The following requirements are for students entering Fall 2019.

**Curriculum - B.S. in Computer Science**

The following requirements are for students entering Fall 2019.

**Computer Science**

- **Computer Science Core (all of the following):**
  - 07-128 First Year Immigration Course **1**

- **Computer Science Core (all of the following):**
  - 07-152 Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122) **10**
  - 15-150 Principles of Functional Programming **10**
  - 15-210 Parallel and Sequential Data Structures and Algorithms **12**
  - 15-213 Introduction to Computer Systems **12**
  - 15-251 Great Ideas in Theoretical Computer Science **12**
  - 15-451 Algorithm Design and Analysis **12**

- **One Logics/Languages elective (min. 9 units):**
  - 15-312 Foundations of Programming Languages **12**
  - 15-314 Programming Language Semantics **12**
  - 15-316 Software Foundations of Security and Privacy **9**
  - 15-317 Constructive Logic **9**
  - 15-414 Bug Catching: Automated Program Verification **9**
  - 15-424 Logical Foundations of Cyber-Physical Systems **12**
  - 17-355 Program Analysis **12**
  - 80-413 Category Theory **9**

- **One Artificial Intelligence elective (min. 9 units):**
  - 15-441 Computational Thinking **9**
  - 15-418 Parallel and Distributed Systems **12**
  - 15-411 Computer Architecture and Programming **12**
  - 16-384 Robot Kinematics and Dynamics **12**
  - 16-385 Computer Vision **12**
  - 16-385 Vision and Robotics **12**

- **One Software Systems elective (min. 12 units):**
  - 15-410 Operating System Design and Implementation **15**
  - 15-411 Compiler Design **15**
  - 15-418 Parallel Computer Architecture and Programming **12**
  - 15-440 Distributed Systems **12**
  - 15-441 Networking and the Internet **12**
  - 15-445 Database Systems **12**

- **One Domains elective (min. 9 units):**
  - 15-201 Database Systems **12**
  - 15-213 Introduction to Computer Systems **12**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
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  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**

- **One Domains elective (min. 9 units):**
  - 15-201 Database Systems **12**
  - 15-213 Introduction to Computer Systems **12**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**
  - 15-317 Constructive Logic **9**

- **Two Computer Science electives:**
  - Units **18**

These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)

### Mathematics

All of the following courses:

- 15-151 Mathematical Foundations for Computer Science **10**
  - (if not offered, substitute 21-127 or 21-128)
Double Counting

In general, courses taken in satisfaction of the minor or additional major may also count toward any general education category in the CS major (i.e., courses outside of the Computer Science and Mathematics requirements). Double counting toward Computer Science and Mathematics courses in the CS major is strictly limited and depends on the chosen minor (or additional major). In general, students may double count at most 5 of the 12 core Computer Science requirements toward all other declared additional majors and minors. Additional majors and minors have their own double counting rules as well. Consult with a CS undergraduate advisor and an advisor from the department of the minor (or additional major) for specific restrictions on double counting.

Computer Science Program

Computing @ Carnegie Mellon (1 course)
The following course is required of all students to familiarize them with the campus computing environment:
99-101 Computing @ Carnegie Mellon 3

Free Electives
A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements:

<table>
<thead>
<tr>
<th>Area</th>
<th>Courses</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Science (core courses, constrained electives, and SCS electives)</td>
<td>12</td>
<td>125</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Technical Communication</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Science/Engineering</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Humanities/Arts</td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Minor or Concentration Requirement/Free electives</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Computing @ Carnegie Mellon</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>First Year Seminar</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and one semester of calculus. Students with credit for two semesters of calculus may start with a more advanced math class (e.g. 21-241) in their first year. Students with no credit for introductory programming and/or one semester of calculus will take 15-112 and/or 21-120 in their first semester and shift a few courses to later semesters after consulting with their academic advisor; these students should still be able to complete their degree in four years. It is recommended that students keep their academic load lighter for their Senior Fall semester to account for on-site job interviews or for their Senior Spring semester to account for visits to graduate schools.

