CS	CS elective <sup>5</sup>	3
CS	CS elective <sup>5</sup>	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3
HSS/UE	HSS or unrestricted elective <sup>2,3</sup>	3

## 2.3 Miscellaneous Information

### 2.3.1 CS 2190 (290) Specific Details

While students can take courses in any semester, there is an issue to consider with CS 2190 (290): this course should be taken in the second year or (less preferably) the third year. If a student reaches his/her fourth year without taking the course, then s/he must take a 3 credit in ethics and technology in its place (even though CS 2190 (290) is only 1 credit). This course taken in place of CS 2190 (290) does not count towards any other requirement except to replace CS 2190 (290).

## 2.4 Course Requirements Flowchart



## Chapter 3

# Bachelors of Arts in Computer Science

### 3.1 Introduction

Computer Science is the study of information processes. Computer scientists learn how to describe information processes, how to reason about and predict properties of information processes, and how to implement information processes elegantly and efficiently in hardware and software. The Computer Science major concentrates on developing the deep understanding of computing and critical thinking skills that will enable graduates to pursue a wide variety of possible fields and to become academic, cultural, and industrial leaders in areas that integrate the arts and sciences with computing. The Computer Science major is designed to provide students entering the University without previous background in computing with an opportunity to major in Computer Science, while taking courses in arts, humanities, and sciences to develop broad understanding of other areas and their connections to computing. Computing connects closely with a wide range of disciplines including, but not limited to, the visual arts, music, life sciences including biology and cognitive science, the physical sciences, linguistics, mathematics, and the social sciences. The core curriculum focuses on developing methods and tools for describing, implementing, and analyzing information processes and for managing complexity including abstraction, specification, and recursion.

### 3.2 Curriculum

**Prerequisites** Before declaring the computer science major, all students should have taken one introductory computer science course (either CS

1120 (150), CS 1110 (101), CS 1111 (101-E), or CS 1112 (101-X)) with a grade of C+ or better, or have comparable experience. Students may be permitted to declare the major while they are currently taking the introductory course.

The major requires the College Competency and Area Requirements<sup>1</sup> as well as at least 27 credits in Computer Science courses and 12 credits in Integration Electives.

### 3.2.1 Required “Core” Courses

The following courses are required for all BA CS majors. Full descriptions can be found in the Course Descriptions section (page 44).

- CS 2110 (201), Software Development Methods, or CS 2220 (205), Engineering Software
- CS 2102 (202), Discrete Math
- CS 2150 (216), Program and Data Representation
- CS 3330 (333), Computer Architecture
- CS 4102 (432), Algorithms

Note that the CS1 class, either CS 111x (101/101E/101X), Introduction to Programming, or CS 1120 (150), Introduction to Computing: Language, Logic, and Machines, is required to enroll in CS 2110 (201) or CS 2220 (205), respectively.

### 3.2.2 CS Electives

Four computing-intensive electives are to be selected from a list of approved courses. The list of approved courses will initially comprise current Computer Science courses at 3000-level or above as well as CS 2330. Additional courses that may be jointly offered by CLAS and CS departments will be added to the list of approved computing electives based on approval by the BA committee.

### 3.2.3 Integration Electives

Four courses selected with the approval of the student’s advisor from the list of computing-related courses approved by the BA CS committee. These courses are offered by departments other than Computer Science, and should either provide fundamental computing depth and background or explore applications of computing to arts and sciences fields.

This is a list of the courses that are generally approved as integration electives. This list is not meant to be exhaustive: if you find a course that is not on the list that appears to satisfy the goals of an integration elective,

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<sup>1</sup><http://artsandsciences.virginia.edu/college/requirements/index.html>

discuss with your advisor or the BA Program Director if it should count as an integration elective for you.

Some of these courses are not offered regularly, and some courses may have prerequisites. Courses listed in **bold** are courses that are offered regularly and are among the most commonly taken integration electives.

See online<sup>2</sup> for an up-to-date list of approved integration electives.

## Arts

- ARCH 5420 (Digital Animation & Storytelling)
- ARCH 5710 (Photography and Digital Media)
- DRAM 2620/2630 (Sound Design and Sound Lab)
- DRAM 2110 (Lighting Design)
- DRAM 3210 (Scene Design)
- **MDST 2010 (Introduction to Digital Media)**
- MDST 3050 (History of Media)
- MDST 3703 (Introduction to the Digital Liberal Arts)
- MUSI 2350 (Technosonics and Digital Music)
- MUSI 3390 (Introduction to Music and Computers)
- MUSI 7350 (Interactive Media)
- MUSI 4543 (Sound Studio)

## Mathematics and Logic

- **ECE 2066 (Science of Information)**
- MATH 1160 (Algebra, Number Systems, and Number Theory)
- MATH 3000 (Transition to Higher Mathematics)
- MATH 3351 (Elementary Linear Algebra)
- MATH 3354 (Survey of Algebra)
- MATH 5653 (Number Theory)
- MATH 5110 (Introduction to Stochastic Processes)
- PHIL 1410 (Forms of Reasoning)
- **PHIL 2420 (Introduction to Symbolic Logic)**
- PHIL 5420 (Symbolic Logic)
- STAT 2120 (Introduction to Statistical Analysis)
- STAT 5000 (Introduction to Applied Statistics)
- STAT 5330 (Data Mining/Machine Learning)

(Note: MATH 4040 (Discrete Mathematics) is not included because of overlap with CS 2102.)

## Life Sciences

- BIOL 3170 (Introduction to Neurobiology)

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<sup>2</sup><http://www.cs.virginia.edu/ba/integration.html>

- BIOL 3240 (Introduction to Immunology)
- BIOL 4050 (Developmental Biology)
- BIOL 4130 (Population Ecology and Conservation Biology)
- BIOL 4160 (Functional Genomics)
- BIOL 4170 (Cellular Neurobiology)
- BIOL 4250 (Human Genetics)
- BIOL 4480 (Macromolecular Structure)
- BIOL 5080 (Developmental Mechanisms)
- BIOM 3310 (Biomedical Systems Analysis and Design)
- BIOM 3315 (Computational Biomedical Engineering)
- BME 3636 (Neural Network Models)
- PHIL 2330 (Computers Minds and Brains)
- **PSYC 2150 (Introduction to Cognition)**
- PSYC 2200 (A Survey of the Neural Basis of Behavior)
- **PSYC 2300 (Introduction to Perception)**
- PSYC 4200 (Neural Mechanisms of Behavior)
- PSYC 4300 (Theories of Perception)
- NESC 5330 (Neural Network Models)

### Physical Sciences

- EVSC 3020 (GIS Methods)
- EVSC 5020 (Introduction to Geographic Information Systems)
- EVSC 5030 (Applied Statistics for Environmental Scientists)
- PHYS 2660 (Fundamentals of Scientific Computing)
- **PHYS 5630 (Computational Physics I)**
- PHYS 5640 (Computational Physics II)

### Social Sciences

- ANTH 2430 (Languages of the World)
- ANTH 3490 (Language and Thought)
- ANTH 5040 (Linguistic Field Methods)
- ANTH 5410 (Phonology)
- ANTH 5420 (Theories of Language)
- **ECON 4010 (Game Theory)**
- **ECON 4020 (Auction Theory and Practice)**
- ECON 4720 (Introductory Econometrics)
- ECON 4880 (Seminar in Policy Analysis)
- HIST 4510 (From Vellum to Very Large Databases)
- LNCS 3250 (Introduction to Linguistic Theory and Methodology)
- PSYC 4110 (Psycholinguistics)

**Using other courses.** If a student would like to use a course not on the above list as an integration elective, they should first contact their academic advisor. Their advisor can work with the student to come up with

a good argument as to why the course should qualify, and once the advisor approves it, send it to the BA CS Director of Undergraduate Programs (DUP) (currently David Evans (evans@virginia.edu)). Alternatively, if the advisor prefers, s/he can just send the student to DUP to get approval for a requirement exception.

