# Computer Science & Engineering (CSE)

**Courses**

**CSE 003 Introduction to Programming, Part A 0,2 Credits**
Introduction to programming fundamentals & problem-solving using the Java language. Covers the first half of CSE 007 concepts, including data types, control flow, introduction to methods, arrays and a breadth of computing. No prior programming experience is needed. Cannot be taken by students who have completed CSE 007.
**Attribute/Distribution:** Q

**CSE 004 Introduction to Programming, Part B 0,2 Credits**
Introduction to problem-solving and object-oriented programming (OOP) using the Java language. Covers the second half of CSE 007 concepts, including methods, arrays (including searching & sorting), basics of OOP including data encapsulation, inheritance and polymorphism and a breadth of computing. Cannot be taken by students who have completed CSE 007.
**Prerequisites:** CSE 003

**CSE 007 Introduction to Programming 0,4 Credits**
Introduction to problem-solving and object-oriented programming (OOP) using the Java language. Covers data types, control flow, methods, arrays (including searching & sorting), basics of OOP including data encapsulation, inheritance and polymorphism and a breadth of computing. If credit is given for CSE 007 then no credit will be given for CSE 003 nor CSE 004.
**Attribute/Distribution:** Q

**CSE 012 Introduction to Programming with Python 3 Credits**
Fundamental concepts of computing and "computational thinking": problem analysis, abstraction, algorithms, digital representation of information, and networks. Concepts of software development using the Python language. This course will not be considered as a CSE technical elective for CS majors.
**Attribute/Distribution:** Q

**CSE 017 Programming and Data Structures 0,3 Credits**
Design and implementation of algorithms and data structures using Java. Assumes that students have prior experience using conditional statements, loops, arrays, and object-oriented programming in Java. Algorithmic techniques such as recursion, algorithm analysis, and sorting. Design and implementation of data structures such as lists, queues, stacks, trees, and hash tables.
**Prerequisites:** CSE 004 or CSE 007
**Attribute/Distribution:** Q

**CSE 042 (EMC 042) Game Design 3 Credits**
Modern topics in game design: Finite State Machines, iterative design process, systems and interactivity, designing rules for digital games, emergence in games, games as Schemas of Uncertainty, games as Information Theory Schemas, games as Information Systems, games as Cybernetic Systems. The course does not count as a technical elective for majors in Computer Science, Computer Science and Business, or Computer Engineering.

**CSE 091 Special Topics 1-4 Credits**
Intensive study of a topic of special interest not covered in other courses.
**Repeat Status:** Course may be repeated.

**CSE 100 Teaching Assistant Workshop 0-1 Credits**
The course covers the roles and responsibilities of teaching assistants and graders and how to create a positive learning environment, effectively communicate, manage the classroom, grade and assess, employ various teaching techniques, and leverage technology in the classroom. The challenges faced by students and their perspective while learning and applying new concepts are discussed throughout. Department approval is required.

**CSE 109 Systems Software 0,4 Credits**
Design and implementation of modular programs interacting with the operating system through system calls and programming interfaces using the C programming language. Topics covered include data representation and storage, data and bit manipulation, memory management, stages of compilation, file I/O, interprocess communication, network programming, programmatic testing, interactive debugging, and error handling. Good programming practices, including security, and practical methods for implementing medium-scale programs are also emphasized.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 127 (COGS 127) Survey of Artificial Intelligence 3 Credits**
An introduction to artificial intelligence (AI) intended for non-majors. AI concepts, systems, and history. Credit will not be given for both CSE/COGS 127 and CSE/COGS 327.
**Prerequisites:** CSE 004 or CSE 007 or CSE 012
**Attribute/Distribution:** Q

**CSE 140 Foundations of Discrete Structures and Algorithms 0,3 Credits**
Basic representations used in algorithms: propositional and predicate logic, set operations and functions, relations and their representations, matrices and their representations, graphs and their representations, trees and their representations. Basic formalizations for proving algorithm correctness: logical consequences, induction, structural induction. Basic formalizations for algorithm analysis: counting, pigeonhole principle, permutations. Credit will not be given for both CSE 140 and MATH 261.
**Prerequisites:** (MATH 021 or MATH 031 or MATH 051 or MATH 076) and CSE 017
**Can be taken Concurrently:** CSE 017
**Attribute/Distribution:** Q

**CSE 160 Introduction to Data Science 0,3 Credits**
Data Science is a fast-growing interdisciplinary field, focusing on the computational analysis of data to extract knowledge and insight. Collection, preparation, analysis, modeling, and visualization of data, covering both conceptual and practical issues. Examples from diverse fields and hands-on use of statistical and data manipulation software.
**Prerequisites:** CSE 004 or CSE 007 or CSE 012 or BIS 335
**Attribute/Distribution:** Q

**CSE 190 Special Topics 1-3 Credits**
Supervised reading and research. Consent of department required.

**CSE 191 Special Topics 1-4 Credits**
Intensive study of a topic of special interest not covered in other courses.
**Repeat Status:** Course may be repeated.

