COMPUTER SCIENCE

http://cs.illinois.edu

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Department Office: 2232 Siebel Center, 201 N. Goodwin Avenue, Urbana, (217) 333-3373

For the Degree of Bachelor of Science in Computer Science

The computer science curriculum provides both a broad and deep knowledge of the theory, design, and application of computer systems, with an emphasis on software systems. Because computing is ubiquitous, application areas involve virtually any field imaginable - from developing gene sequencing algorithms via techniques in computational biology, to designing user interfaces for mobile applications; from designing methods for high frequency trading, to creating computer generated graphics and special effects in the gaming industry; and from creating embedded real time systems to be deployed in medical devices, to analyzing social data from internet communication patterns. During the first two years the curriculum provides a strong foundation in mathematics, science, and computation. Advanced coursework in areas of the student's choosing follows in the second two years, which include either a senior thesis or a senior project. Graduates may go on to graduate study or leading positions in industry.

A combined B.S.-M.S. Computer Science degree program is available. Its admission and course requirements are described in the College of Engineering program information section (http://catalog.illinois.edu/undergraduate/engineer).

A Software Engineering Certificate (https://wiki.cites.illinois.edu/wiki/display/undergradProg/Degree+Requirements/#DegreeRequirements-softengcert) is also available to all students in the computer science curriculum interested in a career in software engineering. It provides the depth and breadth necessary for satisfying possible future software engineering accreditation requirements.

Overview of Curricular Requirements

The curriculum requires 128 hours for graduation and is organized as shown below.

A technical grade point average requirement for graduation applies to students in this curriculum. This rule is summarized at the College of Engineering’s Undergraduate Advising Website (https://wiki.cites.illinois.edu/wiki/display/ugadvise/Liberal+Education+Electives) develop students' understanding of human culture and society, build skills of inquiry and critical thinking, and lay a foundation for civic engagement and lifelong learning.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 100</td>
<td>Freshman Orientation 1,2</td>
<td>1</td>
</tr>
<tr>
<td>CS 210</td>
<td>Ethical &amp; Professional Issues</td>
<td>2</td>
</tr>
<tr>
<td>ENG 100</td>
<td>Engineering Orientation 2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

1. This optional course is highly recommended and may be used to help meet free elective requirements.
2. External transfer students take ENG 300 instead.

Foundational Mathematics and Science

These courses stress the basic mathematical and scientific principles upon which the engineering discipline is based.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 221</td>
<td>Calculus I 1</td>
<td>4</td>
</tr>
<tr>
<td>MATH 231</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>MATH 241</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MATH 415</td>
<td>Applied Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 211</td>
<td>University Physics: Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 212</td>
<td>University Physics: Elec &amp; Mag</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>Science elective, from departmentally approved list</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

1. MATH 220 may be substituted, with four of the five credit hours applying toward the degree. MATH 220 is appropriate for students with no background in calculus.

Computer Science Technical Core

These courses stress fundamental concepts and basic laboratory techniques that comprise the common intellectual understanding of computer science.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>CS 125</td>
<td>Intro to Computer Science</td>
<td>4</td>
</tr>
<tr>
<td>CS 126</td>
<td>Software Design Studio</td>
<td>3</td>
</tr>
<tr>
<td>CS 173</td>
<td>Discrete Structures</td>
<td>3</td>
</tr>
<tr>
<td>CS 225</td>
<td>Data Structures</td>
<td>4</td>
</tr>
<tr>
<td>CS 233</td>
<td>Computer Architecture</td>
<td>4</td>
</tr>
<tr>
<td>CS 241</td>
<td>System Programming</td>
<td>4</td>
</tr>
<tr>
<td>CS 361</td>
<td>Probability &amp; Statistics for Computer Science</td>
<td>3</td>
</tr>
<tr>
<td>CS 357</td>
<td>Numerical Methods I</td>
<td>3</td>
</tr>
<tr>
<td>CS 374</td>
<td>Introduction to Algorithms &amp; Models of Computation</td>
<td>4</td>
</tr>
<tr>
<td>CS 421</td>
<td>Progrmg Languages &amp; Compilers</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