### 3.3 Miscellaneous Information

#### 3.3.1 Declaring the Major

Before declaring the computer science major, students should have taken one introductory computer science course (CS 111x (101, 101E, 101x), Introduction to Programming, or CS 1120 (150), Introduction to Computing: Language, Logic, and Machines) with a grade of C+ or better, or have comparable experience. Students may be permitted to declare the major while they are currently taking the introductory course.

To declare the major:

1. Satisfy the major prerequisite by taking one of the introductory computer science courses. CS 1120 (150) is the recommended course for most BA CS majors, but the other introductory courses (CS 1110 CS1111, and CS 1112) can also be used to satisfy the prerequisite. You may declare the major before completing the course as long as you are on track to complete the course successfully. If you believe you have comparable experience in some other way, you may also be able to declare the major.
2. Pick up a Major Declaration Form from the Dean's office, and fill out the top half.
3. Arrange to meet with David Evans (evans@virginia.edu), Director of the Undergraduate Program (DUP). You can email to arrange a meeting time, or drop by his office hours.

#### 3.3.2 Distinguished Majors Program

BS CS majors who have completed 18 credit hours towards their major and who have a cumulative GPA of 3.4 or better may apply to the Distinguished Majors Program. Students who are accepted must complete a thesis based on two semesters of empirical or theoretical research. The Distinguished Majors Program features opportunities for students and advisors to collaborate on creative research; it is not a lock-step thesis program with strict content requirements. Upon successful completion of the program, students will likely be recommended for a baccalaureate award of Distinction, High Distinction, or Highest Distinction.

Students applying to the DMP must have a minimum cumulative GPA of 3.4 and have completed 18 credit hours towards their Computer Sci-

ence major by the end of the semester in which they apply. These 18 credit hours can come from any course used to fulfill the “Major Subject Requirements”, “Computing Electives” or “Integration Electives” of the (Exceptions to the 18 credit hours rule may be granted at the discretion of the Distinguished Majors Program Director.)

In addition to the normal requirements for the computer science major, they must register for two semesters of supervised research (CS 4998 (495) for 3 credits each semester). Students may apply to the DMP before completing this supervised research, but students must complete the supervised research to complete the DMP. Based on their independent research, students must complete, to the satisfaction of their advisor and the Distinguished Major Program Director, a project at least one month prior to graduation.

Please note: The CS 4998 DMP credits do not apply towards the credit hours required for the major. That is, they cannot be used to fulfill any requirement listed on the BA CS curriculum.

For more information on the DMP, see online<sup>3</sup>. You may also contact Westley Weimer ([weimer@virginia.edu](mailto:weimer@virginia.edu)), who is in charge of the BA DMP program.

### 3.3.3 Double majors in CLAS

From the CLAS website on majors (<sup>4</sup>), regarding double majors:

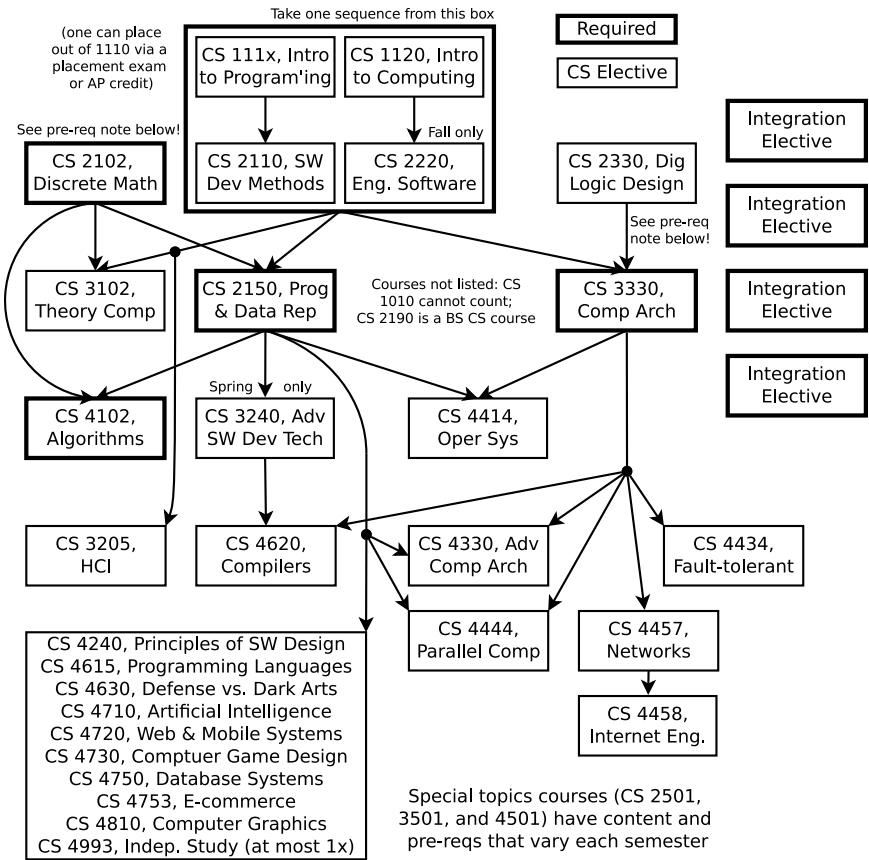
You may major in two subjects, in which case the application for a degree must be approved by both departments or inter-departmental programs. Students who double major must submit at least 18 credits in each major; these credits may not be duplicated in the other major. There is no triple major.

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<sup>3</sup><http://www.cs.virginia.edu/ba/dmp/>

<sup>4</sup>[http://artsandsciences.virginia.edu/college/major/major\\_type.html](http://artsandsciences.virginia.edu/college/major/major_type.html)

### 3.4 Course Requirements Flowchart



Notes:

- CS 2102 requires *either* CS 111x or CS 1220 as a prerequisite.
- Some instructors may not enforce CS 2330 as a prerequisite for CS 3330; check with the individual instructors to be sure.



# Chapter 4

## Bachelors of Science in Computer Engineering

### 4.1 Introduction

Computer Engineering is an exciting field that spans topics across electrical engineering and computer science. Students learn and practice the design and analysis of computer systems, including both hardware and software aspects and their integration. Careers in Computer Engineering (CpE) are as wide and varied as computer systems themselves, which range from embedded computer systems found in consumer products or medical devices, to control systems for automobiles, aircraft, and trains, to more wide-ranging applications in entertainment, telecommunications, financial transactions, and information systems.

#### 4.1.1 Program Objectives

Graduates of the Computer Engineering program at the University of Virginia utilize their academic preparation to become successful practitioners and innovators in computer engineering and other fields. They analyze, design and implement creative solutions to problems with computer hardware, software, systems and applications. They contribute effectively as team members, communicate clearly and interact responsibly with colleagues, clients, employers and society.

Faculty from the Computer Science and Electrical & Computer Engineering departments jointly administer the CpE undergraduate degree program at the University of Virginia.

The Computer Engineering program does not offer a minor.

## 4.2 Curriculum

Our curriculum has been carefully designed to ensure that the students obtain an excellent background in both Computer Science and Electrical Engineering, providing breadth across these disciplines as well as depth in at least one. All Computer Engineering students work through an extended sequence of introductory, intermediate and advanced courses:

- CS 1110 (101) Introduction to Computer Science
- CS 2110 (201) Software Development Methods
- CS 2102 (202) Discrete Math
- ECE 2630 (203) Introductory Circuit Analysis
- ECE 2660 (204) Electronics I
- CS 2150 (216) Program and Data Representation
- ECE/CS 2330 (230) Digital Logic Design
- ECE 3750 (323) Signals & Systems I
- CS/ECE 3330 (333) Computer Architecture
- CS 3240 (340) Advanced Software Development
- CS 4414 (414) Operating Systems
- ECE 4435 (435) Computer Organization & Design
- ECE 4440 (436) Advanced Digital Design
- CS/ECE 4457 (457) Computer Networks

Please Note: Course numbers changed in 2009. The old course numbers are shown in parentheses.