**CSE 202 Computer Organization and Architecture 0,3 Credits**
Interaction between low-level computer architectural properties and high-level program behaviors: instruction set design; digital logic and assembly language; processor organization; the memory hierarchy; multicore and GPU architectures; and processor interrupt/exception models. Credit will not be given for both CSE 201 and CSE 202.
**Prerequisites:** CSE 017 or CSE 018

**CSE 216 Software Engineering 0,3 Credits**
The software lifecycle; lifecycle models; software planning; testing; specification methods; maintenance. Emphasis on team work and large-scale software systems, including oral presentations and written reports.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 217 Computer Science Projects 3 Credits**
Project-based learning through independent or small-group projects related to computer systems and/or applications. Students will progress through the software development lifecycle, including high-level design, functional and non-functional requirements, implementation, testing, and maintenance. One large group meeting per week, where students serve as consultants to each other as they present their progress.
**Prerequisites:** CSE 216
**Attribute/Distribution:** W

**CSE 241 Database Systems and Applications 0,3 Credits**
Design of large databases: Integration of databases and applications using SQL and JDBC; transaction processing; performance tuning; data mining and data warehouses. Not available to students who have credit for CSE 341 or ISE 224.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 242 Blockchain Algorithms and Systems 3 Credits**
Blockchain system concepts, data structures, and algorithms. Cryptographic algorithms for blockchain security. Distributed consensus algorithms for decentralized control in both a public and permissioned blockchain setting. Smart contracts. Cross-chain transactions. Blockchain databases and enterprise blockchains.
**Prerequisites:** CSE 109 or CSE 241 or CSE 341
**Can be taken Concurrently:** CSE 109
**Attribute/Distribution:** Q

**CSE 252 (EMC 252) Computing Ethics 3 Credits**
An interactive exploration that provides students with concepts and frameworks to reason about ethical and social issues related with computing. Topics may include: privacy, corporate responsibility, the changing nature of work, language technologies, professional ethics, autonomous systems, online political communication, fairness and bias, environmental impacts, legal regulation, political economy, and other relevant technologies, concepts, issues.
**Attribute/Distribution:** SS, SW, W

**CSE 260 Foundations of Robotics 3 Credits**
This course introduces students to the field of robotics, covering foundational mathematics and physics as well as important algorithms and tools. Topics include simulation, kinematics, control, machine learning, and probabilistic inference. The mathematical basis of each area will be covered, followed by practical application to common robotics tasks. This course is designed to be taught remotely using simulated robot platforms and sensors.
**Prerequisites:** CSE 140
**Attribute/Distribution:** Q

**CSE 262 Programming Languages 0,3 Credits**
Use, structure and implementation of several programming languages.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 264 Web Systems Programming 3 Credits**
Practical experience in designing and implementing modern Web applications. Concepts, tools, and techniques, including: HTTP, HTML, CSS, DOM, JavaScript, Ajax, PHP, graphic design principles, mobile web development. Not available to students who have credit for IE 275.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 265 System and Network Administration 0,3 Credits**
Overview of systems and network administration in a networked UNIX-like environment. System installation, configuration, administration, and maintenance; security principles; ethics; network, host, and user management; standard services such as electronic mail, DNS, and WWW; file systems; backups and disaster recovery planning; troubleshooting and support services; automation, scripting; infrastructure planning.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 271 Programming in Linux and Windows Operating Systems 3 Credits**
Students learn Linux and Windows operating system fundamentals, including features, history, organization, process management, and file systems. Tools commonly available with these operating systems, such as those for program development, text processing, scheduling jobs, and communications, are also explored. Emphasis is placed on learning the BASh and PowerShell scripting languages, and students should expect to work on a variety of small programming assignments.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 280 Capstone Project I 3 Credits**
First of a two semester capstone course sequence that involves the design, implementation, and evaluation of a computer science software project. Conducted by small student teams working from project definition to final documentation. Each student team has a CSE faculty member serving as its advisor. The first semester emphasis is on project definition, planning and implementation. Communication skills such as technical writing, oral presentations, and use of visual aids are also emphasized. Project work is supplemented by weekly seminars.
**Prerequisites:** CSE 216
**Attribute/Distribution:** Q, W