Technical Electives

These courses stress the rigorous analysis and design principles practiced in major subdisciplines of computer science. Students select eight courses, at least six of which must be advanced CS courses. Three courses must be selected from one area of CS and at least one course should satisfy the team project requirement.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>Technical electives to be chosen from departmentally approved list</td>
<td>24</td>
</tr>
</tbody>
</table>

Liberal Education

The liberal education courses (https://wiki.cites.illinois.edu/wiki/display/ugadvise/Liberal+Education+Electives) develop students' understanding of human culture and society, build skills of inquiry and critical thinking, and lay a foundation for civic engagement and lifelong learning.

Information listed in this catalog is current as of 04/2018.
### Code Title Hours
Electives from the campus General Education Social and Behavioral Sciences list. 6
Electives from the campus General Education Humanities and the Arts list. 6
Electives either from a list approved by the college, or from the campus General Education lists for Social and Behavioral Sciences or Humanities and the Arts. 6
Total Hours 18

Students must also complete the campus cultural studies requirement by completing (i) one western/comparative culture(s) course and (ii) one non-western/U.S. minority culture(s) course from the General Education cultural studies lists. Most students select liberal education courses that simultaneously satisfy these cultural studies requirements. Courses from the western and non-western lists that fall into free electives or other categories may also be used satisfy the cultural studies requirements.

### Composition
These courses teach fundamentals of expository writing.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHET 105</td>
<td>Writing and Research</td>
<td>4</td>
</tr>
</tbody>
</table>

Advanced Composition. May be satisfied by taking any course in either the liberal education or free elective categories which has the Advanced Composition designation.

Total Hours 4

### Free Electives
These unrestricted electives, subject to certain exceptions as noted at the College of Engineering Advising Website (https://wiki.cites.illinois.edu/wiki/display/ugadvise/Free+Electives), give the student the opportunity to explore any intellectual area of unique interest. This freedom plays a critical role in helping students to define research specialties or to complete minors.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free electives.</td>
<td>19</td>
</tr>
</tbody>
</table>

### Suggested Sequence
The schedule that follows is illustrative, showing the typical sequence in which courses would be taken by a student with no college course credit already earned and who intends to graduate in four years. Each individual's case may vary, but the position of required named courses is generally indicative of the order in which they should be taken.

#### First Year

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science elective</td>
<td>3</td>
</tr>
<tr>
<td>CS 100 Freshman Orientation</td>
<td>1</td>
</tr>
<tr>
<td>CS 125 Intro to Computer Science</td>
<td>4</td>
</tr>
<tr>
<td>ENG 100 Engineering Orientation</td>
<td>0</td>
</tr>
<tr>
<td>MATH 221 Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>RHET 105 Writing and Research (or Liberal education elective)</td>
<td>3-4</td>
</tr>
</tbody>
</table>

Semester Hours 15-16

#### Second Semester

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 126</td>
<td>Software Design Studio</td>
<td>3</td>
</tr>
<tr>
<td>CS 173</td>
<td>Discrete Structures</td>
<td>3</td>
</tr>
<tr>
<td>MATH 231</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 211</td>
<td>University Physics: Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>RHET 105</td>
<td>Writing and Research</td>
<td>4-3</td>
</tr>
</tbody>
</table>

Semester Hours 17-16

#### Second Year

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 225 Data Structures</td>
<td>4</td>
</tr>
<tr>
<td>CS 233 Computer Architecture</td>
<td>4</td>
</tr>
<tr>
<td>MATH 241 Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 212 University Physics: Elec Mag</td>
<td>4</td>
</tr>
</tbody>
</table>

Semester Hours 16

<table>
<thead>
<tr>
<th>Second Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 241 System Programming</td>
<td>4</td>
</tr>
<tr>
<td>CS 361 Probability Statistics for Computer Science</td>
<td>3</td>
</tr>
<tr>
<td>MATH 415 Applied Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>Liberal education elective</td>
<td>6</td>
</tr>
</tbody>
</table>

