



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>

Handbook version for the 2013–2014 through the 2017-2018 academic years

The last major updates to this undergraduate handbook were made in the summer of 2013. This version is valid for the 2013–2014 through the 2017–2018 academic years.

Any updates, both errata and addendums, to this version of the handbook will be listed on the individual degree web pages to which the errata or addendum applies.

The BS CS web site is at <http://www.cs.virginia.edu/acad/bscs/>

The BA CS web site is at <http://www.cs.virginia.edu/acad/ba/>

The BS CpE web site is at <http://www.cpe.virginia.edu/ugrads/>

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The information contained on this handbook is for informational purposes only. The Undergraduate Record and Graduate Record represent the official repository for academic program requirements. These publications may be found online at <http://records.ureg.virginia.edu/index.php>. We have ensured that the requirements in this handbook match those in the Undergraduate Record.

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Chapter 1

Introduction

Online: <http://www.cs.virginia.edu/>

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 many 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) awards in recent academic years. In fact, of all US 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 bachelor’s degree in computer engineering. It also projects an employment increase of over 38% by 2016 for occupations available to graduates with a bachelor’s degree in computer engineering¹.

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.

¹<http://www.bls.gov/oco>

- Minor in Computer Science. Note that the minor is restricted in whom can apply for it; see section 5.2 (page 23) for details.

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 Computing Curricula 2005: The Overview Report². 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).

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 ABET³.

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 BS CS 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 program 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 engineer-

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

³<http://www.abet.org>

ing 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.

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 ABET⁴. The Bachelor of Science in Computer Engineering is accredited by the Engineering Accreditation Commission of ABET⁴.

See online for program objectives, student outcomes, and graduation data for both Computer Science⁵ and Computer Engineering⁶.

1.3 Major Course Requirements Comparison

See figure 1.3. The SEAS school requirements consist of:

- APMA 1110 & 2120
- CHEM 1610 & 1611
- ENGR 1620 & ENGR 1621
- PHYS 1425 & 1429
- PHYS 2415 & 2419
- Science elective
- STS 1500

⁴<http://www.abet.org>

⁵<http://www.cs.virginia.edu/acad/accreditation.html>

⁶http://www.cpe.virginia.edu/ugrads/Accreditation_Information_CpE.html

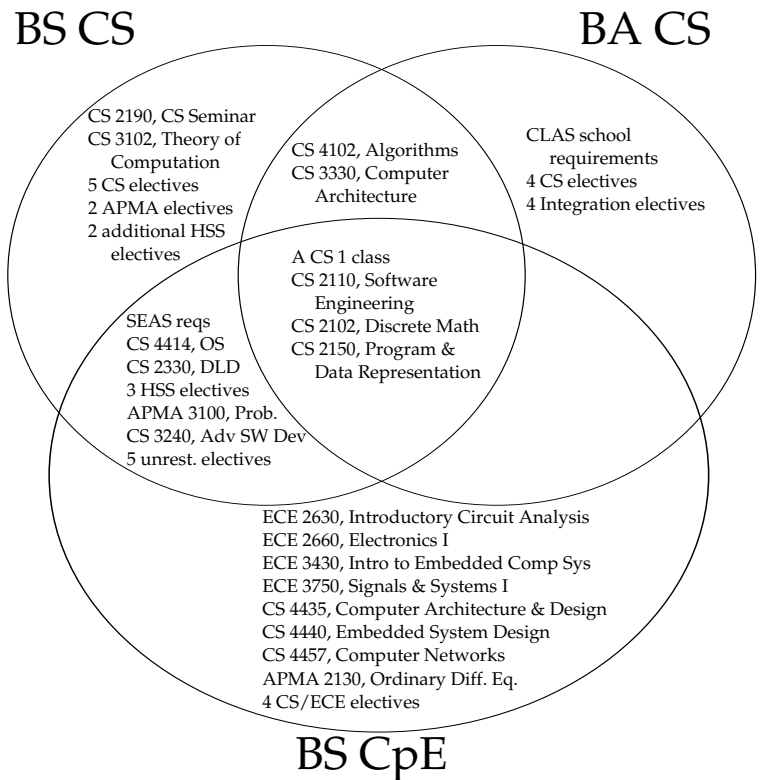


Figure 1.1: Course Requirements Comparison

- 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

A “CS 1 class” is CS 1110, CS 1111, or CS 1112. CLAS majors can take CS 1120, provided they have Java experience. Placement is available; see sections 7.2.3 (page 28) & 7.2.4 (page 28).

Chapter 2

Bachelor of Science in Computer Science

Online: <http://www.cs.virginia.edu/acad/bscs/>

2.1 Disclaimer

The information contained on this handbook is for informational purposes only. The Undergraduate Record and Graduate Record represent the official repository for academic program requirements. These publications may be found online^{1,2}.

2.2 Introduction

The Bachelor of Science degree in Computer Science is a wide-ranging program, encompassing both the theoretical and the practical. This program builds upon the engineering and mathematical principles introduced in the Engineering School's core curriculum. Our students are then 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 satisfaction.

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, secu-

rity, 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.

2.3 Program Objectives

Graduates of the Bachelor of Science in Computer Science program:

- Have the knowledge and skills that allow them to make tangible contributions in their profession.
- Have the knowledge and skills that allow them meet new technical challenges.
- Are able to contribute effectively to society.
- Are able to work effectively as team leaders and members.
- Have the ability to be innovators in the design, analysis and application of computer systems.

Grading Policy Majors and minors are required to maintain a C average or better in their CS courses.

2.4 Application Process

For SEAS students who started (as first years) in 2016 or later, there are no major caps for any of the majors – thus, the application process is simply a matter of filling out which major one wants to major in. Note that this lack of major caps does not apply to the BA CS (yet), and is for students who entered in 2016 or later. This is the same as the Computer Engineering degree. Also note that the lack of major caps applies to the first major that one selects during the major selection period in the spring semester of one's first year. Transfer students, individuals who want to choose Computer Science as a second major, or change majors after their first year, may be subject to major caps. For details about those, please see the Computer Science main office (Rice Hall, room 527).

¹<http://records.ureg.virginia.edu/index.php>

²http://records.ureg.virginia.edu/preview_program.php?catoid=42&poid=4962

Students may switch between the Computer Science and Computer Engineering degrees at any time – once a student is accepted into the computing major, they can select either one. Note, however, that one will still have to complete all the requirements for the major that was just switched into.

2.5 Curriculum

The requirements for the computer science degree consist of a number of required courses, as well as a series of elective choices for the student to make. A table of all the requirements is shown in figure 2.5.3 (page 8).

2.5.1 Elective Information

The numbers in the list below correspond to the footnote numbers from the sample course schedule shown in section 2.5.4 (page 7).

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

Science elective (1 required): Students must choose one of BIOL 2010 (Introduction to Biology: Cell Biology and Genetics), BIOL 2020 (Introduction to Biology: Organismal and Evolutionary Biology), CHEM 1620 (Introductory Chemistry for Engineers), ECE 2066 (Science of Information), MSE 2090 (Introduction to the Science and Engineering of Materials), or PHYS 2620 (Introductory Physics IV: Quantum Physics). Additional courses in this list can count as an unrestricted elective.

HSS (Humanities and Social Science) elective (5 required): Studies in the humanities and social sciences serve not only to meet the objectives of a broad education, but 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 online³ and in this handbook in section 7.1. Note that there are a number of courses that do not count as HSS electives, but would count as an unrestricted elective. See the URL for details. Note that three of the five HSS electives are required by SEAS, and the other two are required by the CS department; however, all five must comply with the SEAS requirements for HSS electives, or must be approved through the petition process described in the SEAS undergraduate handbook³.

Unrestricted elective (5 required): Any graded course in the University, with a few exceptions. From the SEAS Undergraduate Student Handbook³: “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, PHYS 2020, CS 1010, CS 1020, or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should obtain the approval of their adviser and the dean’s office, Thornton Hall, Room A122. APMA 1090 counts as a three credit unrestricted elective for students.” Note that Band classes (such as marching band) and ROTC classes can count for the unrestricted elective.

APMA (Applied Mathematics) elective (2 required): Must choose two from: APMA 2130 (Ordinary Differential Equations), APMA 3080 (Linear Algebra), APMA 3120 (Statistics), or APMA 3150 (From Data to Knowledge). Note that APMA 3100 (Probability) is a required course in addition to the two APMA electives.

CS (Computer Science) elective (5 required): Any 3 credit CS class at the 3000 level or above. A course that is fulfilling another requirement cannot count as a CS elective. If you take more than five CS electives, you can count additional CS elective course(s) as unrestricted electives. Note that ECE 4440 (Embedded Systems Design) can count as a CS elective, but see the details in section 4.6.1 (page 21). Due to substantial overlap with CS 3330 (Computer Architecture), ECE 4435 (Computer Architecture & Design) can NOT count as a CS elective. CS 4993 (Independent Study) can be used at the most once for a CS elective (i.e. no more than 3 credits); additional CS 4993 credits can be used as unrestricted electives. Note that for a class that does 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); this process can be initiated by emailing the BS CS director at bscsdirector@cs.virginia.edu.

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

2.5.2 Capstone Sequence

All SEAS students must complete a senior thesis, which is encapsulated in the STS 4500 and STS 4600 courses. In addition to the STS courses, BS CS students must complete one or two CS courses to fulfill the computer science capstone sequence requirement. There are two “tracks” to complete the capstone, described below, and students may choose either track.

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

Formally, students must complete 3 credits of one of the two capstone courses, depending on which track they choose to fulfill: either CS 4971 (Capstone Practicum II) for the Capstone Practicum track, or CS 4980 (Research Capstone) for the Research Capstone track. But note that CS 4970 (Capstone Practicum I), which is a CS elective, is a strict prerequisite to CS 4971! Also note that STS 4500 and STS 4600 must **still** be taken; the CS courses are in addition to, not instead of, the STS courses.