In addition to providing breadth across the two areas, this core of the Computer Engineering program provides depth in the following areas:

### Circuits

- ECE 2630 (203): Introductory Circuit Analysis
- ECE 2660 (204): Electronics I

### Software Engineering

- CS 2110 (201): Software Development Methods
- CS 3240 (340): Advanced Software Development

### Digital Logic

- ECE/CS 2330 (230): Digital Logic Design
- CS 2102 (202): Discrete Math

## Computer Systems

- CS 2150 (216): Program and Data Representation
- CS/ECE 3330 (333): Computer Architecture
- CS 4414 (414): Operating Systems
- ECE 4435 (435): Computer Organization & Design
- ECE 4436 (436): Advanced Digital Design
- CS/ECE 4457 (457): Computer Networks

### 4.2.1 Grade Requirement

In completing their program of study, computer engineering majors must achieve a C average or better in their Computer Science and Electrical Engineering courses.

### 4.2.2 Sample BS CpE Course Schedule

<u>First semester</u>		<u>15</u>
APMA 1110 (111)	Single Variable Calculus	4
CHEM 1610 (151)	Chemistry for Engineers	3
CHEM 1611 (151L)	Chemistry Lab	1
ENGR 1620 (162)	Introduction to Engineering	4
STS 1010/1500 (101)	Engineering, Technology & Society	3
 <u>Second semester</u>		 <u>17</u>
APMA 2120 (212)	Multivariate Calculus	4
PHYS 1425 (142E)	Physics I	3
PHYS 1429 (142W)	Physics I Workshop	1
CS 1110 (101)	Intro to Computer Science	3
SCI	Science elective <sup>2</sup>	3
HSS	HSS elective <sup>1</sup>	3
 <u>Third semester</u>		 <u>16</u>
APMA 2130	Ordinary Differential Equations	4
CS 2110 (201)	Software Development Methods	3
CS 2102 (202)	Discrete Mathematics	3
ECE 2630 ()	Introductory Circuit Analysis	3
HSS	HSS elective <sup>1</sup>	3

<u>Fourth semester</u>		<u>16</u>
CS 2150 (216)	Program and Data Representation	3
CS/ECE 2330 (230)	Digital Logic Design	3
ECE 2660 ()	Electronics I	4
CS/ECE	CS/ECE elective <sup>3,5</sup>	3
STS STS	2xx/3xx elective	3
<u>Fifth semester</u>		<u>16</u>
CS/ECE 3330 (333)	Computer Architecture	3
ECE 3750 ()	Signals & Systems	3
APMA 3100	Probability	3
PHYS 2415 (241E)	General Physics II	3
PHYS 2419 (241W)	General Physics Lab I	1
UE	Unrestricted elective <sup>4</sup>	3
<u>Sixth semester</u>		<u>15</u>
CS 3240 (340)	Advanced Software Development	3
CS/ECE	CS/ECE elective <sup>3,5</sup>	3
CS 4414 (414)	Operating Systems	3
HSS	HSS elective <sup>1</sup>	3
UE	Unrestricted elective <sup>4</sup>	3
<u>Seventh semester</u>		<u>16.5</u>
ECE 4435	Computer Org. & Design	4.5
CS/ECE 4457 ()	Computer Networks	3
CS/ECE	CS/ECE elective <sup>3,5</sup>	3
UE	Unrestricted elective <sup>4</sup>	3
STS 4010/4500 (401)	Western Tech and Culture	3
<u>Eighth semester</u>		<u>16.5</u>
ECE 4440	Advanced Digital Design	4.5
CS/ECE	CS/ECE elective <sup>3,5</sup>	3
UE	Unrestricted elective <sup>4</sup>	3
STS 4020/4600 (402)	Engineer in Society	3
UE	Unrestricted elective <sup>4</sup>	3

**Footnotes:**

1. Chosen from the approved list available in A122 Thornton Hall.
2. Chosen from: among BIOL 2010, BIOL 2020, CHEM 1620, ECE 2066, ENGR 2500, MSE 2090, and PHYS 2620.
3. Students interested in selected advanced CS electives should consider CS 3102. Students interested in selected advanced ECE electives can delay this elective until the sixth semester and take another elective instead.

4. Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 1310 including STAT 1100 and 1120, and courses that substantially duplicate any others offered for the degree, including PHYS 2010, 2020; CS 1010, 1020; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 1090 counts as a three-credit unrestricted elective.
5. Chosen from CS/ECE course at the 3000 level or higher. Two CS/ECE electives must be 4000 level or above.

### 4.3 Miscellaneous Information

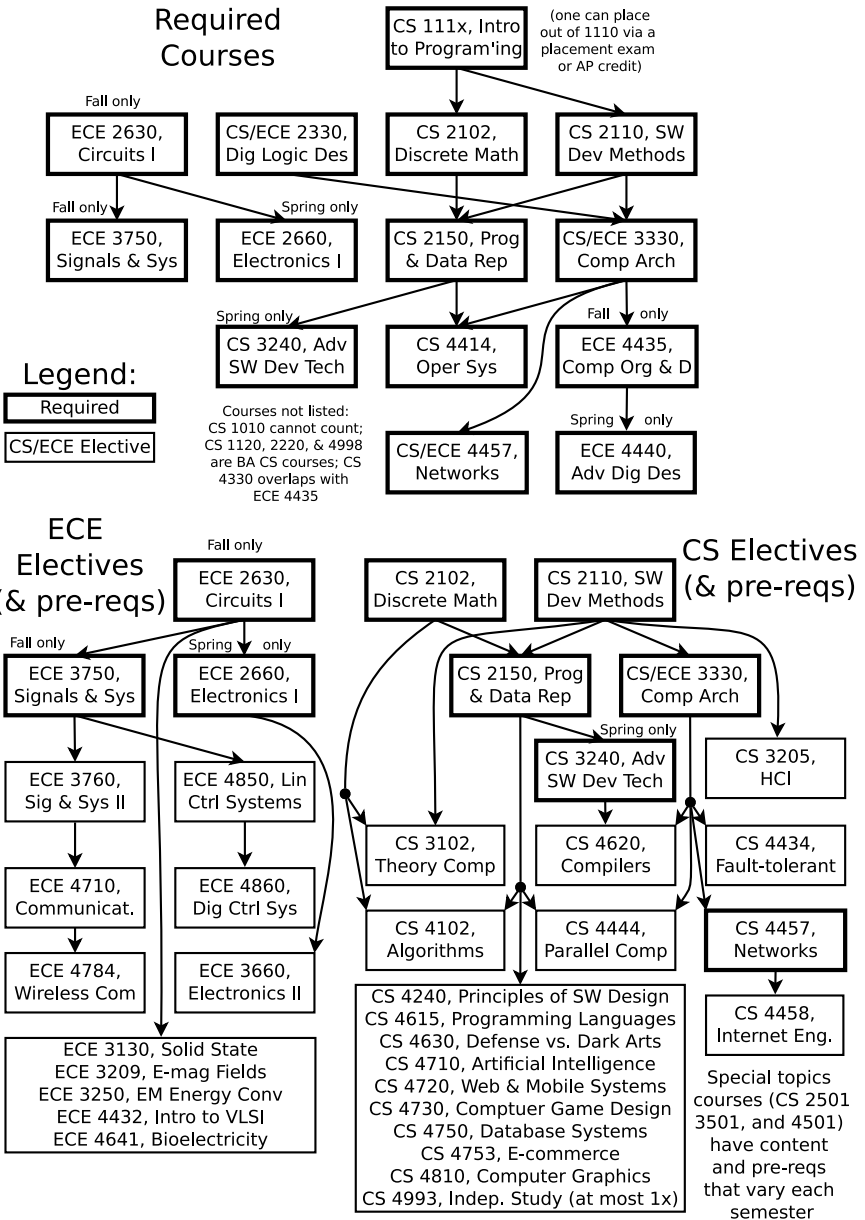
Please refer to the Undergraduate Record for detailed information about SEAS Academic Rules and Regulations including HSS electives. Guidelines such as Course Load, Academic Probation and Academic Suspension can also be found in the Record.

The Registrar web site provides a Course Renumbering Crosswalk to assist with the transition from 3 to 4 digit course numbers<sup>1</sup>.