**CSE 281 Capstone Project II 0,3 Credits**
Second of a two semester capstone course sequence that involves the design, implementation, and evaluation of a computer science software project; conducted by small student teams working from project definition to final documentation; each student team has a CSE faculty member serving as its advisor; The second semester emphasis is on project implementation, verification & validation, and documentation requirements. It culminates in a public presentation and live demonstration to external judges as well as CSE faculty and students.
**Prerequisites:** CSE 280
**Attribute/Distribution:** Q, W

**CSE 300 Apprentice Teaching 1-4 Credits**
Practical teaching experience under supervision of an experienced instructor. Students learn fundamentals of teaching, including course and lecture planning, instructional delivery, classroom environment and management, and assessment. Students will benefit from significant hands-on experience in the lectures, recitations, and office hours. Department approval is required.
**Repeat Status:** Course may be repeated.

**CSE 302 Compiler Design 3 Credits**
Principles of artificial language description and design. Sentence parsing techniques, including operator precedence, bounded-context, and syntax-directed recognizer schemes. The semantic problem as it relates to interpreters and compilers. Dynamic storage allocation, table grammars, code optimization, compiler-writing languages.
**Prerequisites:** (CSE 109)
**Attribute/Distribution:** Q

**CSE 303 Operating System Design 3 Credits**
Process and thread programming models, management, and scheduling. Resource sharing and deadlocks. Memory management, including virtual memory and page replacement strategies. I/O issues in the operating system. File system implementation. Multiprocessing. Computer security as it impacts the operating system.
**Prerequisites:** ECE 201 or (CSE 201 or CSE 202) and CSE 109
**Attribute/Distribution:** Q

**CSE 307 (BIOE 307) Structural Bioinformatics 3 Credits**
Computational techniques and principles of structural biology used to examine molecular structure, function, and evolution. Topics include: protein structure alignment and prediction; molecular surface analysis; statistical modeling; QSAR; computational drug design; influences on binding specificity; protein-ligand, -protein, and -DNA interactions; molecular simulation, electrostatics. Tutorials on UNIX systems and research software support an interdisciplinary collaborative project in computational structural biology. Credit will not be given for both CSE 307 and CSE 407. Must have junior standing or higher.
**Prerequisites:** BIOS 120 or CSE 109 or CHM 113 or MATH 231
**Attribute/Distribution:** Q

**CSE 308 (BIOE 308) Genomics 3 Credits**
Biological discoveries and computational techniques affecting modern biotechnology. Genome assembly, genome annotation, and genome evolution in three interdisciplinary projects. No prior background in biology is assumed. Credit will not be given for both CSE 308 (BIOE 308) and CSE 408 (BIOE 408).
**Prerequisites:** CSE 017

**CSE 310 (BSTA 310) Assistive Technologies 3 Credits**
This class will introduce typical challenges faced by persons with disabilities and the role of assistive technologies (ATs) in solving such challenges. The class will examine opportunities presented by recent advances in mobile and AI technologies. Working in groups, each student will be expected to acquire and apply relevant skills in designing AT solutions. The class can be taken by students with diverse backgrounds including the following: community and population health, social and behavioral sciences, business, engineering and computer science.
**Prerequisites:** CSE 017 or (BSTA 101 and BSTA 102)
**Attribute/Distribution:** Q

**CSE 313 Computer Graphics 3 Credits**
Algorithms and programming techniques for generating three dimensional computer graphics. Rasterization, color, animation, interaction, textures, lighting models, ray tracing. Substantial focus on the interaction between the CPU and the GPU, relating to vertex and fragment shaders.
**Prerequisites:** CSE 109 and (MATH 043 or MATH 205 or MATH 242)
**Attribute/Distribution:** Q

**CSE 318 Introduction to the Theory of Computation 3 Credits**
Provides a deep understanding of computation, its capabilities and its limitations. The course uses discrete formal methods to (1) formulate precise definitions of three kinds of finite-state machines (finite automata, pushdown automata, and Turing machines); (2) prove properties of these machines by studying their expressiveness (i.e., the kinds of problems that can be solved with these machines), and (3) study computational problems that cannot be solved with algorithms.
**Prerequisites:** CSE 140
**Attribute/Distribution:** Q

**CSE 320 (BIOE 320) Biomedical Image Computing and Modeling 3 Credits**
This course provides an introduction to biomedical image modalities, computing techniques, and informatics systems, with a focus on advanced imaging analysis. It covers algorithms and software for extracting quantitative insights from biomedical image data, including topics such as image processing, geometric and statistical modeling, and AI-based techniques for segmentation, registration, and enhancement. The course also explores brain network analysis for understanding neurological interactions and imaging informatics systems in biomedicine.
**Prerequisites:** (MATH 205 or MATH 241 or MATH 043) and CSE 017
**Attribute/Distribution:** Q