Research Capstone Track

This track is intended for students who are interested in performing an independent project, either a research-based project or an implementation-based project. The student must seek out a faculty member, who will agree to advise the project. The requirements of the project, workload, etc., are to be agreed upon by the student and advisor. Students will receive 3 credits for CS 4980 (Research Capstone), which is what formally fulfills the capstone requirement for the degree. Faculty advisors may decide to assign the three credits in a single semester, or spread the three credits across multiple semesters; as long as three credits are eventually earned, then the requirement will be fulfilled. Group projects are up to the discretion of the advisor, but are certainly permissible. Large projects may receive additional credit through CS 4993 (Independent Study), but this is solely up to the advisor. Note that there is a maximum of 3 credits (1 course) of CS electives that that CS 4993 may count toward; any additional credits count toward the unrestricted elective requirement.

This track is essentially how the senior thesis technical requirement worked previously, except that students now receive three credits for the technical work performed.

Capstone Practicum Track

This track is intended for any students who are not planning on performing an independent project. Students under this track will register for CS 4970 (Capstone Practicum I) in the fall of their 4th year, and CS 4971 (Capstone Practicum II) in the spring of their 4th year – specifically, those classes are to be taken concurrently with STS 4500 and STS 4600, respectively. Both of these CS courses are 3 credits.

These two courses form a year-long project implementation course. Students will be grouped into teams, will have requirements, real customers to interact with, real deadlines, and will need to complete real deliverables. While the domain of the course is up to the instructor, the current implementation of the courses is a Service Learning Practicum⁴.

Note that only CS 4971 counts toward the capstone requirement; CS 4970 is a CS elective. However, CS 4970 is a **strict** prerequisite to CS 4971. In particular, because the

projects are year-long group-based projects, there will be absolutely no allowances for students to join the sequence for just CS 4971 in the spring semester.

Double Majors and the Capstone

A SEAS student who is double majoring with the BS CS and another SEAS degree must complete the capstone or major design experience (MDE) course requirements in their non-CS major **in addition to** the capstone sequence in the computer science major. This means that they will still have to take either CS 4980 (Research Capstone) or the practicum capstone sequence (CS 4970 and CS 4971). Students can negotiate with their capstone/MDE instructors and their STS instructor which degree program's work will be used to satisfy the STS thesis portfolio requirements. However, the student should be aware that the capstone/MDE instructors in both departments will almost certainly require some kind of documentation of the technical work done for that program's requirement.

2.5.3 Degree Requirements Checklist

The degree requirement checklist is shown in figure 2.5.3 (page 8), and is available online⁵ in a full (letter-sized) page format.

2.5.4 Sample BS CS Course Schedule

Below is the recommended course of study for the bachelor's degree. If one has 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 six types of electives that the student can choose from. These electives are indicated by the footnotes below, and are described in detail in section 2.5.1 (page 6). 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 section 7.3 (page 30) 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 (section 7.5, page 35), 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 a previous version of the recommended course schedule.

Academic requirements are managed by SIS (UVA's Student Information System), which is where your individual

⁴<http://www.cs.virginia.edu/~asb/slp/>

⁵<http://www.cs.virginia.edu/acad/bscs/>

BS CS 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 3330: Computer Architecture			
CS 3240: Advanced SW Devel. Tech.			
CS 4414: Operating Systems			
CS 4102: Analysis of Algorithms			
Capstone course (circle: CS 4971 or 4980)			
APMA 3100: Probability			
APMA 2130, 3080, 3120, or 3150 (circle one)			
APMA 2130, 3080, 3120, or 3150 (circle one)			

SEAS required courses

Course	Grade	Semester
APMA 1110		
APMA 2120		
CHEM 1610		
CHEM 1611		
ENGR 1620		
ENGR 1621		
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 1500		
STS 2xxx/3xxx		
STS 4500		
STS 4600		

CS Electives (5)

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

Unrestricted electives (5)

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

Figure 2.1: BS CS Degree Requirements Checklist

set of requirements can be found. You may also want to see the FAQ question about how HSS requirements list in the SIS report (section 7.2.9, page 30).

The sample course schedule below exactly matched the undergraduate course record⁶ on July 31, 2016.

<u>First semester</u>		<u>15</u>
APMA 1110	Single Variable Calculus	4
CHEM 1610	Intro Chemistry I for Engineers	3
CHEM 1611	Intro Chem. I for Engineers Lab	1
ENGR 1620	Introduction to Engineering	3
ENGR 1621	Intro. to Engineering Lab	1
STS 1500 or HSS elective	Science, Tech., & Contemporary Issues or HSS elective ¹	3
<u>Second semester</u>		<u>17</u>
SCI elective	Science elective ²	3
HSS elective or STS 1500	HSS elective ¹ or Science, Tech., & Contemporary Issues	3
APMA 2120	Multivariate Calculus	4
PHYS 1425	Physics I: Mechanics, Thermo.	3
PHYS 1429	Physics I Workshop	1
CS 1110 or 1111 or 1112 or 1113 or 1120	Introduction to Programming (CS 1110-1113) or Introduction to Computing (CS 1120)	3
<u>Third semester</u>		<u>16</u>
APMA course	APMA elective ³ or APMA 3100	3
HSS elective	HSS elective ¹	3
CS 2110	Software Develop. Methods	3
CS 2102	Discrete Mathematics	3
PHYS 2415	General Physics II: E&M & Lab	3
PHYS 2419	General Physics II Workshop	1
<u>Fourth semester</u>		<u>16</u>
STS 2xxx/3xxx	STS 2xxx/3xxx elective	3
UE elective	Unrestricted elective ⁴	3
CS 2150	Prog. & Data Representation	3
CS/ECE 2330	Digital Logic Design	3
CS 2190	CS Seminar ⁶	1
CS 3102	Theory of Computation	3
<u>Fifth semester</u>		<u>18</u>
APMA course	APMA elective ³ or APMA 3100	3
HSS elective	HSS elective ¹	3
UE elective	Unrestricted elective ⁴	3
CS elective	CS elective	3
CS 3330	Computer Architecture	3
CS 4102	Algorithms	3

<u>Sixth semester</u>		<u>15</u>
APMA course	APMA elective ³ or APMA 3100	3
UE elective	Unrestricted elective ⁴	3
HSS elective	HSS elective ¹	3
CS elective	CS elective	3
CS 3240	Advanced Software Develop.	3
<u>Seventh semester</u>		<u>15</u>
CS elective	CS elective	3
CS 4970 or CS elective	Capstone Practicum I ⁵ or CS elective	3
UE elective	Unrestricted elective ⁴	3
CS 4414	Operating Systems	3
STS 4500	STS and Engineering Practice	3

<u>Eighth semester</u>		<u>15</u>
CS 4971 or 4980	Capstone Practicum II or Capstone Research	3
CS elective	CS elective	3
UE elective	Unrestricted elective ⁴	3
HSS elective	HSS elective ¹	3
STS 4600	Engineer, Ethics, & Prof. Society	3

Footnotes

The footnotes below correspond to the footnote numbers in the sample schedule, above; you can see them described in more detail in section 2.5.1, page 6.

1. Chosen from the approved list available in A122 Thornton Hall.
2. Chosen from: BIOL 2010, 2020; CHEM 1620; ECE 2066; MSE 2090; and PHYS 2620.
3. Chosen from APMA 2130, 3080, 3100, 3120 or 3150 (but cannot take both 3120 and 3150).
4. Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 1310 and courses that substantially duplicate any others offered for the degree, including PHYS 2010, 2020; CS 1100, 1200; 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 deans office, located in A122 Thornton Hall. APMA 1090 counts as a three-credit unrestricted elective.
5. The CS capstone experience 4970 and 4971 requires 4th year standing.
6. CS 2190 requires second- or third-year standing.

2.6 Miscellaneous Information

2.6.1 GPA Requirement

Students must have a 2.0 GPA in all computer science courses in order to complete the degree. This means all