Semester Hours 16

#### Third Year

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 357 Numerical Methods I</td>
<td>3</td>
</tr>
<tr>
<td>CS 374 Introduction to Algorithms Models of Computation</td>
<td>4</td>
</tr>
<tr>
<td>CS Technical elective</td>
<td>3</td>
</tr>
<tr>
<td>Liberal education elective</td>
<td>3</td>
</tr>
<tr>
<td>Free elective</td>
<td>3</td>
</tr>
</tbody>
</table>

Semester Hours 16

<table>
<thead>
<tr>
<th>Second Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS Technical electives</td>
<td>9</td>
</tr>
<tr>
<td>CS 210 Ethical Professional Issues</td>
<td>2</td>
</tr>
<tr>
<td>Liberal education elective</td>
<td>3</td>
</tr>
<tr>
<td>Free elective</td>
<td>3</td>
</tr>
</tbody>
</table>

Semester Hours 17

#### Fourth Year

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 421 Progmr Languages Compilers</td>
<td>3</td>
</tr>
<tr>
<td>CS Technical electives</td>
<td>6</td>
</tr>
<tr>
<td>Liberal education elective</td>
<td>4</td>
</tr>
<tr>
<td>Free electives</td>
<td>3</td>
</tr>
</tbody>
</table>

Semester Hours 16

<table>
<thead>
<tr>
<th>Second Semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS Technical electives</td>
<td>6</td>
</tr>
<tr>
<td>Free electives</td>
<td>9</td>
</tr>
</tbody>
</table>

Semester Hours 15

Total Hours: 128

1. This optional course is highly recommended for freshmen, who may use it to help meet free elective requirements.
Quantitative Reasoning I

This course satisfies the General Education Criteria for: majors. Prerequisite: MATH 112.

Different application areas. Intended for non-science and non-engineering and practice of programming for the solution of simple problems in application packages such as spreadsheets and databases. Concepts hardware, systems and applications software, and networks. Widely used Functions and interrelationships of computer system components: Computing as an essential tool of academic and professional activities.

CS 105   Intro Computing: Non-Tech   credit: 3 Hours.
Computing as an essential tool of academic and professional activities. Functions and interrelationships of computer system components: hardware, systems and applications software, and networks. Widely used application packages such as spreadsheets and databases. Concepts and practice of programming for the solution of simple problems in different application areas. Intended for non-science and non-engineering majors. Prerequisite: MATH 112.

This course satisfies the General Education Criteria for: Quantitative Reasoning I

CS 125   Intro to Computer Science   credit: 4 Hours.
Basic concepts in computing and fundamental techniques for solving computational problems. Intended as a first course for computer science majors and others with a deep interest in computing. Prerequisite: Three years of high school mathematics or MATH 112.

This course satisfies the General Education Criteria for: Quantitative Reasoning I

CS 126   Software Design Studio   credit: 3 Hours.
Fundamental principles and techniques of software development. Design, documentation, testing, and debugging software, with a significant emphasis on code review. Credit is not given for both CS 242 and CS 126. Prerequisite: CS 125. For majors only.

CS 173   Discrete Structures   credit: 3 Hours.
Discrete mathematical structures frequently encountered in the study of Computer Science. Sets, propositions, Boolean algebra, induction, recursion, relations, functions, and graphs. Credit is not given for both Math 213 and MATH 213. Prerequisite: One of CS 125, ECE 220; one of MATH 220, MATH 221.

CS 199   Undergraduate Open Seminar in Computer Science   credit: 0 to 5 Hours.
Topics vary. Approved for Letter and S/U grading. May be repeated.

CS 210   Ethical & Professional Issues   credit: 2 Hours.
Ethics for the computing profession. Ethical decision-making; licensing; intellectual property, freedom of information, and privacy. Credit is not given for both CS 210 and ECE 316. Prerequisite: CS 225. Junior standing required.

CS 225   Data Structures   credit: 4 Hours.
Data abstractions: elementary data structures (lists, stacks, queues, and trees) and their implementation using an object-oriented programming language. Solutions to a variety of computational problems such as search on graphs and trees. Elementary analysis of algorithms. Prerequisite: CS 125 or ECE 220; CS 173 or MATH 213.