**CSE 323 Computer Vision 3 Credits**
Fundamental techniques from image processing, pattern recognition, machine learning and deep learning used to process and understand visual data. Build full pipelines for solutions to classic vision problems such as object detection and recognition, image matching and retrieval, and scene understanding and reconstruction. New and challenging problems such as synthetic image generation. Credit will not be given for both CSE 323 and CSE 423.
**Prerequisites:** ((MATH 205 or MATH 242) and (MATH 231 or ECO 045) and CSE 017) or (DSCI 311 and DSCI 321)

**CSE 325 Natural Language Processing 3 Credits**
Overview of modern natural language processing techniques: text normalization, language model, part-of-speech tagging, hidden Markov model, syntactic and dependency parsing, semantics, word sense, reference resolution, dialog agent, machine translation. Design, implementation and evaluation of classic NLP algorithms. Credit will not be given for both CSE 325 and CSE 425.
**Prerequisites:** (MATH 231 or ECO 045 or ISE 121) and CSE 017 and (MATH 205 or MATH 241 or MATH 242) and (CSE 160 or CSE 326 or CSE 327 or MATH 365 or ECE 414 or ISE 364 or ISE 365 or ISE 367)
**Attribute/Distribution:** Q

**CSE 326 Fundamentals of Machine Learning 3 Credits**
Bayesian decision theory and the design of parametric and nonparametric classification and regression: linear, quadratic, nearest-neighbors, neural nets. Boosting, bagging. Credit will not be given for both CSE 326 and CSE 426.
**Prerequisites:** CSE 017 and (MATH 205 or MATH 043) and (MATH 231 or ISE 121 or ECO 045)

**CSE 327 (COGS 327) Artificial Intelligence Theory and Practice 3 Credits**
Detailed analysis of a broad range of artificial intelligence (AI) algorithms and systems. Problem solving, knowledge representation, reasoning, planning, uncertainty and machine learning. Applications of AI to areas such as natural language processing, vision, and robotics. Credit will not be given for both CSE/COGS 127 and CSE/COGS 327.
**Prerequisites:** CSE 017 and CSE 140
**Attribute/Distribution:** Q

**CSE 330 (CEE 330) Deep Learning 3 Credits**
An introduction to deep learning, a subset of machine learning, concerned with the development and application of modern neural networks. We will cover a range of topics from basic Neural Networks, Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN), Attention, Transformers, Generative Adversarial Networks (GAN), and state-of-the art networks and their applications in computer vision, engineering, remote sensing, medical, language, and AI for social good applications. Credit will not be given for both CSE 330 and CSE 430.
**Prerequisites:** (ENGR 010 or CSE 004 or CSE 007 or CSE 012) and (MATH 205 or MATH 241 or MATH 242)
**Attribute/Distribution:** Q

**CSE 331 User Interface Systems and Techniques 3 Credits**
Principles and practice of creating effective human-computer interfaces. Design and user evaluation of user interfaces; design and use of interface building tools. Programming projects using a variety of interface building tools to construct and evaluate interfaces.
**Prerequisites:** CSE 017
**Attribute/Distribution:** Q

**CSE 333 Methods for Understanding Human-Computer Interactions 3 Credits**
Covers a variety of methods for conducting research on human interactions with computing systems. Methods covered may include: controlled experiments, surveys, ethnography, grounded theory, research through design, log data analysis, retrospective techniques, social network analysis, and others. Taking this course will familiarize the student with several of these methods through readings and in-class discussion and activities, as well as provide the student the opportunity to gain significant experience applying one of these methods in a project.
**Prerequisites:** CSE 252 or CSE 331

**CSE 335 Topics on Intelligent Decision Support Systems 3 Credits**
Intelligent decision support systems (IDSSs). AI techniques that are used to build IDSSs: case-based reasoning, decision trees and knowledge representation. Applications of these techniques: help-desk systems, e-commerce, and knowledge management. Credit will not be given for both CSE 335 and CSE 435.
**Prerequisites:** CSE 327 or CSE 109
**Attribute/Distribution:** Q

**CSE 336 (ECE 336) Embedded Systems 3 Credits**
Use of small computers embedded as part of other machines. Limited-resource microcontrollers and state machines from high description language. Embedded hardware: RAM, ROM, flash, timers, UARTs, PWM, A/D, multiplexing, debouncing. Development and debugging tools running on host computers. Real-Time Operating System (RTOS) semaphores, mailboxes, queues. Task priorities and rate monotonic scheduling. Software architectures for embedded systems.
**Prerequisites:** CSE 017