⁶http://records.ureg.virginia.edu/preview_program.php?catoid=42&poid=4962

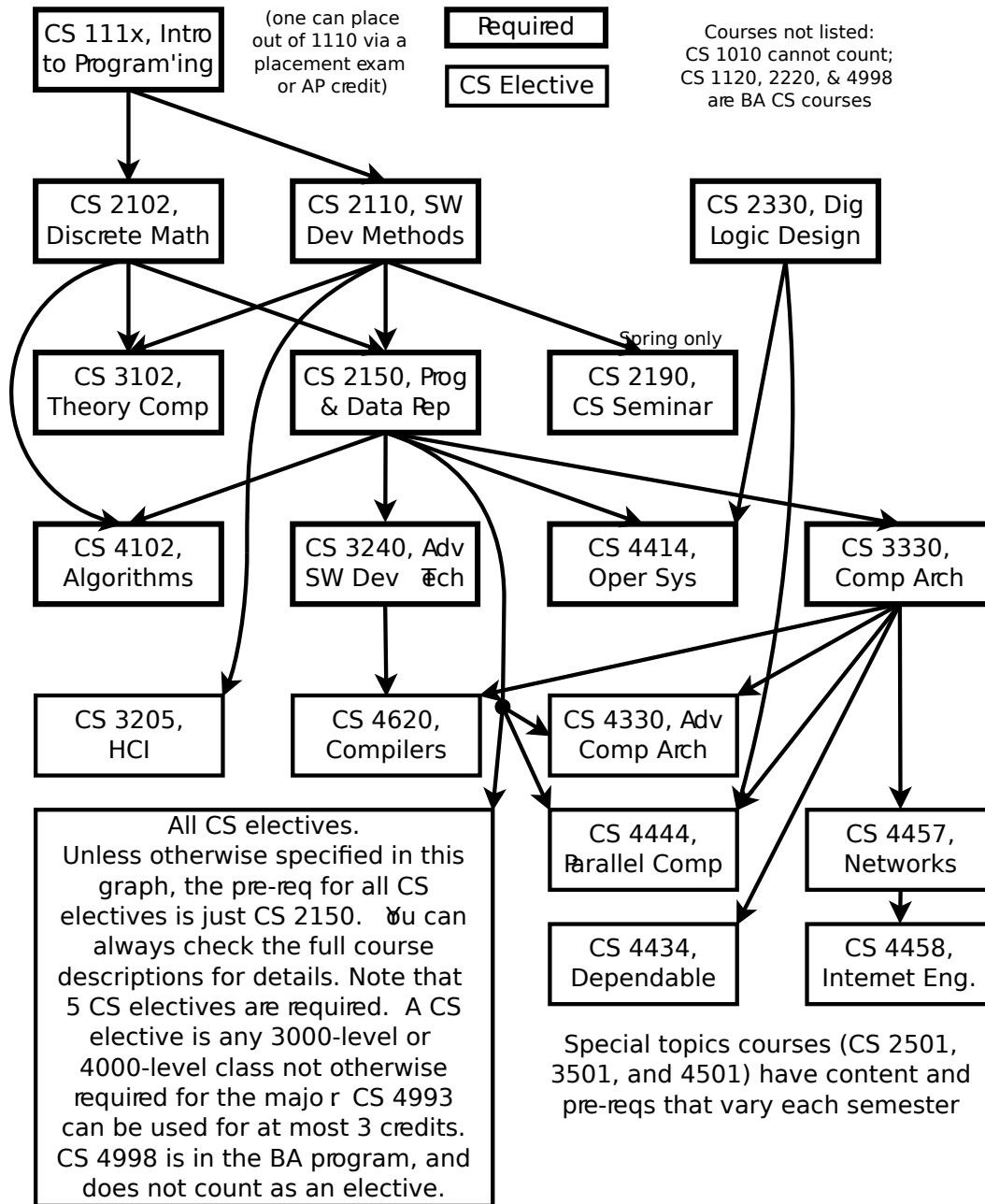
courses with a “CS” courses as well as the ECE versions of CS 2330 (Digital Logic Design) and CS 4457 (Computer Networks). A cumulative GPA less than 2.0 in these courses will prevent successful completion of the degree. Note that the University policy for Engineering students is such that if you take a course multiple times, then *all* of the grades received will count toward the GPA.

2.6.2 CS 2190 Specific Details

While students can take courses in any semester, there is an issue to consider with CS 2190: 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 course in ethics and technology in its place (even though CS 2190 is only 1 credit). This course taken in place of CS 2190 does not count toward any other requirement except to replace CS 2190.

2.7 Course Requirements Flowchart

(Updated April 2015)



Note that ECE 4440 can also count as a CS elective, but its pre-req is ECE 3430 (which does NOT count as a CS elective). These two courses are in the Computer Engineering curriculum, and are not shown here.

Students must take one capstone course (CS 4971 or CS 4980) to fulfill the capstone requirement; note that CS 4970 (which counts as a CS elective) is a strict pre-req for CS 4971.

Chapter 3

Bachelor of Arts in Computer Science

Online: <http://www.cs.virginia.edu/acad/ba/>

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 Application Process

The Department of Computer Science is experiencing tremendous student interest in our degree programs. Our goal is to accommodate as many BA in Computer Science (BA CS) majors as possible. However, because of current resources, the Department has had to institute a cap on the number of students who can declare the BA CS major.

Requirements to declare the major: In order to apply for the major, students must have taken one introductory com-

puter science course (either CS 1110, CS 1111, or CS 1112, or CS 1120) with a grade of C+ or better, and must be enrolled in CS 2110 and CS 2102 (or must have already completed CS 2110 and CS 2102 with a grade of C+ or better). Students are accepted into the major in the spring semester of their second year upon review of their applications. This is a selective process which takes into account the applicant's GPA and application essay, as well as other factors.

Application information: Applications must be completed in the spring semester (normally the student's fourth semester). Deadlines are posted in the Computer Science Department office and on the departmental web site; the deadline will be on or about March 15. Due to prerequisite dependencies, it is difficult for rising third year students who have not completed CS 2110 and CS 2102 to complete the major in the 4 remaining semesters; however, in exceptional cases, students in that situation may apply for the major by petition to the Chair.

Students apply to the Computer Science major by completing a form available on the departmental web site¹. Students list all CS courses taken or in progress and discuss any career goals or aspirations, computing-related extra-curricular activities, internships or experience. The essay invites students to reflect on their intellectual objectives in wishing to pursue the major and asks students to consider their career goals and how the BA in CS advances those goals. Applications are read and evaluated by the core faculty in Computer Science. All applicants will be notified of admission decisions by April 1.

Second majors: College of Arts and Sciences students who wish to declare the BA CS as a second major must follow the same application process described here. Only College of Arts and Sciences students are eligible to apply for the BA CS degree as a second major.

Transfer students from outside the University: Students transferring into the University from other institutions must apply to the department to be allowed to declare the BA CS major. Qualified applicants will be considered on a space-available basis, given our target caps for each class year. Ap-

¹<http://www.cs.virginia.edu/acad/declaring.html>

plications will be considered the summer before a transfer student begins classes, and the application process will be discussed during the summer orientation session. If an incoming transfer does not attend summer orientation, they must meet with a CS advisor before classes begin to discuss applying. Due to prerequisite dependencies, it is difficult for rising third year students who have not completed CS 2110 and CS 2102 to complete the BA CS in the 4 remaining semesters. It is important that students transferring to the University as third years complete the equivalent of these courses before coming to UVa. In exceptional cases, students in this situation may apply for the major, but the ability to complete the degree in a timely fashion is considered in determining if you are accepted into the degree program.

3.3 Curriculum

Before declaring the computer science major, all students should have taken one introductory computer science course (either CS 1110, CS 1111, or CS 1112; CS 1120 is also allowed if the student has Java experience) 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 Requirements² as well as at least 27 credits in Computer Science courses and 12 credits in Integration Electives.

3.3.1 Required Core Courses

The following courses are required for all BA CS majors. Full descriptions can be found in the Course Descriptions section (section 7.3, page 30).

- CS 2110, Software Development Methods
- CS 2102, Discrete Math
- CS 2150, Program and Data Representation
- CS 3330, Computer Architecture
- CS 4102, Algorithms

Note that any CS1 class, either CS 111x, Introduction to Programming, or CS 1120, Introduction to Computing: Language, Logic, and Machines, is required to enroll in CS 2110.

3.3.2 CS Electives

Four computing intensive electives are to be selected from a list of approved courses. The list of approved courses includes all current Computer Science courses at 3000-level or 4000-level. Additional courses that may be jointly offered by CLAS and CS departments will be added to the list of

²<http://artsandsciences.virginia.edu/college/requirements/index.html>

approved computing electives based on approval by the BA committee.

There are a few restrictions on which upper-level CS courses can count as a CS elective:

- CS 4971 (Capstone Practicum II) does not count as a CS elective, as it is part of the BS CS capstone requirement. Note that its prerequisite (CS 4970, Capstone Practicum I) *does* count as a CS elective.
- CS 4980 (Capstone Research) does not count as a CS elective, as it is part of the BS CS capstone requirement.
- CS 4993 (Independent Study) credits can only count for at most 1 CS elective (i.e., 3 credits).
- CS 4998 (Distinguished BA Majors Research) is a separate requirement for the DMP (see section 3.4.1, page 16), and thus does not count as a CS elective.

3.3.3 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, 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. The list of integration electives may change slightly from year to year. You can always check the current list of integration electives on SIS. The list below is according to SIS as of September 2013.

Anthropology

- ANTH 2430: Languages of the World
- ANTH 3480: Language and Prehistory
- ANTH 3490: Language and Thought
- ANTH 5401: Linguistic Field Methods
- ANTH 5410: Phonology
- ANTH 5420: Theories of Language
- ANTH 5440: Morphology

Architecture

- ARCH 3450: Digital Moviemaking & Animation
- ARCH 5420: Digital Animation & Storytelling
- ARCH 5450: Digital Moviemaking & Animation
- ARCH 5470: Information Space
- ARCH 5710: Photography and Digital Media

- ARCH 6410: Advanced CAAD 3D Modeling & Visualization

Studio Art

- ARTS 2220: Introduction to New Media I
- ARTS 2222: Introduction to New Media II
- ARTS 3222: Intermediate New Media II
- ARTS 4220: Advanced New Media I
- ARTS 4222: Advanced New Media II

Biochemistry

- BIOC 5080: Computer Analysis of DNA & Protein

Biology

- BIOL 3170: Introduction to Neurobiology
- BIOL 3240: Introduction to Immunology
- BIOL 4010: Macroevolution
- BIOL 4020: Ecol & Evolutionary Genetics
- BIOL 4030: Evolutionary Biology Lab
- BIOL 4050: Developmental Biology
- BIOL 4080: Neuronal Organization of Behavior
- BIOL 4130: Population Ecology and Conservation Biology
- BIOL 4160: Functional Genomics Lab
- BIOL 4170: Cellular Neurobiology
- BIOL 4250: Human Genetics
- BIOL 4480: Complex Macromolecules
- BIOL 5080: Developmental Mechanisms
- BIOL 5370: Epidemiology and Evolution of Infections Disease

Biomedical Engineering

- BME 3310: Biomedical Systems Analysis & Design
- BME 3315: Computational BME
- BME 3636: Neural Network Models
- BME 4783: Medical Imaging Modalities
- BME 4784: Medical Image Analysis

Chemistry

- CHEM 4411: Biological Chemistry Lab I

Drama

- DRAM 2110: Lighting Technology
- DRAM 2110: Lighting Technology
- DRAM 2210: Scenic Technology
- DRAM 2240: Digital Design: Re-making and Re-imagining
- DRAM 2620: Sound Design
- DRAM 2630: Production Laboratory: Sound

- DRAM 3210: Scene Design I
- DRAM 4110: Lighting Design
- DRAM 4410: Acting III

Electrical Engineering

- ECE 2066: Science of Information

Economics

- ECON 4010: Game Theory
- ECON 4020: Auction Theory and Practice
- ECON 4720: Econometric Methods
- ECON 4880: Seminar in Policy Analysis

