# COMPUTER SCIENCE (CS)

## CS 400 - Introduction to Computing
**Credits:** 2
Introduces students to the available computing-related majors and a variety of topics foundational to success in computing-related fields. Coverage includes ethics, skills, and knowledge applicable to a broad range of computing disciplines.
**Grade Mode:** Letter Grading

## CS #401 - Computers and Their Applications
**Credits:** 4
Use of computers to manage and analyze information across a variety of settings and disciplines. Introduces major categories of computer software, including word processing, spreadsheets and database systems. Covers basic computer concepts and the computer's role in today's society. Significant hands-on work required outside of the class.
**Grade Mode:** Letter Grading

## CS #404 - Do-It-Yourself Internet
**Credits:** 4
The objective of this course is to demystify the design process that leads to the evolution of the Internet. In doing so, we investigate the ways that technology changes to meet the needs of society, how society changes in response to these new technologies and how these societal changes create pressures that produce needs for new technologies.
**Attributes:** Environment,TechSociety(Disc)

## CS #405 - Introduction to Applications Programming
**Credits:** 4
Introduces the concepts and techniques of computer programming. Particular emphasis on computer programming as a problem-solving technique for business applications. The basic software development process (modeling, algorithm design, programming, testing and debugging) is illustrated. CEPS students should check with their major department for approval.
**Grade Mode:** Letter Grading

## CS 410C - Introduction to Scientific Programming/C
**Credits:** 0 or 4
Introduces the concepts and techniques of computer programming. Particular emphasis on computer programming as a problem-solving technique in science and engineering applications. Good programming style is stressed. Significant out-of-class programming required.
**Equivalent(s):** CS 410
**Mutual Exclusion:** No credit for students who have taken CS 415.
**Grade Mode:** Letter Grading

## CS 410P - Introduction to Scientific Programming/Python
**Credits:** 0 or 4
Introduces the concepts and techniques of computer programming. Particular emphasis on computer programming as a problem-solving technique in science and engineering applications. Good programming style is stressed. Significant out-of-class programming required. Not open to students who have completed CS 415 or the equivalent.
**Equivalent(s):** CS 410, CS 415
**Grade Mode:** Letter Grading

## CS 414 - From Problems to Algorithms to Programs
**Credits:** 4
This course is an introduction to the design and implementation of computer programs. The basic software development process (modeling, algorithm design, programming, testing and debugging) is illustrated through problem examples. Programming techniques are introduced to allow students to implement and evaluate solutions as programs.
**Attributes:** Quantitative Reasoning(Disc)

## CS 415 - Introduction to Computer Science I
**Credits:** 0 or 4
Theory and practice of computer science. Algorithm development and analysis; data abstraction techniques; elementary data structures; dynamic memory manipulation; debugging; and program design issues. Computer systems and applications. Intended for CS majors.
**Mutual Exclusion:** No credit for students who have taken CS 410C.
**Grade Mode:** Letter Grading

## CS 416 - Introduction to Computer Science II
**Credits:** 0 or 4
Theory and practice of computer science. Algorithm development and analysis; data abstraction techniques; elementary data structures; dynamic memory manipulation; debugging; and program design issues. Computer systems and applications. Intended for CS majors. Prereq: CS 415.
**Grade Mode:** Letter Grading

## CS 417 - From Programs to Computer Science
**Credits:** 0 or 4
Accelerated coverage of programming techniques for students with experience equivalent to CS410 or CS 414. Covers basic algorithm analysis. Topics include basics of classes, inheritance, and data abstraction; linear data structures (vectors, lists, stacks and queues); trees and simple graphs; hash tables; sorting and searching; recursion; and basic graph traversal algorithms. Numerous labs and programming assignments build skills in planning, problem solving, and debugging; this is a hands on course. Prereq: CS 410 or CS 414 or equivalent.
**Grade Mode:** Letter Grading
CS 419 - Computer Science for Engineers and Scientists
Credits: 4
This course provides an accelerated coverage of programming techniques for students with programming experience from an introductory programming course. Topics covered include: basics of classes, inheritance, and data abstraction; linear data structures (vectors, lists, stacks, and queues); trees and simple graphs; hash tables; sorting and searching; and recursion. Students will learn basic algorithm analysis. Numerous labs and programming assignments will build skills in planning, problem solving, and debugging: this is a hands-on course. Prereq: CS 410C.
Equivalent(s): CS 416, CS 417
Grade Mode: Letter Grading