This course satisfies the General Education Criteria for: Quantitative Reasoning I

CS 233   Computer Architecture   credit: 4 Hours.
Fundamentals of computer architecture: digital logic design, working up from the logic gate level to understand the function of a simple computer; machine-level programming to understand implementation of high-level languages; performance models of modern computer architectures to enable performance optimization of software; hardware primitives for parallelism and security. Prerequisite: CS 125 and CS 173; credit or concurrent enrollment in CS 225.

CS 240   Introduction to Computer Systems   credit: 3 Hours.
Basics of computer systems. Number representations, assembly/ machine language, abstract models of processors (fetch/execute, memory hierarchy), processes/process control, simple memory management, file I/O and directories, network programming, usage of cloud services. Prerequisite: CS 225 or both CS 205 and CS 110C++.
CS 241 System Programming  credit: 4 Hours.
Basics of system programming, including POSIX processes, process
control, inter-process communication, synchronization, signals, simple
memory management, file I/O and directories, shell programming, socket
network programming, RPC programming in distributed systems, basic
security mechanisms, and standard tools for systems programming such
as debugging tools. Credit is not given for both CS 241 and ECE 391.
Prerequisite: CS 225; credit or concurrent registration in CS 233.

CS 242 Programming Studio  credit: 3 Hours.
Intensive programming lab intended to strengthen skills in programming.
Prerequisite: CS 241.

CS 296 Honors Course  credit: 1 Hour.
Group projects for honors credit in computer science. Sections of this
course are offered in conjunction with other 200-level computer science
courses taken concurrently. A special examination may be required for
admission to this course. May be repeated. Prerequisite: Concurrent
registration in another 200-level computer science course (see Schedule).

CS 357 Numerical Methods I  credit: 3 Hours.
Fundamentals of numerical methods for students in science and
engineering; floating-point computation, systems of linear equations,
approximation of functions and integrals, the single nonlinear equation,
and the numerical solution of ordinary differential equations; various
applications in science and engineering; programming exercises and use
of high quality mathematical library routines. Same as MATH 357. Credit
is not given for CS 357 if credit for CS 450 has been earned. (Counts
for advanced hours in LAS). Prerequisite: A 100-level computer science
course; MATH 225 or MATH 241; MATH 241.

CS 361 Probability & Statistics for Computer Science  credit: 3 Hours.
Introduction to probability theory and statistics with applications to
computer science. Topics include: visualizing datasets, summarizing
data, basic descriptive statistics, conditional probability, independence,
Bayes theorem, random variables, joint and conditional distributions,
expectation, variance and covariance, central limit theorem. Markov
inequality, Chebyshev inequality, law of large numbers, Markov chains,
simulation, the PageRank algorithm, populations and sampling, sample
mean, standard error, maximum likelihood estimation, Bayes estimation,
hyothesis testing, confidence intervals, linear regression, principal
component analysis, classification, and decision trees. Same as
STAT 361. Credit is not given for both CS 361 and ECE 313. Prerequisite:
MATH 220 or 221; credit or concurrent registration in MATH 225. For
majors only.

CS 374 Introduction to Algorithms & Models of Computation  credit: 4 Hours.
Analysis of algorithms, major paradigms of algorithm design including
recursive algorithms, divide-and-conquer algorithms, dynamic
programming, greedy algorithms, and graph algorithms. Formal
models of computation including finite automata and Turing machines.
Limitations of computation arising from fundamental notions of
algorithm and from complexity-theoretic constraints. Reductions,
undecidability and NP-completeness. Same as ECE 374. Prerequisite:
CS 225; MATH 225 or MATH 415.

CS 397 Individual Study  credit: 1 to 3 Hours.
May be repeated. Prerequisite: Consent of instructor.

CS 398 Special Topics  credit: 1 to 4 Hours.
Subject offerings of new and developing areas of knowledge in computer
science intended to augment the existing curriculum. See Class Schedule
or departmental course information for topics and prerequisites. May be
repeated in the same or separate terms if topics vary.