Environmental Science

- EVSC 3020: GIS Methods
- EVSC 4010: Introduction to Remote Sensing
- EVSC 4040: Climate Change: Science, Markets & Policy
- EVSC 4070: Advanced GIS
- EVSC 5020: GIS Methods
- EVSC 5030: Applied Statistics for Environmental Scientists
- EVSC 5110: Systems Analysis in Environmental Sciences

United States History

- HIUS 3162: Digitizing America

Linguistics

- LING 3400: Structure of English
- LING 5010: Synchronic Linguistics
- LING 5060: Syntax and Semantics
- LING 5070: Syntactic Theory

General Linguistics

- LNLS 3250: Intro to Linguistic Theory

Mathematics

- MATH 1160: Algebra, Number Systems, and Number Theory
- MATH 3000: Transition to Higher Math
- MATH 3100: Intro Mathematical Probability
- MATH 3120: Intro Mathematical Statistics
- MATH 3351: Elementary Linear Algebra
- MATH 3354: Survey of Algebra
- MATH 4080: Operations Research
- MATH 4300: Elementary Numerical Analysis
- MATH 4452: Algebraic Coding Theory
- MATH 4750: Introduction to Knot Theory

- MATH 5110: Intro to Stochastic Processes
- MATH 5651: Advanced Linear Algebra
- MATH 5653: Number Theory

Media Studies

- MDST 2010: Introduction to Digital Media
- MDST 3050: History of Media
- MDST 3702: Computers and Languages
- MDST 3703: Digital Liberal Arts
- MDST 4700: Theory of New Media

Music

- MUSI 2350: Technosonics: Digital Music & Sound Art Composition
- MUSI 3390: Intro to Music & Computers
- MUSI 4535: Interactive Media
- MUSI 4540: Computer Sound Generation
- MUSI 4543: Sound Studio
- MUSI 4545: Computer Applications in Music
- MUSI 7350: Interactive Media

Neuroscience

- NESC 5330: Neural Network Models

Philosophy

- PHIL 1410: Forms of Reasoning
- PHIL 2330: Computers, Minds and Brains
- PHIL 2420: Introduction to Symbolic Logic
- PHIL 5420: Advanced Logic
- PHIL 5450: Language and Logic

Physics

- PHYS 2660: Fundamentals Scientific Computing
- PHYS 5630: Computational Physics I
- PHYS 5640: Computational Physics II

Psychology

- PSYC 2150: Introduction to Cognition
- PSYC 2200: Survey of the Neural Basis of Behavior
- PSYC 2300: Introduction to Perception
- PSYC 4110: Psycholinguistics
- PSYC 4111: Language Development & Disorders
- PSYC 4125: Psychology of Language
- PSYC 4150: Cognitive Processes
- PSYC 4200: Neural Mechanisms of Behavior
- PSYC 4290: Memory Distortions
- PSYC 4300: Theories of Perception
- PSYC 4330: Topics in Child Development
- PSYC 4500: Special Topics: Psychology

- PSYC 5150: Advanced Cognition
- PSYC 5210: Developmental Psychobiology
- PSYC 5260: Brain Systems Involved in Learning and Memory

Statistics

- STAT 2120: Intro to Statistical Analysis
- STAT 3010: Statist Computing & Graphics
- STAT 5000: Intro to Applied Statistics
- STAT 5330: Data Mining

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 at bacsdirector@cs.virginia.edu. Alternatively, if the advisor prefers, s/he can just send the student to BA CS director to get approval for a requirement exception. This will require a SIS exception to be entered for the student; see section 7.2.8 (page 29) for the manual SIS exception process.

3.4 Miscellaneous Information

3.4.1 Distinguished Majors Program

BA CS majors who have completed 18 credit hours toward 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 toward their Computer Science major by the end of the semester in which they apply. These 18 credit hours can come from any course used to fulfill the core course requirement (section 3.3.1, page 14), CS electives (section 3.3.2, page 14), or the integration electives (section 3.3.3, page 14). 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 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 toward 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 online³. You may also contact the BA CS director at bacsdirector@cs.virginia.edu, who is in charge of the BA DMP program.

3.4.2 Double majors in CLAS

From the CLAS web site on majors⁴ regarding double majors:

You may major in two subjects, in which case the application for a degree must be approved by both departments or interdepartmental 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.

However, you should be aware of the application process described in section 3.2 (page 13).

3.5 Course Requirements Flowchart

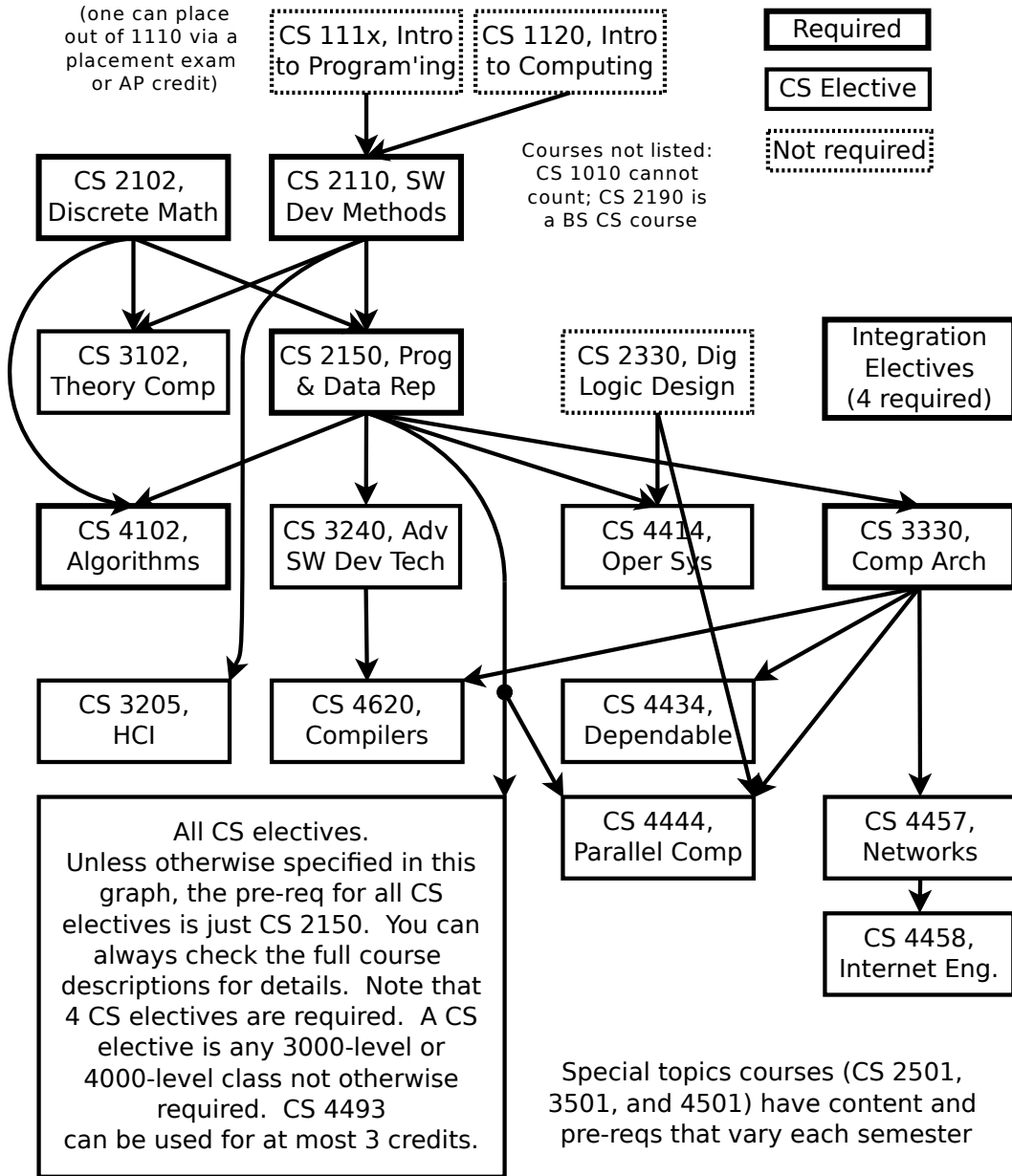
See figure 3.5 on page 18. Note that CS 2102 requires *either* CS 111x or CS 1120 as a prerequisite.

³<http://www.cs.virginia.edu/acad/ba/distinguished-major.html>

⁴<http://college.artsandsciences.virginia.edu/majortypes>

Course Requirements Flowchart

(Updated April 2015)



CS 4998, Distinguished BA Majors Research, is also in the BA program

Chapter 4

Bachelor of Science in Computer Engineering

Online: <http://www.cpe.virginia.edu/ugrads/>

4.1 Disclaimer

The information contained on this handbook is for informational purposes only. The Undergraduate Record and Graduate Record represent the official repository for academic program requirements. These publications may be found online^{1,2}.

4.2 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.

4.2.1 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.

¹<http://records.ureg.virginia.edu/index.php>

²http://records.ureg.virginia.edu/preview_program.php?catoid=42&poid=4960

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.

4.3 Application Process

The application process for the Computer Engineering degree are the exact same as with the BS Computer Science degree (section 2.4, page 5), and thus it is not repeated here.