CS 420 - Foundations of Programming for Digital Systems
Credits: 4
A systems-oriented introduction to C, with an emphasis on low-level operations, memory management, and debugging. Foundational digital systems concepts and methods will be introduced, including Boolean algebra, basic logic gates, number systems & conversions, integer representation, and theoretical aspects of combinational and sequential logic. Aspects of effective programming such as incremental development, appropriate structure and commenting, and basic testing will be stressed. Prereq: (CS 410C with a minimum grade of C- or CS 410P with a minimum grade of C- or CS 414 with a minimum grade of C- or CS 415 with a minimum grade of C-).
Grade Mode: Letter Grading

CS 457 - Introduction to Data Science and Analytics
Credits: 4
An introduction to data science and analytics. Overview of the use of analytics by industry, government, and nongovernmental organizations. Impact of analytics on society, ethical use of analytics. Methods of data generation, data management, data cleaning, and data preparation, with a focus on visual and exploratory analysis. Project-based, with an emphasis on collaborative, experiential learning. Design and implementation of programs, use of statistical software. Not open to CS and IT majors.
Attributes: Environment, TechSociety(Disc)
Equivalent(s): DATA 557
Grade Mode: Letter Grading

CS 515 - Data Structures and Introduction to Algorithms
Credits: 0 or 4
Reviews basic data structures. Covers the mechanics and relative efficiencies of advanced data structures. Students will implement several data structures such as AVL trees, heaps, hash tables, and adjacency lists. Discusses abstract data types such as maps, priority queues, and graphs. Introduction to algorithm analysis, sorting algorithms, and graph algorithms. Prereq: (CS 416 with minimum grade of C- or CS 417 with minimum grade of C-).
Grade Mode: Letter Grading

CS 518 - Introduction to Software Engineering
Credits: 4
Study of software development practices and processes in the following areas: software life cycle; system validation and verification; development pipeline; cloud infrastructures; virtual machines, and containers; logging, instrumentation, and performance; fundamental security concepts. Experience working in groups. Restricted to students not in Senior Standing. Prereq: CS 416 or CS 417 or equivalent.
Grade Mode: Letter Grading

CS 520 - Computer Organization and System-Level Programming
Credits: 0 or 4
Study software/hardware interaction, understand data and program representation. Topics include fundamentals of computer organization, CPU, memory, registers, addressing modes, instruction sets, assemblers, linkers, concurrency, memory hierarchy and memory management. Prereq: (CS 416 with minimum grade of C- or CS 417 with minimum grade of C-), CS 420 with minimum grade of C-.
Grade Mode: Letter Grading

CS 527 - Fundamentals of Cybersecurity
Credits: 4
An entry-level introduction to a wide range of fundamental cybersecurity topics: authentication, authorization, auditing, cryptography, human element, network security, OS security, mobile & IoT security. The emphasis is to explain basic concepts with real world examples. Prereq: (CS 416 or CS 417).
Grade Mode: Letter Grading

CS 519 - Introduction to Object-Oriented Design and Development
Credits: 4
Principles of problem analysis and software design applied to the development cycle of a software system (i.e. from system requirements specification to design, implementation, and system test). Design and implementation using object-oriented principles, patterns, and tools. Experience in understanding and debugging software systems. Experience in working in groups. Prereq: CS 515 with minimum grade of C-, CS 518.
Grade Mode: Letter Grading