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<sup>1</sup><http://www.virginia.edu/registrar/search.php>

# 4.4 Course Requirements Flowchart



# Chapter 5

## Minor in Computer Science

### 5.1 Introduction

The Department of Computer Science provides a minor program for qualified students. The courses in the minor program provide a solid foundation in computer science. The minor program is a six course, eighteen credit curriculum. The curriculum consists of the four required courses and two elective courses. Full course descriptions are at the end of this document, beginning on page 44.

In the past, there were separate requirements for the minor for SEAS students and non-SEAS students. These requirements have been streamlined into a single set of requirements for everybody.

### 5.2 Curriculum

All SEAS (School of Engineering and Applied Science) students are required to take (or place out of) CS 1110 (101), as part of the SEAS first-year curriculum. This course is also the first required course for the minor.

The following are the first four courses required for the minor.

- CS 1110 (101), CS 1111 (101E), or CS 1112 (101X): Introduction to Computer Science
- CS 2110 (201): Software Development Methods
- CS 2102 (202): Discrete Mathematics
- CS 2150 (216): Program and Data Representation

Note that CS 1120 (From Ada and Euclid to Quantum Computing and the World Wide Web) can replace the CS 111x requirement. However, all SEAS students are required to take a CS 111x course regardless, so courses, so taking CS 1120 would not help at all.

Likewise, CS 2220 (Engineering Software) can replace CS 2110.

Note that if you place out of CS 1110 (101) via the placement exam, you still have to take 6 CS courses; if you receive course credit for it via the AP exam or transfer credit, then you need not substitute a course in its place.

Furthermore, two additional computer science electives are required. The elective courses must be computer science courses at the 3000 level or above. The only restriction on elective courses is a limit to how many independent study courses one can count toward a minor – contact the minor advisor for details at [minoradvisor@cs.virginia.edu](mailto:minoradvisor@cs.virginia.edu).

Computer science courses typically build upon each other. In particular, CS 1110 (101) is a prerequisite of both CS 2110 (201) and CS 2102 (202). CS 2110 (201) and CS 2102 (202) are both prerequisites of CS 2150 (216). In addition, CS 2150 (216) is a prerequisite for almost all of the computer science electives. The Department of Computer Science also requires that its courses be passed at a certain level (typically a C- or higher) in order to take successive courses. Be aware that the department strictly enforces its prerequisite policy.

## 5.3 Miscellaneous Information

### 5.3.1 Declaring the minor

To declare the minor:

1. A student should have completed CS 1110 (101) or 1120 (150), CS 2110 (201) or 2220 (205), and CS 2102 (202). Furthermore, the student should have completed, or at least be enrolled in, CS 2150 (216).
2. Complete the minor declaration form, which is available in the Computer Science department's front office (Rice Hall, room 527). The form has the title, "School of Engineering and Applied Science, Minor Declaration" – this is the form for everybody; the SEAS school title at the top is because the CS department is in SEAS.
3. Meet with the CS department's minor advisor(s), currently Mark Sherriff and Tom Horton ([minoradvisor@cs.virginia.edu](mailto:minoradvisor@cs.virginia.edu)). Bring a the minor declaration form and your transcript (unofficial is fine).
4. Assuming the form is approved, it will be processed by the department.

# Chapter 6

# Masters in Computer Science

## 6.1 Introduction

There are multiple ways that one can pursue a graduate degree. Typically, undergraduates are interested in completing a Masters program in 5 years, 1 year beyond that for a Bachelors.

The department maintains graduate program information online<sup>1</sup>; that website contains more complete information than this chapter. This section pertains solely to obtaining a Masters in 5 years.

Students are often better served going to a different school for graduate work. Every school has biases and ways of doing things, and if one spends all of their academic career at one institution, then they don't see any other way. This is especially true for Ph.D. degrees, but also important (although less so) for Masters.

Students are aiming for a 5-year Masters must still follow the same rules and guidelines for all Computer Science and SEAS graduate students. These rules and guidelines can be found in the graduate handbook (see above), and online<sup>2</sup>.

We would like to stress again that this chapter focuses solely on earning a Masters degree in 5 years, where the Bachelors also was earned at UVA.

### 6.1.1 When to Apply

Although you are earning both degrees in 5 years, there is still will be a formal switch between undergraduate and graduate student status. Also

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<sup>1</sup>[http://www.cs.virginia.edu/grad\\_curriculum/](http://www.cs.virginia.edu/grad_curriculum/)

<sup>2</sup><http://www.seas.virginia.edu/admissions/graduate.php>

see the graduate applications web page<sup>3</sup>.

A student applies to the UVa graduate program in CS like anybody else, but mentions in the application packet (specifically, in the statement of purpose) that they are going for a terminal 5-year Masters. Here, 'terminal' means that you are not pursuing a degree beyond that (i.e., a Ph.D.).

Note that in the application process, you are NOT considered a transfer student, even if you already have taken some graduate courses at UVa.

The easiest time to apply is in the fall of your 4th year (i.e. during your 7th semester). This would allow one to finish up 8 full semesters as an undergraduate, and have 2 full semesters (plus summers, potentially) as a graduate student.

Often students will use the summer (either before or after their 5th year) to complete some Masters requirements. Note that it is very possible to complete a Masters in 1 year, but it will be a heavy work load if classes are not taken during the summers. Check the course availability to see what courses, if any, are being offered.

One can certainly take more than 5 year to complete the Masters – you are paying tuition, after all – but typically students aim to complete their Masters after 5 full years.

However, nothing requires that you apply at that time. You can apply in the spring of your 6th year (i.e. 6th semester) or even earlier. Should one decide to apply then (6th semester), they may graduate early in 3.5 years (i.e. 7 semesters) – thus, they graduate 1 semester early from undergraduate, then enroll in their 8th semester as a Masters student.

The benefit of applying a semester early is that one can have an additional semester to work on graduate courses. This must be balanced with the concern of completing their undergraduate degree in 7 semesters.

Note that if you are a SEAS student and are graduating one semester early, you must still write a senior thesis, and take STS 4500 and STS 4600.

One can apply earlier as well, such as in the fall of one's 3rd year (i.e. in your 5th semester). This would mean that one would complete the undergraduate degree in 3 years (following the same time line as completion of the undergraduate degree in 8 semesters, but accelerated by 1 year), and complete the Masters in their 4th year.

## 6.1.2 Degrees Offered

The Department of Computer Science offers two different Masters degrees. The first is a Masters of Computer Science (MCS), and the second is a Masters of Science in Computer Science (MS). Both may be obtained in 5 years, although most students will opt for the MCS.

From the perspective of employers, the two degrees are, for the most part, equivalent. The primary difference is that a MS requires a full Masters thesis, with a complete faculty committee that looks for a significant

<sup>3</sup><http://www.seas.virginia.edu/admissions/graduate.php>

amount of work to have been accomplished. A MS requires a 3-credit project, and that is judged only by the student's advisor. A faculty committee looking at a MS thesis will look for significantly more work than what is required for an MCS project. As a result, a MCS is an easier degree to earn.

Students tend to complete the MCS instead of the MS, as the MS requires a significant thesis, and the MCS requires a project that is smaller in scope.

## 6.2 Curriculum

The full curriculum for a Masters degree is listed in the graduate handbook. As of publication of this version of this undergraduate handbook, the graduate handbook is only a draft, and is not a final version yet. It can be found online<sup>4</sup>. This section is only intended as a summary.

A Masters curriculum generally consists of 30 credits (i.e. 10 courses) in computer science. One or two of these courses will be the MCS project course or the MS thesis course(s).

Any course that counts towards the graduation requirements for your undergraduate degree may **NOT** count towards the graduation requirements for your Masters – even if it is as an unrestricted elective. Thus, if you want to take graduate class(es) as an undergraduate, and you want it to count towards your Masters graduation requirements, you must ensure that you take enough classes so that you could have graduated **without** those graduate class(es). Thus, one must carefully work out which courses will count for which degree.

Masters students do not need to take (or pass) the qualification exams, as those are required for the Ph.D. degree only. If you decide to later transfer into the Ph.D. degree, then you will need to take (or have taken) the qualification exams.