4.4 General Curriculum Details

The curriculum has been carefully designed to ensure that 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 Introduction to Computer Science
- CS 2110 Software Development Methods
- CS 2102 Discrete Math
- ECE 2630 Introductory Circuit Analysis
- ECE 2660 Electronics I
- CS 2150 Program and Data Representation
- ECE/CS 2330 Digital Logic Design
- ECE 3750 Signals & Systems I
- CS 3240 Advanced Software Development
- CS 3430 Introduction to Embedded Computer Systems
- CS 4414 Operating Systems
- ECE 4435 Computer Architecture & Design
- ECE 4440 Embedded Systems Design
- CS/ECE 4457 Computer Networks

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

Circuits		<u>Second semester</u>		<u>17</u>	
• ECE 2630: Introductory Circuit Analysis		SCI elective	Science elective ²	3	
• ECE 2660: Electronics I		HSS elective	HSS elective ¹	3	
		APMA 2120	Multivariate Calculus	4	
		PHYS 1425	Physics I: Mechanics, Thermo.	3	
		PHYS 1429	Physics I Workshop	1	
Software Engineering		CS 1110 <i>or</i> 1111	Introduction to Programming	3	
• CS 2110: Software Development Methods		<i>or</i> 1112 <i>or</i>			
• CS 3240: Advanced Software Development		1113			
		<u>Third semester</u>		<u>17</u>	
Digital Logic		HSS elective	HSS elective ¹	3	
• ECE/CS 2330: Digital Logic Design		APMA 2130	Ordinary Differential Eq.	4	
• CS 2102: Discrete Math		CS 2110	Software Develop. Methods	3	
		CS 2102	Discrete Mathematics	3	
Computer Systems		ECE 2630	ECE Fundamentals I	4	
• CS 2150: Program and Data Representation		<u>Fourth semester</u>		<u>16</u>	
• CS 3430 Introduction to Embedded Computer Systems		STS 2xxx/3xxx	STS 2xxx/3xxx elective	3	
• CS 4414: Operating Systems		UE elective	Unrestricted elective ³	3	
• ECE 4435: Computer Architecture & Design		CS 2150	Prog. & Data Representation	3	
• ECE 4436: Embedded Systems Design		ECE 2660	ECE Fundamentals II	4	
• CS/ECE 4457: Computer Networks		CS/ECE 2330	Digital Logic Design	3	
		<u>Fifth semester</u>		<u>15</u>	
4.4.1 Grade Requirement		CS/ECE	CS/ECE elective ⁴	3	
To complete their program of study, computer engineering majors must achieve a C average or better in their Computer Science and Electrical Engineering courses.		ECE 3430	Intro to Embed. Systems	4	
		ECE 3750	ECE Fundamentals III	4	
		PHYS 2415	General Physics II: E&M & Lab	3	
		PHYS 2419	General Physics II Workshop	1	
		<u>Sixth semester</u>		<u>18</u>	
4.5 Curriculum		CS/ECE	CS/ECE elective ⁴	3	
Below is the recommended course of study for the bachelor's degree. If one has 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.		UE elective	Unrestricted elective ³	3	
		ECE 4550	Applied Research & Design Labd	1.5	
		APMA 3100	Probability	3	
		CS 3240	Advanced Software Develop.	3	
		ECE 4435	Computer Arch. & Design	4.5	
<u>First semester</u>		<u>Seventh semester</u>		<u>15</u>	
APMA 1110	Single Variable Calculus	4	CS/ECE	CS/ECE elective ⁴	3
CHEM 1610	Intro Chemistry I for Engineers	3	UE elective	Unrestricted elective ³	3
CHEM 1611	Intro Chem. I for Engineers Lab	1	ECE 4440	Embedded Systems Design	3
ENGR 1620	Introduction to Engineering	3	STS 4500	STS & Engineering Practice	3
ENGR 1621	Intro. to Engineering Lab	1	CS/ECE 4457	Computer Networks	3
STS 1500	Science, Tech., & Contemporary Issues	3			
		<u>Eighth semester</u>		<u>15</u>	
		CS/ECE	CS/ECE elective ⁴	3	
		UE elective	Unrestricted elective ³	3	
		UE elective	Unrestricted elective ³	3	
		CS 4414	Operating Systems	3	
		STS 4600	Engineer, Ethics, & Prof. Society	3	

Footnotes:

1. Chosen from the approved list available in A122 Thornton Hall.
2. Chosen from: among BIOL 2100, 2200; CHEM 1620; ECE 2066; MSE 2090; and PHYS 2620.
3. Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 1310 including STAT 1100 and STAT 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 deans office, located A122 Thornton Hall. APMA 1090 counts as three-credit unrestricted elective.
4. Chosen from CS/ECE courses at the 3000 level or higher. Two CS/ECE electives must be 4000 level or above.

4.6 Miscellaneous Information

There are three CS capstone courses: CS 4970 (Capstone Practicum I), CS 4971 (Capstone Practicum II), and CS 4980 (Capstone Research). Only the first one (CS 4970) counts as a CS/ECE elective for the Computer Engineering degree; the other two can only count as an unrestricted elective.

Please refer to the Undergraduate Record³ for detailed information about SEAS Academic Rules and Regulations including HSS electives. In addition, guidelines such as course load, academic probation and academic suspension can also be found in the Record.

4.6.1 Double BS CS & BS CpE majors

Due to substantial overlap with CS 3330 (Computer Architecture), ECE 4435 (Computer Architecture & Design) can NOT count as a CS elective. However, double majors may have ECE 4435 count as their CS 3330 requirement, although this will require a manual SIS exception to do so; see section 7.2.8 (page 29) for the SIS exception process.

ECE 4440 (Embedded Systems Design) can count as a CS elective, but this also requires a SIS exception to be entered – see section 7.2.8 (page 29) and section ?? (page ??) for details. Note that even though ECE 4440 is a 4.5 credit course, it can only count as one CS elective (i.e., only 3 credits).

Computer engineering majors are allowed to take ECE 3209 (Electromagnetic Fields) in place of PHYS 2415/2419. While this option is only open to computer engineering majors, it also applies to dual CS/CpE majors as well.

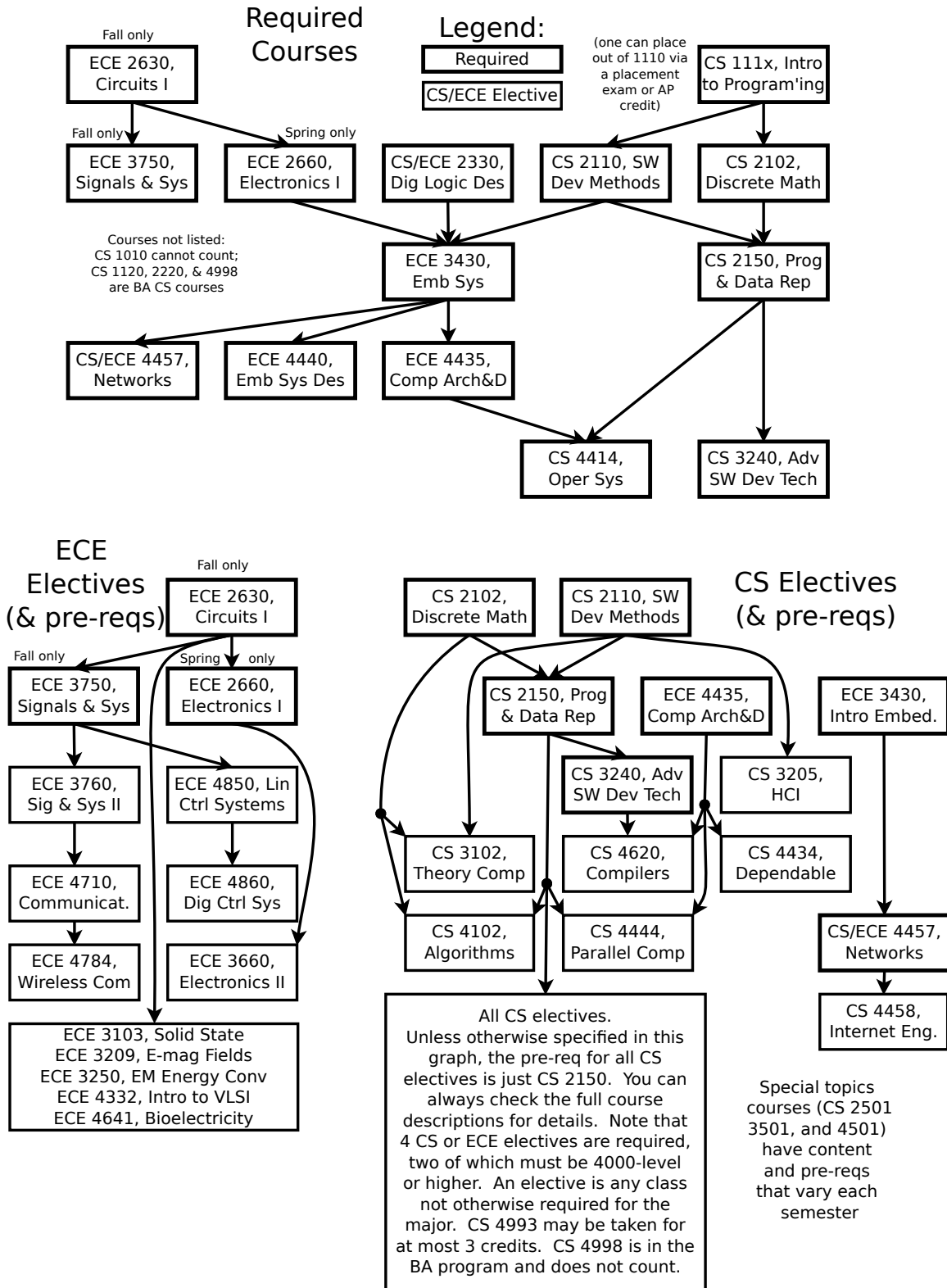
The BS CpE web site⁴ has a sample course schedule for double majors.

³<http://records.ureg.virginia.edu/>

⁴<http://www.cpe.virginia.edu/ugrads/>

4.7 Course Requirements Flowchart

(Updated October 2013)



Chapter 5

Minor in Computer Science

Online: http://www.cs.virginia.edu/acad/cs_minor.html

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 in section 7.3 (page 30).