**CSE 337 Reinforcement Learning 3 Credits**
Algorithms for automated learning from interactions with the environment to optimize long-term performance. Markov decision processes, dynamic programming, temporal-difference learning, Monte Carlo reinforcement learning methods. Credit will not be given for both CSE 337 and CSE 437.
**Prerequisites:** (MATH 231 or ECO 045) and CSE 109
**Attribute/Distribution:** Q

**CSE 340 (MATH 340) Design and Analysis of Algorithms 0,3 Credits**
Algorithms for searching, sorting, manipulating graphs and trees, finding shortest paths and minimum spanning trees, scheduling tasks, etc.: proofs of their correctness and analysis of their asymptotic runtime and memory demands. Designing algorithms: recursion, divide-and-conquer, greediness, dynamic programming. Limits on algorithm efficiency using elementary NP-completeness theory.
**Prerequisites:** (MATH 021 or MATH 031 or MATH 076) and CSE 140 and CSE 017
**Attribute/Distribution:** Q

**CSE 341 Database Systems, Algorithms, and Applications 3 Credits**
Design of large databases; normalization; query languages (including SQL); Transaction-processing protocols; Query optimization; performance tuning; distributed systems. Not available to students who have credit for CSE 241.
**Prerequisites:** CSE 017 and CSE 140
**Attribute/Distribution:** Q

**CSE 342 Fundamentals of Internetworking 3 Credits**
Architecture and protocols of computer networks. Protocol layers; network topology; data-communication principles, including circuit switching, packet switching and error control techniques; sliding window protocols, protocol analysis and verification; routing and flow control; local and wide area networks; network interconnection; client-server interaction; emerging networking trends and technologies; topics in security and privacy.
**Prerequisites:** CSE 109
**Attribute/Distribution:** Q

**CSE 343 Network Security 3 Credits**
Overview of network security threats and vulnerabilities. Techniques and tools for detecting, responding to and recovering from security incidents. Fundamentals of cryptography. Hands-on experience with programming techniques for security protocols. Credit will not be given for both CSE 343 and CSE 443.
**Prerequisites:** CSE 202 or CSE 342
**Attribute/Distribution:** Q

**CSE 345 WWW Search Engines 3 Credits**
Study of algorithms, architectures, and implementations of WWW search engines; Information retrieval (IR) models; performance evaluation; properties of hypertext crawling, indexing, searching and ranking; link analysis; parallel and distributed IR; user interfaces. Credit will not be given for both CSE 345 and CSE 445.
**Prerequisites:** CSE 109
**Attribute/Distribution:** Q

**CSE 347 Data Mining 3 Credits**
Overview of modern data mining techniques: data cleaning; attribute and subset selection; model construction, evaluation and application. Fundamental mathematics and algorithms for decision trees, covering algorithms, association mining, statistical modeling, linear models, neural networks, instance-based learning and clustering covered. Practical design, implementation, application, and evaluation of data mining techniques in class projects. Credit will not be given for both CSE 347 and CSE 447.
**Prerequisites:** CSE 017 and (CSE 160 or CSE 326) and (MATH 231 or MATH 205 or MATH 241 or MATH 242 or ECO 045 or ISE 121)
**Attribute/Distribution:** Q

**CSE 348 AI Game Programming 3 Credits**
Contemporary computer games: techniques for implementing the program controlling the computer component; using Artificial Intelligence in contemporary computer games to enhance the gaming experience: pathfinding and navigation systems; group movement and tactics; adaptive games, game genres, machine scripting language for game designers, and player modeling. Credit will not be given for both CSE 348 and CSE 448.
**Prerequisites:** CSE 327 or CSE 109
**Attribute/Distribution:** Q

**CSE 349 Big Data Analytics 3 Credits**
Provides working knowledge of large-scale data analysis using open source frameworks such as Apache Spark and Waikato Environment for Knowledge Analysis (Weka). Includes patterns employed in big data analytics, including classification, collaborative filtering, recommender systems, natural language processing, simulation, deep learning, and anomaly detection. Project-oriented software course; students should have substantial programming experience in one or more high-level languages. Past experience in data mining and/or machine learning expected. Credit will not be given for both 349 and 449.
**Prerequisites:** CSE 109 and (CSE 326 or CSE 347)

**CSE 350 Special Topics 3 Credits**
Selected topics in the field of computer science not included in other courses.
**Repeat Status:** Course may be repeated.