## 6.3 Miscellaneous Information

Generally, Masters students are not funded. Thus, students will pay tuition (and room/board, as appropriate). The costs are analogous to undergraduate rates: lower for in-state residents, and higher for out-of-state residents.

The “easiest” – and most typical – path to a 5-year Masters is to apply in 7th semester, and already have some graduate classes that are NOT counting towards your undergraduate degree. You will have had to have talked to your undergraduate advisor about who you are going to work

<sup>4</sup><http://www.cs.virginia.edu/~csgsg/graduate-guide/>

with for your Masters. You would then complete the degree in 1 full additional year (summer, fall, and spring), aiming for a May graduation date.

# Chapter 7

## Common Information

### 7.1 Major Focal Paths

A focal path is a selection of courses that a student can take to fulfill the various elective requirements, which are described in detail in the sections on elective information for the various majors. They do not change any of the requirements, and students are not required to follow a focal path. They are included simply to give prospective majors an idea about various classes that they can take to fulfill an interest that they may have in computing. Not all focal paths have classes to fulfill each elective requirement. And some will have more classes than are needed for the given requirement.

In an effort to keep down the space for each listing, the reason for each class is not listed. If interested, speak to a CS faculty member in that particular area. Also, as BA CS students may be interested in these focal paths, a line listing the BA CS requirements is also shown below.

There are a number of other areas for which focal paths are being developed, and we expect to include them in future editions of this handbook. Those areas are: Systems, Parallel & Distributed Computing, Graphics, Languages & Compilers, Software Engineering, Hardware, and Security & Privacy.

#### 7.1.1 Game Design

- Science elective (1): N/A
- HSS electives (5): digital art classes, such as ARTS 2220, 2222, 3220, 3222, 4220, and 4222; sound design courses, such as DRAM 2620 and DRAM 3640; modeling classes such as ARCH 3410
- Unrestricted elective (5): see the HSS electives choices, above, and consider additional CS electives.
- APMA electives (2): linear algebra (APMA 3080)

- CS electives (5): game development courses (offered as special topics courses, CS 4501); graphics (CS 4810), artificial intelligence (CS 4710), networks (CS 4457), databases (CS 4750), parallel computing (CS 4444)
- STS 2xxx/3xxx elective (1): N/A
- Notes: You will need a lot of C++ experience upon graduation

### 7.1.2 Theory

- Science elective (1): ECE 2066 (200) (Science of Information)
- HSS electives (5): mathematical economics (ECON 3090), psycholinguistics (PSYC 4110)
- Unrestricted electives (5): game theory (ECON 401), various math courses (MATH 4452, MATH 5700, STAT 3010)
- Unrestricted elective (1): N/A
- APMA electives (2): linear algebra (APMA 3080)
- CS electives (5): programming languages (CS 4610), artificial intelligence (CS 4710), cryptography (offered as special topics courses, CS 4501)
- STS 2xxx/3xxx elective (1): N/A
- Notes: BA students need to take CS 302 which is critical for a theory focal path, but is not (at this time) a required course for the BA

### 7.1.3 Networks (including wireless networks)

- Science elective (1): ECE 2066 (Science of Information)
- HSS (5): N/A
- Unrestricted electives (5): ECE 2630 (Circuits), ECE 3750 (Signals), ECE 4710 (Communications), ECE 4290 (Wireless Systems), ECE 4785 (Optical Communications)
- APMA electives (2): APMA 3120 (Statistics)
- CS electives (5): CS 4457 (Networks), CS 4458 (Internet Networks), all wireless sensor networks courses offered as special topics, CS 4753 (Electronic Commerce), CS 4720 (Web and Mobile Systems), CS 4444 (Parallel Computing)
- STS 2xxx/3xxx elective (1): N/A
- Notes: The wireless networking class is often offered as a graduate class (called wireless sensor networks) and can be added with instructor permission.

### 7.1.4 Web technologies

- Science elective (1): ECE 2066 (Science of Information)
- HSS (5): Digital art classes, ECON 2010 (Micro Economics), ECON 2020 (Macro Economics), PSYC 1010 (Intro to Psychology)

- Unrestricted electives (5): STS 4110 (Business of New Product Development)
- APMA electives (2): N/A
- CS electives (5): CS 4753 (Electronic Commerce), CS 4457 (Networks), CS 4720 (Web and Mobile Systems), CS 4750 (Database Systems), CS 4240 (Software Design)
- STS 2xxx/3xxx elective (1): STS 2160 (Intellectual Property)
- Notes: There are a number of IT classes that are relevant, including courses in web design, technology, and marketing. However, these are not allowed as unrestricted electives per SEAS policy.

### 7.1.5 Software Engineering

- Science elective (1): Science of Information (ECE 2066)
- HSS electives (5): See note below regarding the Engineering Business Minor.
- Unrestricted elective (5): See note below regarding the Engineering Business Minor.
- APMA electives (2): any choices are suitable
- CS electives (5): Principles of Software Design (CS 4240) and HCI in Software Development (CS 3205) have a strong software engineering focus. Other courses that include significant development projects would be appropriate, such as Databases (CS 4750), Web and Mobile Systems (CS 4720), and Computer Game Design (CS 4730).
- STS 2xxx/3xxx elective (1): Any offerings related to technology in society or ethics would be appropriate
- Notes: If special topics courses were offered in software testing, software quality, or formal methods, these would be good choices for this focal path. Also, the Engineering Business Minor would be a good addition for this focus. Finally, experience with in a software company through a summer internship will increase your understanding of this area.

## 7.2 Frequently Asked Questions

### 7.2.1 What computer science student groups exist?

There are three main computer science student groups at UVa.

The Association for Computing Machinery Chapter at the University of Virginia is a student chapter of the parent Association for Computing Machinery. The Chapter is a Contracted Independent Organization (CIO) at the University of Virginia, and serves students, faculty, and staff of the University as well as members of the Charlottesville / Albermarle community. Any member of the University or Charlottesville / Albermarle

community may become a Member of the Chapter. Also see their website<sup>1</sup>.

ACM-W is the ACM committee on Women in Computing. It celebrates, informs and supports women in computing, and works with the ACM-W community of computer scientists, educators, employers and policy makers to improve working and learning environments for women. Also see their website<sup>2</sup>.

The Student Game Developers seeks to bring together students who are interested in learning and experiencing the art of computer game development. They have resources available for programmers as well as non-programmers, weekly informative meetings, and many industry contacts for lectures, resume building, and networking. Also see their website<sup>3</sup>.

## 7.2.2 What is ICPC, the International Collegiate Programming Contest, and how do I get involved?

The International Collegiate Programming Contests, abbreviated ICPC, is a world-wide contest of computer programming for college students. UVa has a very active programming contest team. Regional contests occur in the fall our region is the nearest 6 (or so) states and D.C. The top team(s) from each regional contest advance to the world finals, which consists of the top 100 teams from around the world. UVa has qualified for the world finals twice in the recent years: for the 2009 world finals in Stockholm, Sweden, and the 2010 world finals in Harbin, China. We typically have seven teams (of three students each) compete in the regional contest. Our programming contest teams practice throughout the year. If you are interested in more information, you can either contact UVa's local ACM chapter<sup>4</sup> or ACMs advisor, Aaron Bloomfield (aaron@virginia.edu).

## 7.2.3 What kind of advanced placement credit is available?

Advanced placement (AP) credit is awarded by the University for most AP tests in which the grade is a 4 or a 5. This section only deals with the AP computer science test. A student's SIS report will always list which courses qualify for the AP test scores (both in computer science and in other fields).

A 5 on the computer science AB test will receive course credit for CS 1110 (101) and CS 2110 (201). A 4 on the computer science AB test OR a 5 on the computer science A test will receive course credit for CS 1110 (101). If the AP exam was not in Java, proficiency in Java must be demonstrated

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<sup>1</sup><http://acm.cs.virginia.edu/>

<sup>2</sup><http://www.cs.virginia.edu/~acm-w/>

<sup>3</sup><http://gamedevatuva.blogspot.com/>

<sup>4</sup><http://acm.cs.virginia.edu>

prior to taking CS 2110 (201). Note that CS 2110 (201) is required for other majors: computer engineering, systems engineering, and electrical engineering. There is also a placement exam before the fall semester that will allow the student to place out of CS 1110 (101), but does not allow credit to be received for the course – the student must then take another 3 hour CS or technical course (see your advisor for details about a technical course) instead. See the next question and answer for information about the CS 1110 (101) placement exam.