5.2 Application Process

The department can only allow a limited number of SEAS students to declare a minor in Computer Science due to a rapidly growing demand for computing courses. Unfortunately, at this time the University is only able to accept SEAS students as CS minors. This situation will be re-evaluated before each year's application deadline, and if a change is made the CS minor page¹ will be updated to reflect the change. The CS department continues to work with the University to obtain resources that will allow more students to declare the Computer Science minor.

Students wishing to declare the minor normally apply in the spring of their first or second year. Applications from third and fourth year students will be considered only if there are still available spaces that were not taken earlier. The normal deadline is March 1. The application form can be found online². All applicants will be notified if they have been accepted as a CS minor by April 1.

BS in Computer Engineering majors: When the CpE program was created, it was decided by the two departments that CpE students could not declare the minor in CS. Because the CpE combines CS and EE, graduates with this degree will automatically have the equivalent of the minor in CS.

5.3 Curriculum

All SEAS (School of Engineering and Applied Science) students are required to take (or place out of) CS 1110, 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, CS 1111, or CS 1112: Introduction to Computer Science
- CS 2110: Software Development Methods
- CS 2102: Discrete Mathematics
- CS 2150: 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.

Note that if you place out of CS 1110 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.

Computer science courses typically build upon each other. In particular, CS 1110 is a prerequisite of both CS 2110 and CS 2102. CS 2110 and CS 2102 are both prerequisites of CS 2150. In addition, CS 2150 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.

¹http://www.cs.virginia.edu/acad/cs_minor.html

²<http://www.cs.virginia.edu/~horton/cs-minor-apply>

Chapter 6

Master's in Computer Science

Online: http://www.cs.virginia.edu/acad/graduate_program/

6.1 Introduction

There are multiple ways to pursue graduate degrees. If you uncertain about the benefits or general meaning of a graduate degree (e.g., “what *is* a Master’s degree and why might I want one?”) speak to your advisor or attend various graduate school information sessions, such as those produced by the local Association for Computing Machinery Chapter (see Section 7.2.1).

Master’s degrees are the most common graduate degrees and typically requires three to four semesters to complete. Ph.D. students typically initially complete a Master’s degree and then complete the Ph.D. degree four years after that. An additional option is available to UVa undergraduates: any credits not used to satisfy UVA undergraduate requirements can be applied to UVA graduate requirements, allowing for the completion of both a Bachelor’s degree and also a Master’s degree in a total of five years (instead of the usual six).

The department maintains graduate program information online¹; that web site contains more complete information than this chapter. This section pertains solely to obtaining a Master’s in five years. This type of Masters degree is usually one of the “terminal” Masters degrees discussed in the graduate handbook, such as the “terminal coursework-based MCS degree”. Other type of Masters degrees are not discussed here.

Students seeking a Ph.D. are often better served going to a different school for Ph.D. graduate work. Every school has biases and ways of doing things, and spending an entire academic career at one institution precludes one from seeing other approaches to CS research. A student seeing a Ph.D. should consider applying directly to another school’s graduate program or completing a Master’s degree here and then applying to another school’s Ph.D. program.

In recent years UVa CS has made an explicit push to grow

the Master’s program and our five-year Bachelor’s and Master’s approach is likely to be a good fit for students who want to obtain a strong Master’s degree before entering the workforce.

Students that are aiming for a five-year Master’s must still follow the same rules and guidelines for all Computer Science and SEAS graduate students. That is, even though you are “already” a UVa CS student, you must officially apply to the UVa CS graduate program at the usual time (typically by December 15th in your penultimate undergraduate semester). These rules and guidelines can be found in the graduate handbook (see above), and online.²

We would like to stress again that this chapter focuses solely on earning a Master’s degree in five years, where the Bachelors also was earned at UVa.

6.1.1 When to Apply

Although you are earning both degrees in five years, there is still will be a formal switch between undergraduate and graduate student status. See also the graduate applications web page³.

A local undergraduate student applies to the UVa graduate program in CS like any other prospective graduate student, but mentions in the application packet (specifically, in the statement of purpose) that this is an application for the five-year combined Bachelor’s and Master’s program. Students seeking only a Master’s degree (and not a follow-on Ph.D. at UVa or another school) should also indicate explicitly that they are applying for a terminal Master’s degree.

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 fourth year (i.e., during your seventh semester). This would allow you to finish up eight full semesters as an undergraduate, and then have two full semesters (plus summers, potentially) as

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

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

¹http://www.cs.virginia.edu/acad/graduate_program/

a graduate student. Applications to the Computer Science graduate program are typically due on December 15th⁴.

However, nothing requires that you apply at that time. You can apply in the spring of your third year (i.e., sixth semester) or even earlier. Students who decide to apply earlier (sixth semester) may graduate early in 3.5 years (i.e., seven semesters). Such students graduate one semester early from undergraduate, then enroll in their eighth semester as a Master's student.

The benefit of applying a semester early is that one can have an additional semester to work exclusively on graduate courses with full institutional support (e.g., an office in the CS building). This must be balanced with the concern of completing their undergraduate degree in seven 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 third year (i.e. in your fifth semester). This would mean that one would complete the undergraduate degree in three years (following the same time line as completion of the undergraduate degree in eight semesters, but accelerated by one year), and complete the Master's in the fourth year.

6.1.2 Degrees Offered

The Department of Computer Science offers two different Master's degrees. The first is a Master's of Computer Science (MCS), and the second is a Master's of Science in Computer Science (MS). Both may be obtained in five 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 Master's thesis, with a complete faculty committee that looks for a significant amount of work to have been accomplished. The MCS degree requirements can be satisfied entirely via standard coursework or via a three-credit project, and that is judged only by the student's advisor. The MCS degree is a good fit for a terminal Master's degree. See the UVa CS graduate handbook for information about the various combinations of Master's degrees (e.g., terminal or non-terminal; thesis, coursework or project).

6.2 Curriculum

The full curriculum for a Master's degree is listed in the graduate handbook.⁵ This section is only intended as a summary.

A coursework-based Master's degree typically involves ten classes (thirty credits). One or two of these courses of-

ten corresponds to an MCS project or an MS thesis course. Graduate students often take three or four courses for each of three semesters, completing the degree in two years. A UVa undergraduate student with three or four graduate classes beyond the usual undergraduate requirements (e.g., not used to satisfy any undergraduate major requirements or general rules like the 120 credit requirement; see below) can apply those credits toward a UVa CS graduate degree, allowing for completion in fewer semesters.

Any course that counts toward the graduation requirements for your undergraduate degree may **NOT** count toward the graduation requirements for your Master's – even if it is as an unrestricted elective. Thus, if you want to take graduate classes as an undergraduate, and you want them to count toward your Master's 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.

Terminal Master's students do not need to take (or pass) a qualification exam, as that exam is 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 exam.

One can certainly take more than five years to complete the Master's – you are paying tuition, after all – but typically students aim to complete their Master's after five full years. Students will sometimes use the summer (either before or after their fifth year) to complete some Master's requirements.

6.3 Miscellaneous Information

Generally, terminal Master's 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 five-year Master's is to apply in seventh semester, and already have some graduate classes that are *not* counting toward your undergraduate degree. You will have had to have talked to your undergraduate advisor about your plans. For example, if you eventually desire a Ph.D., you should discuss who you might work with for a Master's project or thesis. By contrast, if you desire a terminal Master's degree, you can obtain it entirely via coursework. You would then complete the degree in one full additional year (summer, fall, and spring), aiming for a May graduation date.

For any addition questions, please do not hesitate to contact the chair of the graduate program committee (currently Westley Weimer) or the chair of the graduate admissions committee (currently Marty Humphrey).

⁴<http://www.cs.virginia.edu/admissions/grad/>

⁵http://www.cs.virginia.edu/acad/graduate_program/grad-handbook.pdf

Chapter 7

Common Information

Online: <http://www.cs.virginia.edu/acad/>

7.1 HSS Electives

Humanities and Social Science (HSS) courses are required by both of the Engineering majors: Computer Science requires 5, and Computer Engineering requires three. Note that the BA CS curriculum includes the College requirements¹, which contain a more in-depth set of HSS type requirements.

The following course mnemonics are generally acceptable for HSS elective credit. A student may normally take any course under any one of these mnemonics, with the exception of those listed below.

- | | | | | |
|--------|--------|--------|--------|--------|
| • AAS | • ECON | • HEBR | • MUSI | • RUSS |
| • AMEL | • ENAM | • HIAF | • PERS | • RUTR |
| • AMST | • ENCR | • HIEA | • PETR | • SANS |
| • AMTR | • ENEC | • HIEU | • PHIL | • SATR |
| • ANTH | • ENGL | • HILA | • PLAD | • SCAN |
| • AR | • ENGN | • HIME | • PLAP | • SLAV |
| • ARAB | • ENLS | • HIND | • PLCP | • SLFK |
| • ARTH | • ENLT | • HISA | • PLIR | • SLTR |
| • ARTR | • ENMC | • HIST | • PLPT | • SOC |
| • ASL | • ENMD | • HIUS | • POL | • SPAN |
| • BULG | • ENNC | • ITAL | • PORT | • SPTR |
| • CCFA | • ENRN | • ITTR | • POTR | • SRBC |
| • CCIA | • ENSP | • JAPN | • PSYC | • STS |
| • CCLT | • ENWR | • JPTR | • RELA | • SWAG |
| • CCSS | • ETP* | • KOR | • RELB | • SWAH |
| • CHIN | • FREN | • LATI | • RELC | • SWED |
| • CHTR | • FRTR | • LING | • RELG | • TBTN |
| • CLAS | • GDS | • LNGS | • RELH | • TURK |
| • CPLT | • GERM | • MDST | • RELI | • UKR |
| • CZ | • GETR | • MEST | • RELJ | • URDU |
| • EAST | • GREE | • MSP | • RELS | • YIDD |

Note that only ETP 2020, 2030, 3870, 4800 can count, as well as EDLF 5000 (but not EDLF 5001).