Freshman Year:

<table>
<thead>
<tr>
<th>Fall</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>07-128 First Year Immigration Course</td>
<td>1</td>
</tr>
<tr>
<td>07-131 Great Practical Ideas for Computer Scientists (optional, not required for CS major)</td>
<td>2</td>
</tr>
<tr>
<td>15-122 Principles of Imperative Computation</td>
<td>10</td>
</tr>
<tr>
<td>15-151 Mathematical Foundations for Computer Science (if not offered, substitute 21-127)</td>
<td>10</td>
</tr>
<tr>
<td>21-122 Integration and Approximation</td>
<td>10</td>
</tr>
<tr>
<td>76-101 Interpretation and Argument</td>
<td>9</td>
</tr>
<tr>
<td>99-101 Computing @ Carnegie Mellon</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>45</td>
</tr>
</tbody>
</table>

Spring

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-150 Principles of Functional Programming</td>
</tr>
<tr>
<td>15-213 Introduction to Computer Systems</td>
</tr>
<tr>
<td>21-259 Calculus in Three Dimensions</td>
</tr>
<tr>
<td>xx-xxx Science/Engineering Course</td>
</tr>
<tr>
<td>xx-xxx Humanities and Arts Elective</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Sophomore Year:

<table>
<thead>
<tr>
<th>Fall</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-210 Parallel and Sequential Data Structures and Algorithms</td>
<td>12</td>
</tr>
<tr>
<td>21-241 Matrices and Linear Transformations</td>
<td>10</td>
</tr>
<tr>
<td>xx-xxx Science/Engineering Course</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>39</td>
</tr>
</tbody>
</table>
For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/#scshonorsresearchtheses) section for learning objectives, application requirements and expected outcomes.

**Dual Degree in Computer Science**

Students wishing to pursue a Dual Degree in Computer Science are required to apply in the same way as students wishing to transfer into the Computer Science major. Details are given in the SCS Policies section. Besides the student’s primary degree requirements, a student accepted for Dual Degree in CS is required to complete at least 450 units in total and meet all requirements for the CS major including all general education requirements (humanities/arts and science/engineering). Dual degree students do not need to complete 15-128, and these students will replace 15-151 with either 21-127 or 21-128. Since the CS major requires at least a minor or concentration in another area, the student’s primary major will substitute for this requirement. Note that the primary major must be completed prior to or at the same time as the dual degree in CS to satisfy the minor requirement; a dual degree in CS cannot be certified if the primary degree is not completed. Students should consult with the Assistant Dean in the CS Undergraduate Office and/or their CS academic advisor to review all requirements, once approved.

**Double-Counting Restriction**

Students pursuing a Dual Degree in Computer Science must complete all requirements for the CS primary major (except 15-128 which is not required and 15-151 which will be replaced with 21-127 or 21-128). In addition, at most 5 of the 12 computer science requirements can double count with all other declared majors and minors. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

**Computer Science Additional Major**

Students interested in pursuing an additional major in Computer Science should first consult with an advisor in the CS Undergraduate Office. Students are expected to complete the requirements for the CS minor first before continuing on to the additional major. Completion of the CS additional major requires 12 computer science courses (not including 15-110 and 15-112 if needed), 5 mathematics courses, and 1 technical communication course. Students are expected to complete all courses for the additional major with an average QPA of 3.0 or higher.

Declaraton for the additional major is allowed only after all math requirements are completed or in progress, and at least 9 of the 12 CS requirements (core and electives) are completed or in progress. Due to high demand, seats in upper-level CS courses are not guaranteed for additional majors so students should plan to be flexible in selecting constrained and general electives. Acceptance to complete a Computer Science additional major is not guaranteed and depends on student performance and seat availability.

The following courses are required for the Additional Major in Computer Science:

### Computer Science requirements (12 courses):

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-122 Principles of Imperative Computation</td>
<td>10</td>
</tr>
<tr>
<td>15-150 Principles of Functional Programming</td>
<td>10</td>
</tr>
<tr>
<td>15-210 Parallel and Sequential Data Structures and Algorithms</td>
<td>12</td>
</tr>
<tr>
<td>15-213 Introduction to Computer Systems</td>
<td>12</td>
</tr>
<tr>
<td>15-251 Great Ideas in Theoretical Computer Science</td>
<td>12</td>
</tr>
<tr>
<td>15-451 Algorithm Design and Analysis</td>
<td>12</td>
</tr>
<tr>
<td>One Logic &amp; Languages elective (minimum 9 units):</td>
<td></td>
</tr>
<tr>
<td>15-312 Foundations of Programming Languages</td>
<td>12</td>
</tr>
<tr>
<td>15-314 Programming Language Semantics</td>
<td>12</td>
</tr>
<tr>
<td>15-316 Software Foundations of Security and Privacy</td>
<td>9</td>
</tr>
<tr>
<td>15-317 Constructive Logic</td>
<td>9</td>
</tr>
<tr>
<td>15-414 Bug Catching: Automated Program Verification</td>
<td>9</td>
</tr>
<tr>
<td>15-424 Logical Foundations of Cyber-Physical Systems</td>
<td>12</td>
</tr>
<tr>
<td>17-355 Program Analysis</td>
<td>12</td>
</tr>
</tbody>
</table>