**CSE 351 Iterative Methods 3 Credits**
Commonly used iterative methods for efficiently solving large, sparse linear systems. Review of basic numeric analysis, direct methods, iterative methods, Krylov subspace methods, preconditioning techniques, and multigrid methods. Analysis of theoretical properties, including convergence behavior and computational and memory demands. Evaluation of performance using numerical experimentation on various real-world applications using Matlab. Credit will not be given for both CSE 351 and CSE 451.
**Prerequisites:** CSE 109 and CSE 140 and (MATH 205 or MATH 043)

**CSE 360 Introduction to Mobile Robotics 3 Credits**
Algorithms employed in mobile robotics for navigation, sensing, and estimation. Common sensor systems, motion planning, robust estimation, bayesian estimation techniques, Kalman and Particle filters, localization and mapping. Credit will not be given for both CSE 360 and CSE 460.
**Prerequisites:** MATH 205
**Attribute/Distribution:** Q

**CSE 367 Blockchain Projects 0,3 Credits**
Independent or small-group unique projects related to blockchain systems and/or applications. While pursuing their own project, students serve as consultants to the other teams via a once-weekly class meeting in which each team presents updates on status, progress, and open problems, and one student gives a longer prepared presentation on current research or development results in the blockchain field. Each project team has its own separate second weekly meeting with the instructor for a more in-depth project review and discussion.
**Repeat Status:** Course may be repeated.
**Prerequisites:** CSE 242
**Attribute/Distribution:** Q

**CSE 371 Principles of Mobile Computing 3 Credits**
Fundamental concepts and technology underlying mobile computing. Current research in these areas. Examples drawn from a variety of application domains such as health monitoring, energy management, commerce, and travel. Issues of system efficiency will be studied, including efficient handling of large data such as images and effective use of cloud storage. Recent research papers will be discussed. Credit will not be given for both CSE371 and CSE471.
**Prerequisites:** (CSE 109 and (CSE 202 or ECE 201), )
**Attribute/Distribution:** Q

**CSE 375 Principles of Practice of Parallel Computing 3 Credits**
Parallel computer architectures, parallel languages, parallelizing compilers and operating systems. Design, implementation, and analysis of parallel algorithms for scientific and data-intensive computing. Credit is not given for both CSE 375 and CSE 475.
**Prerequisites:** (ECE 201 or CSE 201) or CSE 303 or CSE 202
**Can be taken Concurrently:** ECE 201, CSE 201, CSE 303, CSE 202
**Attribute/Distribution:** Q

**CSE 376 Distributed Systems 3 Credits**
Exploration of theoretical and practical aspects of topics in distributed systems through a combination of readings, programming assignments, and projects. The main focal point is large distributed systems, in particular protocols to synchronize the activities of machines when operating over shared data. Techniques to ensure fault-tolerance and service-availability will also be discussed. Using distributed systems as a foundation, students gain skills in the design of complex, multilayered systems. Credit will not be given for both CSE 376 and CSE 476.
**Prerequisites:** CSE 303 and CSE 340 and (CSE 241 or CSE 242 or CSE 341 or CSE 375)
**Attribute/Distribution:** Q

**CSE 389 Honors Project 1-8 Credits**

**CSE 392 Independent Study 1-3 Credits**
An intensive study, with report, of a topic in computer science which is not treated in other courses. Consent of instructor required.
**Repeat Status:** Course may be repeated.

**CSE 401 (ECE 401) Advanced Computer Architecture 3 Credits**
Design, analysis and performance of computer architectures; high-speed memory systems; cache design and analysis; modeling cache performance; principle of pipeline processing, performance of pipelined computers; scheduling and control of a pipeline; classification of parallel architectures; systolic and data flow architectures; multiprocessor performance; multiprocessor interconnections and cache coherence.

**CSE 403 Advanced Operating Systems 3 Credits**
Principles of operating systems with emphasis on hardware and software requirements and design methodologies for multi-programming systems. Global topics include the related areas of process management, resource management, and file systems.
**Prerequisites:** CSE 303

**CSE 404 (ECE 404) Computer Networks 3 Credits**
Study of architecture and protocols of computer networks. The ISO model; network topology; data-communication principles, including circuit switching, packet switching and error control techniques; sliding window protocols, protocol analysis and verification; routing and flow control; local area networks; network interconnection; topics in security and privacy.

**CSE 406 Research Methods 3 Credits**
Technical writing, reading the literature critically, analyzing and presenting data, conducting research, making effective presentations, and understanding social and ethical responsibilities. Topics drawn from probability and statistics, use of scripting languages, and conducting large-scale experiments. Must have first-year status in either the CS or CompE Ph. D. program.