CS 410 Text Information Systems  credit: 3 or 4 Hours.
Theory, design, and implementation of text-based information systems.
Text analysis, retrieval models (e.g., Boolean, vector space, probabilistic),
text categorization, text filtering, clustering, retrieval system design and
implementation, and applications to web information management. 3
undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225.

CS 411 Database Systems  credit: 3 or 4 Hours.
Examination of the logical organization of databases: the entity-
relationship model; the hierarchical, network, and relational data models
and their languages. Functional dependencies and normal forms. Design,
implementation, and optimization of query languages; security and
integrity; concurrency control, and distributed database systems. 3
undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225.

CS 412 Introduction to Data Mining  credit: 3 to 4 Hours.
Concepts, techniques, and systems of data warehousing and data
mining. Design and implementation of data warehouse and on-line
analytical processing (OLAP) systems; data mining concepts, methods,
systems, implementations, and applications. 3 undergraduate hours. 3 or
4 graduate hours. Prerequisite: CS 225.

CS 413 Intro to Combinatorics  credit: 3 or 4 Hours.
Same as MATH 413. See MATH 413.

CS 414 Multimedia Systems  credit: 3 or 4 Hours.
Organization and structure of modern multimedia systems; audio and
video encoding; quality of service concepts; scheduling algorithms for
multimedia within OS and networks multimedia protocols over high-
speed networks; synchronization schemes, user-interface design;
multimedia teleservices. 3 undergraduate hours. 3 or 4 graduate hours.
Prerequisite: CS 241 or ECE 391.

CS 418 Interactive Computer Graphics  credit: 3 Hours.
Basic mathematical tools and computational techniques for modeling,
rendering, and animating 3-D scenes. Same as CSE 427. 3 undergraduate
hours. 3 or 4 graduate hours. Prerequisite: CS 225; MATH 225 or
MATH 415; MATH 241.

CS 419 Production Computer Graphics  credit: 3 or 4 Hours.
Advanced methods for representing, displaying, and rendering two-,
three-, and four-dimensional scenes. General algebraic curves and
surfaces, splines, Gaussian and bump-function representation, fractals,
particle systems, constructive solid geometry methods, lighting models,
radiosity, advanced ray-tracing methods, surface texturing animation
techniques, data visualization methods. 3 undergraduate hours. 3 or 4
graduate hours. Prerequisite: CS 418.

CS 420 Parallel Progrmg; Sci & Engr  credit: 3 or 4 Hours.
Fundamental issues in design and development of parallel programs
for various types of parallel computers. Various programming models
according to both machine type and application area. Cost models,
debugging, and performance evaluation of parallel programs with actual
application examples. Same as CSE 402 and ECE 492. 3 undergraduate
hours. 3 or 4 graduate hours. Prerequisite: CS 225.

CS 421 Progrmg Languages & Compilers  credit: 3 or 4 Hours.
Structure of programming languages and their implementation. Basic
language design principles; abstract data types; functional languages;
type systems; object-oriented languages. Basics of lexing, parsing,
syntax-directed translation, semantic analysis, and code generation. 3
undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 233 and CS
373.
CS 422 Programming Language Design credit: 3 or 4 Hours. Exploration of major language design paradigms using imperative and functional programming as unifying themes. Tools include both practical language processor construction and theoretical models. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241.

CS 423 Operating Systems Design credit: 3 or 4 Hours. Organization and structure of modern operating systems and concurrent programming concepts. Deadlock, virtual memory, processor scheduling, and disk systems. Performance, security, and protection. Same as CSE 423. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241 or ECE 391.

CS 424 Real-Time Systems credit: 3 or 4 Hours. Supervisory control aspects of Cyber Physical Systems (CPS): fundamentals of reliability analysis, real-time scheduling, simple feedback control, software fault tolerance architecture, wireless networking and energy saving, principles of safety critical system engineering. Student groups design and demonstrate supervisory control architecture for a robot. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241.