## **7.2.4 Can I place out of CS 1110 (101)? What about CS 2110 (201)?**

There is a placement exam for CS 1110 (101), which covers all the topics taught in the course. For the current semester's syllabus, see the CS 1110 (101) course website. Successful completion will allow a student to place out of the course, but does NOT give course credit – only a sufficient score on the AP test or transfer credit can give course credit for CS 1110 (101). A student must still take CS 2110 (201) or a technical course (see your advisor for details about a technical course) to fulfill the SEAS CS 1110 (101) requirement. The test is offered before the beginning of the fall semester. Note that any student who has enrolled in CS 1110 (101) or equivalent (1111, 1112) and got a letter grade including a W – is not allowed to take the placement exam (in other words, if you enroll and then drop the course without a W, you may still take the placement exam). The exam may be taken by visiting the departmental office in Rice Hall, room 527.

More information about the CS 1110 (101) placement exam may be found online <sup>5</sup>.

For information about the placement exam for CS 2110 (201), please contact the current CS 2110 (201) instructor.

## **7.2.5 How does SEAS handle transfer credit?**

The Engineering school handles transfer credit, such as from an AP course or transfer from another school. The credit will appear on your SIS report, along with the UVa courses that you received credit for. Note that the credit amounts need to match - so if you are getting credit for APMA 2120 (212) (Multivariate Calculus), which is a 4 credit course, the number of credits you transfer in should (ideally) also be 4 credit hours. If it does not (your equivalent course at another school was only 3 credits), you will have to take another math or technical course (see your advisor for details about a technical course) to make up for the discrepancy. Note that placing out of a course (such as CS 1110 (101), APMA 2120 (212), etc.) through the respective placement exam does not give credit and thus the credits need

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<sup>5</sup><http://www.cs.virginia.edu/cs1110/placement.php>

to be made up through other courses (in the case of CS 1110 (101), 3 credits of a technical course will fill that spot; in the case of APMA 2120 (212), 4 credits of math or a technical elective will fill that spot). AP exams do give course credit.

Note that half of the 128 credits that one uses to graduate must be earned at UVa. Thus, if you transfer with more than 64 credits, you must still take 64 credits at UVa.

## 7.2.6 Can CS courses from another college receive credit?

We officially discourage taking major courses elsewhere. This policy is especially true for the lab-based and required courses. If, in spite of this departmental policy, you still want to take a course elsewhere, then the student needs an advisor signature AND the signature of the current instructor of that course from UVa. To receive the required signatures, you must bring in a detailed syllabus, so that faculty can make informed decisions. Note that to receive credit for CS 2150 (216) elsewhere, you need a course (or multiple courses) that cover(s) data structures, C++, and assembly language programming.

## 7.2.7 What are the Rodman Scholar requirements?

Rodman scholars have slightly different requirements for graduation.

- Rodman Scholars are not required to take STS 1010/1500 (101); an HSS elective is substituted
- Rodmans fulfill the STS 2xxx/3xxx elective by taking STS 2000 (formerly known as STS 200R). For the class of 2013, Rodmans will take STS 1010/1500 in the Spring, with a special discussion section for Rodmans only.
- In place of ENGR 1620, Rodmans instead take the two-course sequence, ENGR 1410 (141R) and ENGR 1420 (142R)
- Rodmans take PHYS 1427 (142R) during their first semester, instead of PHYS 1425 (142E) and PHYS 1429 (142W) in the second semester
- Rodmans take a different Physics class during their second semester, instead of PHYS 2415 (241E) and PHYS 2419 (241W). This class used to be called PHYS 241R; as of print time, the new 4-digit course number is not yet known.

Furthermore, Rodman Scholars are required to complete 4 seminars – ENGR 3580 (formerly 307 and 308) prior to graduation. First-year students joining the Rodman program at mid-year are required to take three seminars prior to graduation.

## 7.2.8 Why are ECE 4435 and ECE 4440 not showing up in my list of fulfilled CS electives?

This has to do with a restriction in how SIS handles the CS elective requirements. While ECE 4435 (435) (Computer Organization & Design) and ECE 4440 (436) (Advanced Digital Design) can both count as a CS elective each, in order for this to happen a SIS exception will need to be entered. Your academic advisor can request to have such an exception entered by contacting Brenda Perkins. Note that both of those courses only count as one elective each, even though they are 4.5 credits per course (meaning that taking both of those classes – worth 9 credits total – does not count as three CS electives, but only as two).

## 7.2.9 Why do the SIS requirements for the BS CS major list 6 HSS electives, and not 5?

This has to do with how SIS (the Student Information System, UVas system for handling academic requirements and registration) handles major requirements, and is done to allow for people to place out of STS 1500 (previously STS 101, and STS 1010). If one does not place out of STS 1500, then STS 1500 will list both in the STS 1500 requirement, and in the HSS requirement, thus requiring students to take 5 additional HSS courses. If one does place out of STS 1500, they need to take an additional HSS course in its place. So the credit to place out of STS 1500 will appear in the STS 1500 requirements, and will still require 6 (not 5) HSS courses. We think this is all a bit bizarre as well, but that is how SIS handles requirements.

A sample of the BS CS requirements can be found online<sup>6</sup> – your individual one can be found via SIS.

## 7.2.10 Can CS students study abroad?

Yes! To get more information about studying abroad, see online<sup>7</sup> for more details.

## 7.2.11 How do I transfer into the CS program?

Like other SEAS students, transfer students must formally apply to, and be approved by, the Department of Computer Science to enroll in the computer science program of study. To minimize loss of credit upon transfer, students must take a rigorous program in mathematics and the sciences. The School of Engineering and Applied Science expects a minimum of 63 credits in the first two years, instead of the 60-credit minimum that is customary in the College of Arts and Sciences. The additional credits are often

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<sup>6</sup><http://www.cs.virginia.edu/bscs/bscs-reqs-in-sis.pdf>

<sup>7</sup>[http://www.cs.virginia.edu/curriculum/study\\_abroad/](http://www.cs.virginia.edu/curriculum/study_abroad/)

completed through summer courses. Detailed information on curriculum requirements may be obtained from the Office of the Dean of the School of Engineering and Applied Science.

There is also the Bachelor of Arts in Computer Science, offered through the College; also see their main web page<sup>8</sup>. Students outside of the School of Engineering and Applied Science with an interest in obtaining a BS (as opposed to a BA) degree in computer science must transfer to the Engineering school.

### 7.2.12 Where can I find out about the Business minor?

The courses for the Engineering Business Minor can be worked into the various electives for the BS CS. More details can be found online<sup>9</sup>.

### 7.2.13 What CS electives can be taken without having completed CS 2150 (216)?

There are a few CS electives that one can take having only taken CS 2110 (201). They include:

- CS 3102 (302), Theory of Computation
- CS 3205 (305), Human-Computer Interaction
- For the BA CS, CS 2330 (230), Digital Logic Design, counts as an elective
- CS 3330 (333), Computer Architecture. This course requires CS 2330 (230), Digital Logic Design, as a prerequisite. There are a few courses that require CS 3330 (333) as a prerequisite, but do not also require CS 2150 (216):
  - CS 4434 (434), Fault-tolerant Computing (note that this course has other prerequisites)
  - CS 4457 (457), Computer Networks

## 7.3 Course Descriptions

These course listings are from the undergraduate record<sup>10</sup>. The frequency code for each class specifies how often it is offered. (S) means offered each (spring and fall) semester; (Y) means offered once each academic year, and (SI) means offered upon sufficient student interest.