CS 620 - Operating System Fundamentals
Credits: 4
Introduces operating system concepts and design. Process and memory management; scheduling; file systems; storage devices; inter-process communication. Prereq: CS 520.
Equivalent(s): CS 610
Grade Mode: Letter Grading
CS 659 - Introduction to the Theory of Computation
Credits: 4
Grade Mode: Letter Grading

CS 696 - Independent Study
Credits: 1-6
Individual projects developed and conducted under the supervision of a faculty member. Prereq: permission of faculty supervisor and department chairperson. May be repeated for credit.
Equivalent(s): CS 696W
Grade Mode: Letter Grading

CS 696W - Independent Study
Credits: 1-6
Individual projects developed and conducted under the supervision of a faculty member. Prereq: permission of faculty supervisor and department chairperson.
Attributes: Writing Intensive Course
Repeat Rule: May be repeated for a maximum of 8 credits. May be repeated up to 1 time.
Equivalent(s): CS 696
Grade Mode: Letter Grading

CS 699 - Internship
Credits: 1
Provides the opportunity to apply academic experience in settings associated with future professional employment. A written proposal for the internship must be approved by the instructor. The proposal must specify what the student will learn from the internship and what supervision is available during the internship. A mid-semester report and final report are required. Prereq: permission. Only open to Computer Science majors. Cr/F.
Repeat Rule: May be repeated for a maximum of 4 credits. May be repeated up to 3 times.
Equivalent(s): CS 600
Grade Mode: Credit/Fail Grading

CS 712 - Compiler Design
Credits: 4
Formal languages and formal techniques for syntax analysis and parsing; organization of the compiler and its data structures; code generation. LL and LR parsing; automatic generation of scanners and parsers from high level descriptions. Implementation of features from imperative and object-oriented languages. Students required to design and implement a compiler for a simple language. Prereq: CS 520.
Grade Mode: Letter Grading

CS 720 - Systems Programming
Credits: 4
Study and simulation of various types of systems that include assemblers, linkers, memory management, concurrency and other resource management techniques. Prereq: CS 520.
Prerequisite(s): CS 610.
Grade Mode: Letter Grading

CS 722 - Cloud Computing Systems
Credits: 4
The course covers a variety of topics in cloud computing systems, or more precisely, distributed systems that enable modern cloud computing. The topics include virtualization and its impact on configuration management. The course also covers the latest advancements in cloud computing/systems, IoT, edge, and fog computing. Prereq: CS 620.
Grade Mode: Letter Grading

CS 723 - Performance Evaluation of Computer Systems
Credits: 4
Introduces the main concepts, techniques, and tools needed to evaluate the performance of computer systems under various configurations and workloads. The techniques allow one to perform capacity planning based on quality of service requirements of users and workload characteristics. Course is mainly based on the use of analytic queuing network models of computers systems. The performance techniques are applied to study the performance of centralized, distributed, parallel, and client/server systems. The course also discusses performance measuring tools for operating systems such as Unix and Windows NT. Prereq: CS 620 and (MATH 539 or MATH 644).
Grade Mode: Letter Grading

CS 725 - Computer Networks
Credits: 4
Introduction to fundamental concepts of computer networks and exploration of widely-used networking technologies. Topics include principles of congestion and error control; network routing; local, wireless and access networks; application protocol design; and network programming. In-depth discussion of the Internet suite of protocols. Prereq: CS 520.
Equivalent(s): IT 725
Grade Mode: Letter Grading

CS 727 - Software Security
Credits: 4
Mechanisms and implementation of techniques in software security. Various fundamental security topics include cryptography, access control, protocols, software vulnerabilities, and reverse engineering. Prereq: CS 520 with a minimum grad of C, CS 527.
Grade Mode: Letter Grading