CS 425 Distributed Systems credit: 3 or 4 Hours. Protocols, specification techniques, global states and their determination, reliable broadcast, transactions and commitment, security, and real-time systems. Same as ECE 428. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241 or ECE 391.

CS 426 Compiler Construction credit: 3 or 4 Hours. Compiler structure, syntax analysis, syntax-directed translation, automatically constructed recognizers, semantic analysis, code generation, intermediate language, optimization techniques. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241.

CS 427 Software Engineering I credit: 3 or 4 Hours. Software process, analysis and design. Software development paradigms, system engineering, function-based analysis and design, and object-oriented analysis and design. Course will use team-projects for hands-on exercises. Same as CSE 426. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225 and CS 373.

CS 428 Software Engineering II credit: 3 or 4 Hours. Continuation of CS 427. Software development, management, and maintenance. Project and configuration management, collaborative development models, software quality assurance, interoperability domain engineering and software reuse, and software re-engineering. Same as CSE 429. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 427.

CS 429 Software Engineering II, ACP credit: 3 Hours. Continuation of CS 427. Identical to CS 428 except for the additional writing component. See CS 428. 3 undergraduate hours. 3 graduate hours. Prerequisite: CS 427. This course satisfies the General Education Criteria for: Advanced Composition.

CS 431 Embedded Systems credit: 3 Hours. A survey of sampled data systems and embedded architecture; key concepts in common embedded system applications; signal processing and control; embedded microprocessor and device interface; time-critical I/O handling; data communications; real-time operating systems and techniques for the development and analysis of embedded real-time software; hands-on laboratory projects. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241 or ECE 391.

CS 433 Computer System Organization credit: 3 or 4 Hours. Computer system analysis and design. Organizational dependence on computations to be performed; speed and cost of parts and overall machines; instruction set design; pipeline and vector machines; memory hierarchy design. Same as CSE 422. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 233.

CS 436 Computer Networking Laboratory credit: 3 or 4 Hours. Same as ECE 435. See ECE 435.

CS 438 Communication Networks credit: 3 or 4 Hours. Layered architectures and the OSI Reference Model; design issues and protocols in the transport, network, and data link layers; architectures and control algorithms of local-area, point-to-point, and satellite networks; standards in networks access protocols; models of network interconnection; overview of networking and communication software. Same as ECE 438. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241 or ECE 391; one of ECE 313, MATH 461, MATH 463.

CS 439 Wireless Networks credit: 3 or 4 Hours. Same as ECE 439. See ECE 439.

CS 440 Artificial Intelligence credit: 3 or 4 Hours. Major topics in and directions of research in artificial intelligence: AI languages (LISP and PROLOG), basic problem solving techniques, knowledge representation and computer inference, machine learning, natural language understanding, computer vision, robotics, and societal impacts. Same as ECE 448. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225 or ECE 391.

CS 445 Computational Photography credit: 3 or 4 Hours. Computer vision techniques to enhance, manipulate, and create media from photo collections, such as panoramic stitching, face morphing, texture synthesis, blending, and 3D reconstruction. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225, MATH 225, and MATH 231.

CS 446 Machine Learning credit: 3 or 4 Hours. Theory and basic techniques in machine learning. Major theoretical paradigms and key concepts developed in machine learning in the context of applications such as natural language and text processing, computer vision, data mining, adaptive computer systems and others. Review of several supervised and unsupervised learning approaches: methods for learning linear representations; on-line learning, Bayesian methods; decision-trees; features and kernels; clustering and dimensionality reduction. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 373 and CS 440.

CS 447 Natural Language Processing credit: 3 or 4 Hours. Part-of-speech tagging, parsing, semantic analysis and machine translation. Relevant linguistics concepts from morphology (word formation) and lexical semantics (the meaning of words) to syntax (sentence structure) and compositional semantics (the meaning of sentences). 3 undergraduate hours. 3 or 4 graduate hours. Credit is not given for both CS 447 and LING 406. Prerequisite: CS 374.