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<sup>8</sup><http://www.cs.virginia.edu/ba/>

<sup>9</sup><http://www.seas.virginia.edu/advising/businessminor.php>

<sup>10</sup><http://records.ureg.virginia.edu/content.php?catoid=11&navoid=189>

### 7.3.1 1000 Level Courses

**CS 1010 (110) – Introduction to Information Technology** (3 credits): Provides exposure to a variety of issues in information technology, such as computing ethics and copyright. Introduces and provides experience with various computer applications, including e-mail, newsgroups, library search tools, word processing, Internet search engines, and HTML. Not intended for students expecting to do further work in CS. Cannot be taken for credit by students in SEAS or Commerce. (S)

**CS 1110 (101) – Introduction to Programming** (3 credits): Introduces the basic principles and concepts of object-oriented programming through a study of algorithms, data structures and software development methods in Java. Emphasizes both synthesis and analysis of computer programs. (S)

**CS 1111 (101E) – Introduction to Programming** (3 credits): Introduces the basic principles and concepts of object-oriented programming through a study of algorithms, data structures and software development methods in Java. Emphasizes both synthesis and analysis of computer programs. Prerequisite: Prior programming experience. (S)

**CS 1112 (101X) – Introduction to Programming** (3 credits): Introduces the basic principles and concepts of object-oriented programming through a study of algorithms, data structures and software development methods in Java. Emphasizes both synthesis and analysis of computer programs. Note: No prior programming experience. (SI)

**CS 1120 (150) – Introduction to Computing: Language, Logic, and Machines** (3 credits): Introduction to computer science with no previous background. Focuses on describing and reasoning about information processes using language and logic. Uses motivating examples from liberal arts and sciences areas such as art, biology, economics, narrative, physics, and sociology. (Y)

### 7.3.2 2000 Level Courses

**CS 2102 (202) – Discrete Mathematics** (3 credits): Introduces discrete mathematics and proof techniques involving first order predicate logic and induction. Application areas include sets (finite and infinite), elementary combinatorial problems, and probability. Development of tools and mechanisms for reasoning about discrete problems. Cross-listed as APMA 202. Prerequisite: CS 1110 (101) or 1120 (150) with a grade of C- or higher. (S)

**CS 2110 (201) – Software Development Methods** (3 credits): A continuation of CS 1110 (101), emphasizing modern software development methods. An introduction to the software development life cycle and processes.

Topics include requirements analysis, specification, design, implementation, and verification. Emphasizes the role of the individual programmer in large software development projects. Prerequisite: CS 1110 (101) with a grade of C- or higher. (S)

**CS 2150 (216) – Program and Data Representation** (3 credits): Introduces programs and data representation at the machine level. Data structuring techniques and the representation of data structures during program execution. Operations and control structures and their representation during program execution. Representations of numbers, arithmetic operations, arrays, records, recursion, hashing, stacks, queues, trees, graphs, and related concepts.) Prerequisite: CS 2102 (202) and either CS 2110 (201) or CS 2220 (205) with all grades of C- or higher. (S)

**CS 2190 (290) – Computer Science Seminar I** (1 credit): Provides cultural capstone to the undergraduate experience. Students make presentations based on topics not covered in the traditional curriculum. Emphasizes learning the mechanisms by which researchers and practicing computer scientists can access information relevant to their discipline, and on the professional computer scientist's responsibility in society. Prerequisite: CS 2110 (201) or 2220 (205) with a grade of C- or higher, as well as a computing major (BA CS, BS CS, or BS CpE). (Y)

**CS 2220 (205) – Engineering Software** (3 credits): Covers tools and techniques used to manage complexity and to build, analyze, and test complex software systems including abstraction, analysis, and specification. Notes: Students may not receive credit for both CS 2110 (201) and CS 2220 (205). Prerequisite: CS 150 with a grade of C- or higher. (Y)

**CS/ECE 2330 (230) – Digital Logic Design** (3 credits): Includes number systems and conversion; Boolean algebra and logic gates; minimization of switching functions; combinational network design; ip-ops; sequential network design; arithmetic networks. Introduces computer organization and assembly language. Cross-listed as ECE 2330 (230). (S)

**CS 2501 (251) – Selected Topics in Computer Science** (1 to 3 credits): Content varies annually, depending on students needs and interests. Recent topics include the foundations of computation, artificial intelligence, database design, real-time systems, Internet engineering, and electronic design automation. Prerequisite: Instructor permission. (SI)

### 7.3.3 3000 Level Courses

**CS 3102 (302) – Theory of Computation** (3 credits): Introduces computation theory including grammars, finite state machines and Turing machines; and graph theory. Cross-listed as APMA 3102 (302). Prerequisite:

CS 2102 (202) and either CS 2110 (201) or 2220 (205) all with grades of C- or higher. (Y)

**CS 3205 (305) – HCI in Software Development** (3 credits): Human-computer interaction and user-centered design in the context of software engineering. Examines the fundamental principles of human-computer interaction. Includes evaluating a systems usability based on well-defined criteria; user and task analysis, as well as conceptual models and metaphors; the use of prototyping for evaluating design alternatives; and physical design of software user-interfaces, including windows, menus, and commands. Prerequisite: CS 2110 (201) or 2220 (205) with a grade of C- or higher. (Y)

**CS 3240 (340) – Advanced Software Development Techniques** (3 credits): Analyzes modern software engineering practice for multi-person projects; methods for requirements specification, design, implementation, verification, and maintenance of large software systems; advanced software development techniques and large project management approaches; project planning, scheduling, resource management, accounting, configuration control, and documentation. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS/ECE 3330 (333) – Computer Architecture** (3 credits): Includes the organization and architecture of computer systems hardware; instruction set architectures; addressing modes; register transfer notation; processor design and computer arithmetic; memory systems; hardware implementations of virtual memory, and input/output control and devices. Cross-listed as ECE 3330. Prerequisite: CS 2110 (201) or 2220 (205) with a grade of C- or higher, and CS/ECE 2330 (230) with a grade of C- or higher. (S)

**CS 3501 (351) – Selected Topics in Computer Science** (1 to 3 credits): Content varies annually, depending on students needs and interests. Recent topics include the foundations of computation, artificial intelligence, database design, real-time systems, Internet engineering, and electronic design automation. Prerequisite: Instructor permission. (SI)

### 7.3.4 4000 Level Courses

**CS 4102 (432) – Algorithms** (3 credits): Introduces the analysis of algorithms and the effects of data structures on them. Algorithms selected from areas such as sorting, searching, shortest paths, greedy algorithms, backtracking, divide- and-conquer, and dynamic programming. Data structures include heaps and search, splay, and spanning trees. Analysis techniques include asymptotic worst case, expected time, amortized analysis, and reductions between problems. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4240 (441) – Principles of Software Design** (3 credits): Focuses on techniques for software design in the development of large and complex software systems. Topics will include software architecture, modeling (including UML), object-oriented design patterns, and processes for carrying out analysis and design. More advanced or recent developments may be included at the instructor's discretion. The course will balance an emphasis on design principles with an understanding of how to apply techniques and methods to create successful software systems. Prerequisite: CS 2150 (216) with a C- or higher. (Y)

**CS 4330 (433) – Advanced Computer Architecture** (3 credits): Provides an overview of modern microprocessor design. The topics covered in the course will include the design of super-scalar processors and their memory systems, and the fundamentals of multi-core processor design. Prerequisite: CS 2150 (216) and CS/ECE 3330 (333) with a C- or higher. (Y)

**CS 4414 (414) – Operating Systems** (3 credits): Analyzes process communication and synchronization; resource management; virtual memory management algorithms; file systems; and networking and distributed systems. Prerequisite: CS 2150 (216) and CS/ECE 3330 (333) with grades of C- or higher. (S)

**CS 4434 (434) – Fault-tolerant Computing** (3 credits): Investigates techniques for designing and analyzing dependable computer-based systems. Topics include fault models and effects, fault avoidance techniques, hardware redundancy, error detecting and correcting codes, time redundancy, software redundancy, combinatorial reliability modeling, Markov reliability modeling, availability modeling, maintainability, safety modeling, trade-off analysis, design for testability, and the testing of redundant digital systems. Cross-listed as ECE 434. Prerequisite: CS/ECE 3330 (333), APMA 2130 (213), and APMA 3100 (310), each with grades of C- or higher. (SI)