**Undergraduate Research Thesis**

CS majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work. 15 units per semester. Up to 38 units can be counted toward CS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using Research and Innovation in Computer Science (15-300, 9 units) as their technical communications requirement in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent Research Practicum in Computer Science (15-400, 12 units) that allows students to complete a small-scale research study or experiment and present a research poster. Students who use 15-400 to start their senior thesis can use these units toward the required 36 units.
Computer Science Program

80-413 Category Theory 9
others as designated by the CS Undergraduate Program

One Systems elective (minimum 12 units): Units
15-410 Operating System Design and Implementation 15
15-411 Compiler Design 15
15-418 Parallel Computer Architecture and Programming 12
15-440 Distributed Systems 12
15-441 Networking and the Internet 12
15-445 Database Systems 12
others as designated by the CS Undergraduate Program

One Artificial Intelligence elective (minimum 9 units): Units
10-315 Introduction to Machine Learning (SCS Majors) (or 10-301 by permission) 12
11-411 Natural Language Processing 12
11-485 Introduction to Deep Learning 9
15-281 Artificial Intelligence: Representation and Problem Solving 12
15-386 Neural Computation 9
16-384 Robot Kinematics and Dynamics 12
16-385 Computer Vision 12
others as designated by the CS Undergraduate Program

One Domains elective (minimum 9 units): Units
15-332 Introduction to Computer Music 9
15-330 Introduction to Computer Security 12
15-455 Undergraduate Complexity Theory 9
15-462 Computer Graphics 12
17-313 Foundations of Software Engineering 12
others as designated by the CS Undergraduate Program

Two Computer Science electives (minimum 18 units): 18
These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below):
Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and SCS graduate courses might not be allowed. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)

Math requirements (minimum 5 courses): Units
All of the following courses:
21-122 Integration and Approximation 10
21-259 Calculus in Three Dimensions 9
21-127 Concepts of Mathematics 10
or 21-128 Mathematical Concepts and Proofs 10
21-241 Matrices and Linear Transformations or 21-242 Matrix Theory 10
Plus one of the following:
15-259 Probability and Computing 12
21-325 Probability 9
36-218 Probability Theory for Computer Scientists 9
36-226 Introduction to Statistical Inference (for students already taking 36-217 or 36-225) 9

Technical Communication requirement (1 course): Units
One Technical Communications course:
15-300 Research and Innovation in Computer Science (seating limited, by permission of instructor only) 9
17-200 Ethics and Policy Issues in Computing 9
76-270 Writing for the Professions 9

Double-Counting Restriction
Students pursuing an Additional Major in Computer Science must complete all requirements listed above. In addition, at most 5 of the 12 computer science requirements can be double counted toward all other declared majors and minors. The mathematics and technical communication requirements can be double counted without restriction. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Minor

FOR STUDENTS ENTERING CMU IN FALL 2018

Students interested in pursuing a minor in Computer Science should first consult with an advisor in the CS Undergraduate Office after completion of the prerequisites, 15-122, 15-150 and with at least one of the 200-level required courses in progress. Students are expected to complete all courses for the minor with a C or higher (for a minor average GPA of 2.0 or higher).

The following courses are required for the Minor in Computer Science:

Prerequisites: Units
15-112 Fundamentals of Programming and Computer Science (some students may need to take 15-110 prior to 15-112 for additional preparation) 12
21-127 or 21-128 Concepts of Mathematics Mathematical Concepts and Proofs 10-12

Computer Science core courses:
15-122 Principles of Imperative Computation 10
15-150 Principles of Functional Programming 10
15-210 Parallel and Sequential Data Structures and Algorithms 12

One of the following Computer Science core courses:
15-213 Introduction to Computer Systems 12
15-251 Great Ideas in Theoretical Computer Science 12

Two additional Computer Science electives, of at least 9 units each:
CS elective courses must be 15-213 or higher, at least 9-units each. 15-221 and 15-351 cannot be used. One course can be from any other SCS department besides the Computer Science Department, with prior approval. Note: Students who take 15-213/18-213 or 15-251 as part of another degree are required to replace that CS minor requirement with another CS elective (15-xxx) as defined above, for a total of 3 additional CS electives.

Double-Counting Restriction

Students may double-count a maximum of 2 courses for the CS minor (not including the prerequisites) toward all other majors and minors. Students, especially from computing-related majors, interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to review double-counting restrictions specific to their own situations.