¹<http://college.artsandsciences.virginia.edu/requirements/area>

Exceptions to the approved list. These are courses in the acceptable mnemonics that are not suitable for HSS elective credit, generally because of their specialized nature for majors in that field or because they are predominantly skills courses:

- ANTH: 1090, 3810, 3820, 4991, 4993, 4998, 4999, 5080, 5800, 5870, 5880, 5989
- ECON: 3710, 3720, 4010, 4350, 4710, 5090, 5100
- ENSP: 1600
- GDS: 1100, 4951, 4952
- MDST: 3702
- MUSI: 1310, 1993, 2993, 3310, 3320, 3360, 3390, 3993, 4575
- PSYC: 2200, 2210, 2220, 3005, 3006, 3210, 3870, 3590, 4111, 4125, 4200, 4290, 4330, 4500, 4910, 4970, 4930, 4940, 4980, 5200, 5210, 5260, 5330, 5350, 5401
- SOC: 4800, 4810, 4820, 4970, 5100, 5110, 5120, 5595, 5596
- STS: 4110

Elective credit for ANY course with a temporary course number (often x559 or x595 or x599) must be requested by petition, and the course syllabus must be attached to the petition.

This list is maintained by the office of the undergraduate dean of SEAS (Thornton A122), and only that office may grant petitions and exceptions.

7.2 Frequently Asked Questions

7.2.1 What computer science student groups exist?

There are five computer science student groups at UVa.

The **Association for Computing Machinery** Chapter at the University of Virginia is a student chapter of the national 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. Numerous events are held each year, including technical talks, workshops, social events, hack-a-thons,

etc. Any student at UVa may become a member of the chapter. Also see their web site².

The **Programming Contest Teams** at UVa participates in the International Collegiate Programming Contest (ICPC) – there is a regional contest in the fall, and potentially the World Finals in the late spring. UVa has had great success recently with earning a World Finals berth. The same group of students also host UVa’s High School Programming Contest in the spring, which is the largest such contest in the mid-Atlantic region. More information about the programming contest teams can be found online³.

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 web site⁴.

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 web site⁵.

PARFAIT is a student-run club focused on mobile application development. It provides a way for student developers to meet and create project teams so that they can improve their mobile development skills, develop a portfolio of apps, and provide the University with a much needed mobile development resource. Find out more using the “contact owners” link at the parfait mailing list page⁶.

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 Washington, 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 in-

formation, you can either contact UVa’s local ACM chapter⁷ or ACM’s 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).

Students who receive a 4 or 5 on the Computer Science A test will receive credit for CS 1110. Students who took the higher-level Computer Science course through International Baccalaureate will get credit for CS 1110 with a 5 and for both CS 1110 and CS 2110 with a 6 or 7.

Note that CS 2110 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, 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 placement exam.

7.2.4 Can I place out of CS 1110? What about CS 2110?

There is a placement exam for CS 1110, which covers all the topics taught in the course. For the current semester’s syllabus, see the current CS 1110 course web site. Successful completion of the test will allow a student to place out of the course, but does NOT give course credit – only a sufficient score on an AP or IB test, or transfer credit, can give course credit for CS 1110.

Because course credit is not awarded for the placement exam, another course must be taken instead in order to fulfill the graduation requirements. The different majors have different requirements for what needs to be taken in lieu of CS 1110.

- The BS CS requires a technical course instead (see your advisor for details about a ‘technical course’).
- The BA CS does not require CS 1110 as a major requirement; instead, it is a prerequisite, so there is no need to replace it.
- The BS CpE requires an unrestricted elective instead; see section 2.5.1 (page 6) for details on unrestricted electives; note that while that section is in the BS CS section, the requirements for unrestricted electives are defined by the school, and are the same for all SEAS majors.

²<http://acm.cs.virginia.edu/>

³<http://www.cs.virginia.edu/~asb/icpc/>

⁴<http://www.cs.virginia.edu/~acm-w/>

⁵<http://gamedevatuva.blogspot.com/>

⁶<https://lists.virginia.edu/sympa/info/parfait>

⁷<http://acm.cs.virginia.edu>

- Other Engineering majors will have different rules as to what can be substituted; consult your advisor in that department for details.

The test is offered before the beginning of the fall semester. Note that any student who has enrolled in CS 1110 or equivalent (CS 1111 or CS 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).

More information about the CS 1110 placement exam may be found online ⁸, or you can visit the computer science departmental office in Rice Hall, room 527.

Computing majors may place out of CS 2110, but they must take another CS course of a greater number (i.e., greater than CS 2110) instead. For information about the placement exam for CS 2110, please contact the current CS 2110 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 (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, APMA 2120, etc.) through the respective placement exam does not give credit and thus the credits need to be made up through other courses (in the case of CS 1110, 3 credits of a technical course will fill that spot; in the case of APMA 2120, 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 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 Scholars⁹ have slightly different requirements¹⁰ for graduation. While those requirement differences are included here, one should check at that URL¹⁰ for the most up-to-date information, as that URL will supersede the information in this section.

- Introduction to Engineering: Instead of ENGR 1620 and ENGR 1621, Rodman Scholars take ENGR 1410 (Synthesis Design I) in the fall of their first year, and ENGR 1420 (Synthesis Design II) in the spring of their first year. Note that this sequence is 6 credits, whereas the ENGR 1620 and ENGR 1621 sequence is only 4 credits. Because ENGR 1410 and ENGR 1420 this is a fall-spring sequence, mid-year applicants are not required to take it, and can use ENGR 1620/1621 credit instead.
- A total of four 1-credit seminars (ENGR 3580) must be taken prior to graduation.
- The requirements in place of STS 1500 are in a state of flux. For the classes of 2014 and earlier, STS 1500 is not required, but an HSS elective (or appropriate AP credit) must be taken in its stead. For the classes of 2015 and beyond, STS 1500 is required, but with a separate Rodman-only discussion section.
- Physics: Instead of PHYS 1425 and PHYS 2415 (and their associated labs), Rodmans may choose to take a three-course sequence for Physics majors: PHYS 1610, PHYS 1620, and PHYS 2610.

7.2.8 What is a SIS exception and how can I get one?

SIS, which is UVa’s Student Information System, keeps track of the requirements that all students must fulfill in order to graduate. If any student has an approved reason to differ from the stated guidelines, then a SIS exception has to be entered. Examples would include using a different course for a BA CS integration elective (section 3.3.3, page 14), or a BS CS & BS CpE double major wanting to count ECE 4440 (Embedded Systems Design) as a CS elective (section 4.6.1, page 21). Note that SIS exceptions are only entered with the appropriate approval. Your academic advisor can request approval from the appropriate degree committee, and have such an exception entered by contacting the SEAS undergraduate office.

⁸<http://www.cs.virginia.edu/cs1110/placement.php>

⁹<http://seas.virginia.edu/students/rodmans/>

¹⁰<http://seas.virginia.edu/students/rodmans/curriculum.php>

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, UVa's system for handling academic requirements and registration) handles major requirements, and is done to allow for people to place out of STS 1500. 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.

7.2.10 Can CS students study abroad?

Yes! To get more information about studying abroad, see online¹¹ for more details.

7.2.11 How do I transfer into the computing program?

Students must decide which school they want to receive their degree in: either in the Engineering School (which will yield a BS CS or BS CpE degree; chapter 2 (page 5) details the BS CS degree, and chapter 4 (page 19) details the BS CpE degree) or the College of Arts and Sciences (which will yield a BA CS degree, detailed chapter 3 (page 13)). Students must then apply for the degree in that school; the application process is described in section 2.4 (page 5) for the BS CS and CpE degrees, or section 3.2 (page 13) for the BA CS degree.

7.2.12 Where can I find out about the Business minor?

The courses for the Engineering Business Minor can be found on the web page for the Technology Entrepreneurship Program. These courses can be worked into the various electives for the BS CS. More details can be found online¹².

7.2.13 What CS electives can be taken without having completed CS 2150?

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

- CS 3102, Theory of Computation (this is a required class for the BS CS, and an elective for the BA CS and the BS CpE)
- CS 3205, Human-Computer Interaction

Note that CS 2150 is now a pre-requisite for CS 3330, so any course that requires CS 3330 (such as CS 4434 and CS 4457) still require CS 2150.

7.2.14 Why is CS 2330, Digital Logic Design, not offered in the spring?

CS 2330, Digital Logic Design, is cross-listed with ECE 2330. Either course counts for this requirement, and it does not matter which one you take. For unknown reasons, it is not cross-listed with CS 2330 in the spring, but it is in the fall. We don't understand why, either. But you can take ECE 2330 to fulfill this requirement, as it's all the same course.

7.2.15 How do I conquer the world?

You are on your own on that one. But getting a computing degree from UVa is a good start!

7.3 Course Descriptions

7.3.1 Course Offering History

A history of the course offerings by the department can be found online¹³. These course listings in this section are from the undergraduate record¹⁴.

Most of the lower-level courses (1000-level and 2000-level) are offered every semester. The exception is CS 2190, the 1 credit Computer Science Seminar, which is only offered in the spring. Note that CS 1120 is no longer regularly offered by the department.

Required courses in the 3000-level and 4000-level are typically offered every semester. These include: CS 3102 (Theory of Computation), CS 3240 (Advanced Software Development Techniques), CS 3330 (Computer Architecture), CS 4102 (Algorithms), and CS 4414 (Operating Systems).

The department tries to offer each elective at least once a year. Note that the department cannot guarantee this, as when an elective is offered is dependent on the available faculty. Popular electives tend to be offered every semester. Examples of the popular electives include: CS 4630 (Defense Against the Dark Arts), CS 4720 (Web and Mobile Systems), and CS 4750 (Database Systems).

Special topics courses (CS 1501, 2501, 3501, and 4501) are offered on varying schedules. Because CS 4501 is typically used for new electives, there are often multiple offerings each semester, each one on a different topic. Independent project courses are available every semester, but they are only available by instructor permission. These independent courses

¹³<http://rabi.phys.virginia.edu/mySIS/CS2/page.php?Type=Group&Group=CompSci>

¹⁴<http://records.ureg.virginia.edu/content.php?catoid=11&navoid=189>

¹¹http://www.cs.virginia.edu/~horton/study_abroad/

¹²<http://techentrepreneurship.seas.virginia.edu/>

include: CS 4980 (Capstone Research), CS 4993 (Independent Study), and CS 4998 (Distinguished BA Majors Research).