**CS 4444 (444) – Introduction to Parallel Computing** (3 credits): Introduces the student to the basics of high-performance parallel computing and the national cyber-infrastructure. The course is targeted for both computer science students and students from other disciplines who want to learn how to significantly increase the performance of applications. Prerequisite: CS 2150 (216) and CS/ECE 3330 (333) with a C- or higher. (Y)

**CS/ECE 4457 (457) – Computer Networks** (3 credits): Intended as a first course in communication networks for upper-level undergraduate students. Topics include the design of modern communication networks; point-to-point and broadcast network solutions; advanced issues such as Gigabit networks; ATM networks; and real-time communications. Cross-listed as ECE 457. Prerequisite: CS/ECE 3330 (333) with a grade of C- or higher. (Y)

**CS 4458 (458) – Internet Engineering** (3 credits): An advanced course on computer networks on the technologies and protocols of the Internet. Topics include the design principles of the Internet protocols, including TCP/IP, the Domain Name System, routing protocols, and network management protocols. A set of laboratory exercises covers aspects of traffic engineering in a wide-area network. Prerequisite: CS 4457 (457) with a grade of C- or higher. (Y)

**CS 4501 (451 and 494) – Selected Topics in Computer Science** (1 to 3 credits): Content varies annually, depending on students needs and interests. Recent topics include the foundations of computation, artificial intelligence, database design, real-time systems, Internet engineering, wireless sensor networks, and electronic design automation. Prerequisite: Instructor permission. (SI)

**CS 4610 (415) – Programming Languages** (3 credits): Presents the fundamental concepts of programming language design and implementation. Emphasizes language paradigms and implementation issues. Develops working programs in languages representing different language paradigms. Many programs oriented toward language implementation issues. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4620 (471) – Compilers** (3 credits): Provides an introduction to the field of compilers, which translate programs written in high-level languages to a form that can be executed. The course covers the theories and mechanisms of compilation tools. Students will learn the core ideas behind compilation and how to use software tools such as lex/flex, yacc/bison to build a compiler for a non-trivial programming language. Prerequisite: CS 3240 (340) and CS/ECE 3330 (333) with grades of C- or higher. (Y)

**CS 4630 (425) – Defense Against the Dark Arts** (3 credits): Viruses, worms, and other malicious software are an ever-increasing threat to computer systems. There is an escalating battle between computer security specialists and the designers of malicious software. This course provides an essential understanding of the techniques used by both sides of the computer security battle. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4710 (416) – Artificial Intelligence** (3 credits): Introduces artificial intelligence. Covers fundamental concepts and techniques and surveys selected application areas. Core material includes state space search, logic, and resolution theorem proving. Application areas may include expert systems, natural language understanding, planning, machine learning, or machine perception. Provides exposure to AI implementation methods, emphasizing programming in Common LISP. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4720 (N/A) – Web and Mobile Systems** (3 credits): With advances in the Internet and World Wide Web technologies, research on the design, implementation and management of web-based information systems has become increasingly important. Thus looks at the systematic and disciplined creation of web-based software systems. Students will be expected to work in teams on projects involving mobile devices and web applications. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4730 (N/A) – Computer Game Design** (3 credits): This course will introduce students to the concepts and tools used in the development of modern 2-D and 3-D real-time interactive computer video games. Advanced CS topics such as graphics, parallel processing, human-computer interaction, networking, artificial intelligence, and software engineering play a large role in industry in general. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4750 (462) – Database Systems** (3 credits): Introduces the fundamental concepts for design and development of database systems. Emphasizes relational data model and conceptual schema design using ER model, practical issues in commercial database systems, database design using functional dependencies, and other data models. Develops a working relational database for a realistic application. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4753 (453) – Electronic Commerce Technologies** (3 credits): Focuses on the history of the Internet and electronic commerce on the web; case studies of success and failure; cryptographic techniques for privacy, security, and authentication; digital money; transaction processing; wired and wireless access technologies; Java; streaming multimedia; XML; Bluetooth. Defining, protecting, growing, and raising capital for an e-business. Prerequisite: CS 2150 (216) with a grade of C- or higher. (Y)

**CS 4810 (445) – Introduction to Computer Graphics** (3 credits): Introduces the fundamentals of three-dimensional computer graphics: rendering, modeling, and animation. Students learn how to represent three-dimensional objects (modeling) and the movement of those objects over time (animation). Students learn and implement the standard rendering pipeline, defined as the stages of turning a three-dimensional model into a shaded, lit, texture-mapped two-dimensional image. Prerequisites: CS 2150 (216) with a grade of C-. (Y)

**CS 4993 (493) – Independent Study** (1 to 3 credits): In-depth study of a computer science or computer engineering problem by an individual student in close consultation with departmental faculty. The study is often either a thorough analysis of an abstract computer science problem or the design, implementation, and analysis of a computer system (software or hardware). Prerequisite: Instructor permission. (S)

**CS 4998 (495) – Distinguished BA Majors Research** (3 credits): Required for Distinguished Majors completing the Bachelor of Arts degree in the College of Arts and Sciences. An introduction to computer science research and the writing of a Distinguished Majors thesis. Prerequisite: in the BA program and instructor permission. (S)

## 7.4 Degree Requirement Revisions

Computer science is an evolving field, and our undergraduate curriculum reflects this. The department sometimes makes changes to the requirements for the bachelor's degree. Note that you are allowed to graduate using ANY SINGLE set of requirements that were in effect when you were a declared computer science major – thus, if the requirements change, you are allowed to complete the degree using the older version of the requirements. You cannot “mix and match” requirements from the different sets. For example, a student using the fall 2004 rules below (no general electives) is not allowed to take something other than ECE 435 (Computer Organization and Design) for the computer architecture elective.

Any changes to the requirements will occur after the spring semester and before the following fall semester, unless the change is considered minor. A minor change is something that does not in any way restrict the degree requirements. Examples of minor changes would be expanding the allowed courses for one of the elective types, or clarifying what counts as a given elective. Note that unless the change to the requirements directly affects the third semester (i.e. the first semester of the second year), a student cannot choose to graduate using a set of requirements that were in effect during his or her first year at UVa but that were not in effect during his or her second year, as they were not a declared computer science major during their first year.

The requirement revisions below describe which major changes occurred during the previous years, and what courses students must complete to graduate using that set of requirements. Note that the older sets are kept for historical reasons, even though there may not be any more students who are eligible to graduate with those sets.

The current set of requirements, which this document reflects, became effective in January 2010.

### 7.4.1 Requirements revision from spring 2010

In January of 2010, the elective structure was changed. Previously, majors were required to take 3 HSS electives, 3 general education electives, 3 technical electives, and 1 unrestricted elective. With the change, these 10 elective courses are now split into 5 HSS electives and 5 unrestricted electives. Students wishing to graduate using the old rules (if you were a declared

major prior to 2010) should see the previous editions of this handbook for the description of what constitutes general education electives and technical electives. However, the new requirements are more general, and we expect most students to graduate using these updated requirements. The old versions of this handbook are available online<sup>11</sup>.

### **7.4.2 Requirements revision from fall 2009**

In addition to the course numbering change, the change in the requirements was that the computer architecture elective was replaced with an additional CS elective, to bring the total number of required CS electives to 5. The previous computer architecture requirement had the students take one class from a set of 3: CS 4444 (444) (Introduction to Parallel Computing), CS 4330 (433) (Advanced Computer Architecture) or ECE 4435 (435) (Computer Organization and Design). Since all of those three courses count as CS electives, students who have already fulfilled this old requirement will still fulfill the CS elective that replaced it.

Focal paths were also added to the undergraduate handbook, although they do not change the major requirements.

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<sup>11</sup><http://www.cs.virginia.edu/bscs/>

*Enlighten the people generally, and tyranny and oppression of body and mind will vanish like evil spirits at the dawn of day the diffusion of knowledge among the people is to be the instrument by which it is to be effected.*

– Thomas Jefferson, 1816

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