CS 450 Numerical Analysis credit: 3 Hours. Linear system solvers, optimization techniques, interpolation and approximation of functions, solving systems of nonlinear equations, eigenvalue problems, least squares, and quadrature; numerical handling of ordinary and partial differential equations. Same as CSE 401, ECE 491, and MATH 450. 3 undergraduate hours. 3 or 4 graduate hours. Credit is not given for both CS 450 and CS 457. Prerequisite: CS 101 or CS 125; CS 357 or MATH 415; MATH 285.
CS 457  Numerical Methods II  credit: 3 Hours.
Continuation of CS 357. Orthogonalization methods for least squares, Krylov subspace methods, non-linear equations and optimization in multiple dimensions, initial and boundary value problems for ordinary and partial differential equations. 3 undergraduate hours. No graduate credit. Credit is not given for both CS 457 and CS 450. Prerequisite: CS 357.

CS 460  Security Laboratory  credit: 3 Hours.
Operating systems security: access control, least privilege mechanism and malware techniques. Network security: firewalls, sniffing, tunnels, intrusion detection, AAA and worm structure. System security: forensics security architectures, and attack/defend exercises. Complements CS 461 via hands-on project. Same as ECE 419. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 461.

CS 461  Computer Security I  credit: 4 Hours.
Fundamental principles of computer and communications security and information assurance: ethics, privacy, notions of threat, vulnerabilities, and risk in systems, information warfare, malicious software, data secrecy and integrity issues, network security, trusted computing, mandatory and discretionary access controls, certification and accreditation of systems against security standards. Security mechanisms: authentication, auditing, intrusion detection, access control, cryptography, security protocols, key distribution. Same as ECE 422. 4 undergraduate hours. 4 graduate hours. Prerequisite: CS 241 or ECE 391.

CS 463  Computer Security II  credit: 3 or 4 Hours.
Program security, trusted base, privacy, anonymity, non-interference, information flow, confinement, advanced auditing, forensics, intrusion detection, key management and distribution, policy composition and analysis, formal approaches to specification and verification of secure systems and protocols, and topics in applied cryptography. Same as ECE 424. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 461. Recommended: CS 475.

CS 465  User Interface Design  credit: 3 Hours.
A project-focused course covering fundamental principles of user interface design, implementation, and evaluation. Small teams work on a term-long project that involves: analysis of the problem domain, user skills, and tasks; iterative prototyping of interfaces to address user needs; conducting several forms of evaluation such as cognitive walkthroughs and usability tests; implementation of the final prototype. Non-technical majors may enroll as non-programmers who participate in all aspects of the projects with the possible exception of implementation. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225.

CS 466  Introduction to Bioinformatics  credit: 3 or 4 Hours.
Algorithmic approaches in bioinformatics: (i) biological problems that can be solved computationally (e.g., discovering genes, and interactions among different genes and proteins); (ii) algorithmic techniques with wide applicability in solving these problems (e.g., dynamic programming and probabilistic methods); (iii) practical issues in translating the basic algorithmic ideas into accurate and efficient tools that biologists may use. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225.

CS 467  Social Visualization  credit: 3 or 4 Hours.
Visualizing social interaction in networked spaces: investigation of patterns in networked communications systems such as messaging (email, instant messaging), social networking sites and collaborative sites, social network theory and visualizations; exploration of how to move beyond existing visualization techniques; visualizing the network identity over compilations of online data. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225.

CS 468  Tech and Advertising Campaigns  credit: 3 Hours.
Same as ADV 492. See ADV 492.

CS 473  Algorithms  credit: 4 Hours.
Design and analysis techniques, approximation algorithms, randomized algorithms and amortized analysis, and advanced topics such as network flow, linear programming, and dynamic data structures, among others. Same as CSE 414 and MATH 473. 4 undergraduate hours. 4 graduate hours. Prerequisite: CS 374, and one of CS 361, MATH 461, or STAT 400.

CS 475  Formal Models of Computation  credit: 3 or 4 Hours.
Finite automata and regular languages; pushdown automata and context-free languages; Turing machines and recursively enumerable sets; linear-bounded automata and context-sensitive languages; computability and the halting problem; undecidable problems; recursive functions; Chomsky hierarchy; computational complexity. Same as MATH 475. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 373.