There are a few courses that are no longer regularly offered by the department. These include: CS 4434 (Dependable Computing Systems) and CS 4458 (Internet Engineering).

7.3.2 1000 Level CS Courses

CS 1010 – 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.

CS 1110 – 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.

CS 1111 – 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.

CS 1112 – 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 allowed.

CS 1120 – Introduction to Computing: Explorations in Language, Logic, and Machines (3 credits): This course is an introduction to the most important ideas in computing. It focuses on the big ideas in computer science including the major themes of recursive definitions, universality, and abstraction. It covers how to describe information processes by defining procedures using the Scheme and Python programming languages, how to analyze the costs required to carry out a procedure, and the fundamental limits of what can be computed.

CS 1501 – Special 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.

7.3.3 2000 Level CS Courses

CS 2102 – Discrete Mathematics (3 credits): Introduces discrete mathematics and proof techniques involving first order predicate logic and induction. Application areas include finite and infinite sets and elementary combinatorial problems. Development of tools and mechanisms for reasoning about discrete problems. Prerequisite: CS 1110, 1111, 1112 or 1120 with a grade of C- or higher.

CS 2110 – Software Development Methods (3 credits): A continuation of CS 1010, 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 1010, 1111, or 1112 with a grade of C- or higher.

CS 2150 – 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 and CS 2110, both with grades of C- or higher.

CS 2190 – Computer Science Seminar (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 2102 and 2110, both with a grade of C- or higher.

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

CS 2501 – Special 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 per-

mission.

7.3.4 3000 Level CS Courses

CS 3102 – Theory of Computation (3 credits): Introduces computation theory including grammars, finite state machines and Turing machines; and graph theory. Prerequisites: CS 2102 and CS 2110 both with grades of C- or higher.

CS 3205 – 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 system's 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 with a grade of C- or higher.

CS 3240 – 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 with a grade of C- or higher.

CS 3330 – 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. Prerequisite: CS 2150 with a grade of C- or higher. CS 2330 recommended. Students may not receive credit for both CS 3330 and ECE 3430.

CS 3501 – Special 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.

7.3.5 4000 Level CS Courses

CS 4102 – 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 2102 and 2150 with grades of C- or higher. Also APMA 1090 or MATH 1210 or MATH 1310.

CS 4240 – 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 with grade of C- or higher.

CS 4330 – 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 and CS 3330, both with grades of C- or higher.

CS 4414 – 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 with grade of C- or higher, CS/ECE 2330 with a grade of C- or higher, and CS 3330 or ECE 3430 with a grade of C- or higher.

CS 4434 – Dependable Computing Systems (3 credits): Focuses on the 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.

CS 4444 – 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. Prerequisites: CS 2110 with grade of C- or higher, CS/ECE 2330 with a grade of C- or higher, CS3330 or ECE 3430 with a grade of C- or higher, APMA 3100 and APMA 3110.

CS/ECE 4457 – Computer Networks (3 credits): 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 4457. Prerequisites: CS 2110 with grade of C- or higher, and CS 3330 or ECE 3430 with a grade of C- or higher.

CS 4458 – 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 with a grade of C- or better.

CS 4501 – Special 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.

CS 4610 – 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 with grade of C- or higher.

CS 4620 – 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: CS2150 with grade of C- or higher. CS3330 recommended.

CS 4630 – 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 with a grade of C- or above.

CS 4710 – 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 learn-

ing, or machine perception. Provides exposure to AI implementation methods, emphasizing programming in Common LISP. Prerequisite: CS 2150 with grade of C- or higher.

CS 4720 – 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. In this course, we will look 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 with a grade of C- or higher.

CS 4730 – 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. Topics covered in this include graphics, parallel processing, human-computer interaction, networking, artificial intelligence, and software engineering. Prerequisite: CS 2150 with a grade of C- or higher.

CS 4740 – Cloud Computing (3 credits): Investigates the architectural foundations of the various cloud platforms, as well as examining both current cloud computing platforms and modern cloud research. Student assignments utilize the major cloud platforms. Prerequisite: CS 2150 with a grade of C- or higher.

CS 4750 – 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 with grades of C- or higher.

CS 4753 – Electronic Commerce Technologies (3 credits): History of 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 with a grade of C- or higher.

CS 4810 – 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. Prerequisite: CS 2150 with a grade of C- or higher.

CS 4970 – Capstone Practicum I (3 credits): This course is one option in the CS Senior Thesis track. Under the Practicum track, students will take two 3-credit courses, CS 4970 and CS 4971. These courses would form a year-long group-based and project-based practicum class. There would be an actual customer, which could be either internal (the course instructor, other CS professors, etc.) or external (local companies, local non-profits, etc.). Prerequisite: CS 2150 with a grade of C- or higher.

CS 4971 – Capstone Practicum II (3 credits): This course is one option in the CS Senior Thesis track and is the continuation from CS 4970. Under the Practicum track, students will take two 3-credit courses, CS 4970 and CS 4971. These courses would form a year-long group-based and project-based practicum class. There would be an actual customer, which could be either internal (the course instructor, other CS professors, etc.) or external (local companies, local non-profits, etc.). Prerequisite: CS 4970.

CS 4980 – Capstone Research (1 to 3 credits): This course is one option in the CS Senior Thesis track. Students will seek out a faculty member as an advisor, and do an independent project with said advisor. Instructors can give the 3 credits across multiple semesters, if desired. This course is designed for students who are doing research, and want to use that research for their senior thesis. Note that this track could also be an implementation project, including a group-based project. Prerequisite: CS 2150 with a grade of C- or higher.

CS 4993 – 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.

CS 4998 – 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. Prerequisites: CS 2150 with a grade of C- or higher AND a CLAS student.

7.3.6 Selected ECE Courses

This section is not meant to be an exhaustive list of all courses in the Electrical Engineering department. Instead, it is meant to list the required courses for the Computer Engineering majors. Information about the other Electrical Engineering courses offered can be found online¹⁵. Note that cross-listed courses (CS/ECE 2330 (Digital Logic Design), CS 3330 (Com-

puter Architecture), and CS/ECE 4457 (Networks)) are only listed above.

ECE 2630 – Introductory Circuit Analysis (3 credits): Elementary electrical circuit concepts and their application to linear circuits with passive elements; use of Kirchhoff's voltage and current laws to derive circuit equations; solution methods for first- and second-order transient and DC steady-state responses; AC steady-state analysis; frequency domain representation of signals; trigonometric and complex Fourier series; phasor methods; complex impedance; transfer functions and resonance; Thevenin / Norton equivalent models; controlled sources. Six laboratory assignments. Prerequisite: APMA 1110.

ECE 2660 – Electronics I (3 credits): Studies the modeling, analysis, design, computer simulation, and measurement of electrical circuits which contain non-linear devices such as junction diodes, bipolar junction transistors, and field effect transistors. Includes the gain and frequency response of linear amplifiers, power supplies, and other practical electronic circuits. Three lecture and three laboratory hours. Prerequisite: ECE 2630.

ECE 3430 – Introduction to Embedded Computing Systems (3 credits): An embedded computer is designed to efficiently and (semi-) autonomously perform a small number of tasks, interacting directly with its physical environment. This lab-based course explores architecture and interface issues relating to the design, evaluation and implementation of embedded systems. Topics include hardware and software organization, power management, digital and analog I/O devices, memory systems, timing and interrupts. Prerequisite: CS/ECE 2330, CS 2110, ECE 2660—if ECE 3430 offered in spring

ECE 3750 – Signals and Systems I (3 credits): Develops tools for analyzing signals and systems operating in continuous-time, with applications to control, communications, and signal processing. Primary concepts are representation of signals, linear time-invariant systems, Fourier analysis of signals, frequency response, and frequency-domain input/output analysis, the Laplace transform, and linear feedback principles. Practical examples are employed throughout, and regular usage of computer tools (Matlab, CC) is incorporated. Students cannot receive credit for both this course and BIOM 3310. Prerequisite: ECE 2630 and APMA 2130.

ECE 4435 – Computer Architecture & Design (3 credits): Introduces computer architecture and provides a foundation for the design of complex synchronous digital devices, focusing on: 1) Established approaches of computer architecture, 2) Techniques for managing complexity at the register transfer level, and 3) Tools for digital hardware description, simu-

¹⁵<http://www.ece.virginia.edu/>

lation, and synthesis. Includes laboratory exercises and significant design activities using a hardware description language and simulation. Prerequisite: ECE 3430

ECE 4440 – Embedded System Design (3 credits): Modeling, analysis and design of embedded computer systems. Tradeoff analysis and constraint satisfaction facilitated by the use of appropriate analysis models. Includes a semester-long design of an embedded system to meet a specific need. Counts as MDE (major design experience) for both electrical and computer engineering students.

7.4 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. Earlier versions of this handbook listed both the both the 3-digit number and the 4-digit number, in the form of “CS 1110 (101)” to aid the transition, as well as a full table mapping the 3-digit course numbers to the 4-digit course numbers. The current version no longer lists the courses that way. This handbook no longer lists the old 3-digit course numbers, but they can be found online¹⁶.

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: software 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.

¹⁶<http://www.virginia.edu/registrar/atoz.html#CS>

7.5 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. Whatever set of requirements is completed, it must be *all* the requirements from that set.

Any changes to the requirements will typically 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 the spring of 2013 (and before then-first year SEAS majors declared the BS CS and CpE majors).

7.5.1 Prior requirements revisions

There are no known currently enrolled students who are eligible to graduate using any set of requirements prior to those listed above, and thus prior sets of revisions are not included in this handbook. Earlier editions of this handbook, available from the department, describe the prior sets of requirements.

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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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