**CSE 407 (BIOE 407) Structural Bioinformatics 3 Credits**
Computational techniques and principles of structural biology used to examine molecular structure, function, and evolution. Topics include: protein structure alignment and prediction; molecular surface analysis; statistical modeling; QSAR; computational drug design; influences on binding specificity; protein-ligand, -protein, and –DNA interactions; molecular simulation, electrostatics. This course, a version of 307 for graduate students, requires advanced assignments and a collaborative project. Credit will not be given for both CSE 307 and 407. Consent of instructor required.

**CSE 408 (BIOE 408) Genomics 3 Credits**
Biological discoveries and computational techniques affecting modern biotechnology. Genome Assembly, genome annotation, and genome evolution in three interdisciplinary projects. Credit will not be given for both CSE 308 (BIOE 308) and CSE 408 (BIOE 408). No prior background in biology is assumed.

**CSE 410 (BSTA 410) Assistive Technologies 3 Credits**
This class will introduce typical challenges faced by persons with disabilities and the role of assistive technologies (ATs) in solving such challenges. The class will examine opportunities presented by recent advances in mobile and AI technologies. Working in groups, each student will be expected to acquire and apply relevant skills in designing AT solutions. The class can be taken by students with diverse backgrounds including the following: community and population health, social and behavioral sciences, business, engineering and computer science.

**CSE 411 Advanced Programming Techniques 3 Credits**
Deeper study of programming and software engineering techniques. The majority of assignments involve programming in contemporary programming languages. Topics include memory management, GUI design, testing, refactoring, and writing secure code.

**CSE 412 Introduction to Programming with Python 3 Credits**
Fundamental concepts of computing and "computational thinking": problem analysis, abstraction, algorithms, digital representation of information, and networks. Concepts of software development using the Python language. This course cannot be used toward a computer science undergraduate or graduate degree.

**CSE 413 Computer Graphics 3 Credits**
Algorithms and programming techniques for generating three dimensional computer graphics. Rasterization, color, animation, interaction, textures, lighting models, ray tracing. Substantial focus on the interaction between the CPU and the GPU, relating to vertex and fragment shaders. Department approval required. Credit will not be given for both CSE 313 and CSE 413.

**CSE 418 Theory of Computation 3 Credits**
Finite automata. Pushdown automata. Relationship to definition and parsing of formal grammars. Credit may be given for only one of the following: CSE318 and CSE409 and CSE418.

**CSE 420 (BIOE 420) Biomedical Image Computing and Modeling 3 Credits**
This course provides an introduction to biomedical image modalities, computing techniques, and informatics systems, with a focus on advanced imaging analysis. It covers algorithms and software for extracting quantitative insights from biomedical image data, including topics such as image processing, geometric and statistical modeling, and AI-based techniques for segmentation, registration, and enhancement. The course also explores brain network analysis for understanding neurological interactions and imaging informatics systems in biomedicine. Credit will not be given for CSE 320 and CSE 420.
**Attribute/Distribution:** ND

**CSE 423 Computer Vision 3 Credits**
Fundamental techniques from image processing, pattern recognition, machine learning and deep learning used to process and understand visual data. Build full pipelines for solutions to classic vision problems such as object detection and recognition, image matching and retrieval, and scene understanding and reconstruction. New and challenging problems such as synthetic image generation. Credit will not be given for both CSE 323 and CSE 423.

**CSE 424 Advanced Communication Networks 3 Credits**
Current and emerging research topics in communication networks: network protocols, network measurement, internet routing, network security, adhoc and sensor networks, disruption tolerant networks. Lecture, readings, and discussion, plus a project.
**Prerequisites:** CSE 342 or CSE 303 or CSE 404

**CSE 425 Natural Language Processing 3 Credits**
Overview of modern natural language processing techniques: text normal- ization, language model, part-of-speech tagging, hidden Markov model, syntatic and dependency parsing, semantics, word sense, reference resolution, dialog agent, machine translation. Three projects to design, implement and evaluate classic NLP algorithms. Credit will not be given for both CSE 325 and CSE 425.
**Prerequisites:** (MATH 231 or ECO 045) and CSE 017

**CSE 426 Fundamentals of Machine Learning 3 Credits**
Bayesian decision theory and the design of parametric and nonparametric classification and regression: linear, quadratic, nearest-neighbors, neural nets. Boosting, bagging. This course, a version of CSE 326 for graduate students requires advanced assignments. Credit will not be given for both CSE 326 and CSE 426.