CS 476  Program Verification  credit: 3 or 4 Hours.
Formal methods for demonstrating correctness and other properties of programs. Invariant assertions; Hoare axiomatics; well-founded orderings for proving termination; structural induction; computational induction; data structures; parallel programs; overview of predicate calculus. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225; CS 374 or MATH 414.

CS 477  Formal Software Devel Methods  credit: 3 or 4 Hours.
Mathematical models, languages, and methods for software specification, development, and verification. Same as ECE 478. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 225; CS 373 or MATH 414.

CS 481  Stochastic Processes & Applic  credit: 3 or 4 Hours.
Same as IE 410. See IE 410.

CS 482  Simulation  credit: 3 Hours.
Same as IE 413. See IE 413.

CS 483  Applied Parallel Programming  credit: 4 Hours.
Same as CSE 408 and ECE 408. See ECE 408.

CS 484  Parallel Programming  credit: 3 or 4 Hours.
Techniques for the programming of all classes of parallel computers and devices including shared memory and distributed memory multiprocessors, SIMD processors and co-processors, and special purpose devices. Key concepts in parallel programming such as reactive and transformational programming, speculation, speedup, isoefficiency, and load balancing. Synchronization primitives, libraries and languages for parallel programming such as OpenMP and MPI, performance monitoring, program tuning, analysis and programming of numerical and symbolic parallel algorithms. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 241.

CS 491  Seminar  credit: 0 to 4 Hours.
Seminar on topics of current interest as announced in the Class Schedule. 0 to 4 undergraduate hours. 0 to 4 graduate hours. Approved for S/U grading only. May be repeated in the same or separate terms if topics vary to a maximum of 4 hours. Prerequisite: As specified for each topic offering, see Class Schedule or departmental course description.

Information listed in this catalog is current as of 04/2018
CS 492  Senior Project I  credit: 3 Hours.
First part of a project course in computer science. Students work in
teams to solve typical commercial or industrial problems. Work involves
planning, design, and implementation. Extensive oral and written work is
required both on-campus and possibly off-campus at sponsors' locations.
CS 492 must be taken as a sequence with either CS 493 or CS 494. 3
undergraduate hours. No graduate credit. Credit is not given for both
CS 492 and a project course in another engineering department for the
same project. Prerequisite: For Computer Science majors with senior
standing.

CS 493  Senior Project II, ACP  credit: 3 Hours.
Continuation of CS 492. Identical to CS 494 except for an additional
writing component. See CS 494. 3 undergraduate hours. No graduate
credit. Credit is not given for both CS 493 and a project course in another
engineering department for the same project. Prerequisite: CS 492.
This course satisfies the General Education Criteria for:
Advanced Composition

CS 494  Senior Project II  credit: 3 Hours.
Continuation of CS 492. 3 undergraduate hours. No graduate credit.
Credit is not given for both CS 494 and a project course in another
engineering department for the same project. Prerequisite: CS 492.

CS 497  CS Team Project  credit: 1 to 3 Hours.
Student teams work with CS faculty to complete a significant project
requiring advanced knowledge of CS principles. Project topics vary. 1 to
3 undergraduate hours. No graduate credit. May be repeated in the same
term up to 6 hours, if topics vary; may be repeated in separate terms.
Prerequisite: For majors only; junior or senior standing required.

CS 498  Special Topics  credit: 1 to 4 Hours.
Subject offerings of new and developing areas of knowledge in computer
science intended to augment the existing curriculum. See Class Schedule
or departmental course information for topics and prerequisites. 1 to 4
undergraduate hours. 1 to 4 graduate hours. May be repeated in the same
or separate terms if topics vary.

CS 499  Senior Thesis  credit: 3 Hours.
Research and thesis development experience in computer science
underguidance of a faculty member. Literature search, oral presentation,
analysis and implementation, paper preparation, and completion of
a written thesis. 3 undergraduate hours. No graduate credit. May be
repeated to a maximum of 6 hours. Prerequisite: Consent of instructor.
This course satisfies the General Education Criteria for:
Advanced Composition