CS 730 - Introduction to Artificial Intelligence
Credits: 4
In-depth introduction to artificial intelligence, concentrating on aspects of intelligent problem-solving. Topics include situated agents, advanced search techniques, knowledge representation, logical reasoning techniques, reasoning under uncertainty, advanced planning and control, and learning. Prereq: CS 515.
Grade Mode: Letter Grading

CS 733 - Mobile Robotics
Credits: 4
An introduction to the foundational theory and practices in mobile robotics. Topics include Kinematics of wheeled mobile robots, Sensors for mobile robots, Robot navigation and perception, Robot vision, Localization and mapping of mobile robots. Hands-on experience directed towards implementation with a real robot. Prereq: Programming course of Permission of instructor.
Grade Mode: Letter Grading
CS 735 - Introduction to Parallel and Distributed Programming
Credits: 4
Programming with multiple processes and threads on distributed and parallel computer systems. Introduces programming tools and techniques for building applications on such platforms. Course requirements consist primarily of programming assignments. Prereq: CS 520.
Equivalent(s): CS 735W
Grade Mode: Letter Grading

CS 745 - Formal Specifications and Verification of Software Systems
Credits: 4
Course focuses on the formal specification and verification of reactive systems, most notably concurrent and distributed systems. Topics relevant to these systems, such as non-determinism, safety and liveness properties, asynchronous communication or compositional reasoning, as discussed. We rely on a notation (TLA+, the Temporal Logic of Actions) and a support tool (TLC, the TLA+ Model Checker). Prereq: CS 520 and CS 659.
Grade Mode: Letter Grading

CS 750 - Machine Learning
Credits: 4
An introduction to fundamental concepts and common methods in machine learning. In addition to theoretical topics, the course involves hands-on experience in making predictions using synthetic and real-world datasets. Prereq: MATH 539 or MATH 644, and Programming course or Permission of instructor.
Mutual Exclusion: No credit for students who have taken .
Grade Mode: Letter Grading

CS 752 - Foundations of Neural Networks
Credits: 4
Neural networks are a class of machine learning models which have recently revolutionized many applied machine learning domains such as natural language understanding, image/video processing, bioinformatics, time series analysis. This course teaches students to develop new neural network architectures from scratch and customize them. The course covers all necessary foundations of neural networks including gradient descent optimization and vector calculus. Students will learn how to design models using idioms such as observed variables, latent variables, gate variables and different functions as well as a wide range of state-of-the-art architectures as design examples. Prereq: CS 515.
Grade Mode: Letter Grading

CS 753 - Information Retrieval
Credits: 4
Fundamental algorithms and techniques for text processing and text-based information retrieval systems. Topics include how to build an end-to-end information retrieval system, such as a Web search engine. Prereq: CS 515.
Grade Mode: Letter Grading

CS 755 - Computer Vision
Credits: 4
Studying techniques that make a machine 'see' and 'understand' the world in a human-like fashion. The course discusses the theory behind common computer vision techniques and trains students on designing their own algorithms for understanding image or video. Prereq: (MATH 539 or MATH 644) and Programming course of permission of instructor, Junior standing.
Grade Mode: Letter Grading

CS 757 - Mathematical Optimization for Applications
Credits: 4
This course introduces the foundations of mathematical optimization and reinforces them via applications. The content includes convex optimization, first and second-order methods, constrained problems, duality, linear and quadratic programming, as well as discrete and non-convex optimization. Applications will focus on machine learning methods but also include problems from engineering and operations research. Prereq: MATH 426, Programming proficiency in MATLAB, R, Java, C, Python, or equivalent.
Equivalent(s): MATH 757
Grade Mode: Letter Grading

CS 758 - Algorithms
Credits: 4
An introduction to important concepts in the design and analysis of algorithms and data structures, including implementation, complexity analysis, and proofs of correctness. Prereq: CS 420 with minimum grade of C-, CS 515 with minimum grade of C-, CS 659.
Grade Mode: Letter Grading

CS 761 - Programming Language Concepts and Features
Credits: 4
Explores modern, high-level, general-purpose programming languages from the user (programmer) standpoint. Students learn how specific features of programming languages can be used effectively in solving programming problems. The course is also an opportunity to use paradigms that expand on simple imperative programming, such as object-oriented, functional and concurrent programming. Prereq: CS 520 with a minimum grade of C-, some knowledge of Java.
Equivalent(s): CS 671
Grade Mode: Letter Grading

CS 765 - Introduction to Parallel and Distributed Programming
Credits: 4
Programming with multiple processes and threads on distributed and parallel computer systems. Introduces programming tools and techniques for building applications on such platforms. Course requirements consist primarily of programming assignments. Prereq: CS 520.
Equivalent(s): CS 735W
Grade Mode: Letter Grading

CS 770 - Computer Graphics
Credits: 4
Input-output and representation of pictures from hardware and software points of view; interactive techniques and their applications; three-dimensional image synthesis techniques and their applications. Prereq: CS 515 with a minimum grade of C-, CS 520 with a minimum grade of C-.
Equivalent(s): CS 770W
Grade Mode: Letter Grading

CS 771 - Web Programming Paradigms
Credits: 4
In this course you will learn languages to program the Web. Languages integrated into browsers, like JavaScript, and languages invoked on the server, like Ruby. You will also learn about frameworks, like Rails, and various techniques used to support the programming process. In addition, you will learn languages you will need to create, modify, and process Web documents. Although we will learn how to read and write in these languages, our primary goal will be an understanding of how the design of these multi-paradigm dynamic languages support the process of developing Web applications. Prereq: CS 671.
Equivalent(s): IT 771
Grade Mode: Letter Grading
CS 775 - Database Systems
Credits: 4
Introduction to database management systems --- design, implementation, and usage --- with focus on the relational model. Data description, manipulation, and query language in the context of MySQL. Schema design and normalization; indexes, transaction processing. Web access of databases (PHP); overview of XML and noSQL systems. Prereq: CS 515.
Mutual Exclusion: No credit for students who have taken IT 775.
Grade Mode: Letter Grading

CS 780 - Topics
Credits: 1-4
Material not normally covered in regular course offerings. May be repeated for credit.
Grade Mode: Letter Grading

CS 791 - Senior Project I
Credits: 2
First semester of the capstone design experience. Modern software engineering practices and tools are surveyed and applied in team projects. Students begin development on software projects proposed by faculty or external sponsors, including initial stages of design, implementation, and documentation, with an interim presentation of progress expected toward the end of the semester. Principles of security, testability, and maintainability are stressed. Prereq: BS CS: CS 520 with a minimum grade of C-, CS 619, 1 additional 600 or 700 level course; BA CS Algorithms & Systems: CS 520 with a minimum grade of C-, CS 619, 1 additional 600 or 700 level course; BA CS Cybersecurity: CS 620 and (CS 727 or IT 666); BS ADS: DATA 674 or MATH 738 or CS 750.
Grade Mode: Letter Grading

CS 792 - Senior Project II
Credits: 2
Continuation of CS 791: Senior Project I. Students complete the project by implementing their design. Students work in teams. Successful completion of this course fulfills the Capstone Experience requirement for Computer Science majors. Prereq: CS 791. Writing intensive.
Attributes: Writing Intensive Course
Grade Mode: Letter Grading

CS 799 - Thesis
Credits: 1-5
Students work under the direction of a faculty sponsor to plan and carry out independent research resulting in a written thesis. Required for honors-in-major. Prereq: CS 520, CS 619, CS 600 level course, GPA >3.4, permission. A minimum of 4.0 credits is required for the completion of the course.
Attributes: Writing Intensive Course
Repeat Rule: May be repeated for a maximum of 8 credits.
Grade Mode: Letter Grading