**CSE 428 Semantic Web Topics 3 Credits**
Theory, architecture and applications of the Semantic Web. Issues in designing distributed knowledge representation languages, ontology development, knowledge acquisition, scalable reasoning, integrating heterogeneous data sources, and web-based agents.

**CSE 430 (CEE 430) Deep Learning 3 Credits**
Introduction to deep learning, a subset of machine learning, concerned with the development and application of modern neural networks. We will cover a range of topics from basic Neural Networks, Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN), Attention, Transformers, Generative Adversarial Networks (GAN), and state-of-the art networks and their applications in computer vision, engineering, remote sensing, medical, language, and AI for social good applications. Credit will not be given for both CSE 330 and CSE 430.
**Prerequisites:** CSE 347 or CSC 347

**CSE 431 Intelligent Agents 3 Credits**
Principles of rational autonomous software systems. Agent theory; agent architectures, including logic-based, utility-based, practical reasoning, and reactive; multi-agent systems; communication languages; coordination methods including negotiation and distributed problem solving; applications.

**CSE 433 Advanced Methods for Understanding Human-Computer Interactions 3 Credits**
Covers a variety of methods for conducting research on human interactions with computing systems. Methods covered may include: controlled experiments, surveys, ethnography, grounded theory, research through design, log data analysis, retrospective techniques, social network analysis, and others. Taking this course will familiarize the student with several of these methods through readings and in-class discussion and activities, as well as provide the student the opportunity to gain significant experience applying one of these methods in a project.
**Prerequisites:** CSE 333

**CSE 435 Topics on Intelligent Decision Support Systems 3 Credits**
AI techniques used to build IDSSs: case-based reasoning, decision trees and knowledge representation. Applications: helpdesk systems, e-commerce, and knowledge management. This course, a version of CSE 335 for graduate students, requires research projects and advanced assignments. Credit will not be given for both CSE 335 and CSE 435.

**CSE 437 Reinforcement Learning and Markov Decision Precesses 3 Credits**
Formal model based on Markov decision processes for automated learning from interactions with stochastic, incompletely known environments. Markov decision processes, dynamic programming, temporal-difference learning, Monte Carlo reinforcement learning methods. Credit will not be given for both CSE 337 and CSE 437. Must have graduate standing in Computer Science or have consent of instructor.

**CSE 440 Advanced Algorithms 3 Credits**
Average-case runtime analysis of algorithms. Randomized algorithms and probabilistic analysis of their performance. Analysis of data structures including hash tables, augmented data structures with order statistics. Amortized analysis. Elementary computational geometry. Limits on algorithm space efficiency using PSPACE-completeness theory. Credit will not be given for both CSE 440 and CSE 441.
**Prerequisites:** CSE 340 or MATH 340

**CSE 442 Advanced Blockchain Systems and Theory 3 Credits**
Formal foundations of blockchain systems: cryptography, consensus, zero-knowledge proofs, transaction processing both on-chain and cross-chain, validation, and governance. Algorithms and data structures for blockchain systems. Programming paradigms for smart contracts. Current research in blockchain drawing from the cryptography, database, operating system, and parallel computing research communities.
**Prerequisites:** CSE 241 or CSE 341 or CSE 303 or CSE 403 or CSE 375 or CSE 475

**CSE 443 Network Security 3 Credits**
Overview of network security threats and vulnerabilities. Techniques and tools for detecting, responding to and recovering from security incidents. Fundamentals of cryptography. Hands-on experience with programming techniques for security protocols. This course, a version of CSE 343 for graduate students, requires research projects and advanced assignments. Credit will not be given for both CSE 343 and CSE 443.
**Prerequisites:** (CSE 404 or ECE 404) or CSE 271 or CSE 202 or CSE 342

**CSE 445 WWW Search Engines 3 Credits**
Study of algorithms, architectures, and implementations of WWW search engines. Information retrieval (IR) models; performance evaluation; properties of hypertext crawling, indexing, searching and ranking; link analysis; parallel and distributed IR; user interfaces. This course, a version of CSE 345 for graduate students, requires research projects and advanced assignments. Credit will not be given for both CSE 345 and CSE 445.

**CSE 447 Data Mining 3 Credits**
Modern data mining techniques: data cleaning; attribute and subset selection; model construction, evaluation and application. Algorithms for decision trees, covering algorithms, association rule mining, statistical modeling, model and regression trees, neural networks, instance-based learning and clustering covered. This course, a version of CSE 347 for graduate students, requires research projects and advanced assignments, and expects students to have a background in probability, statistics, and programming. Credit will not be given for both CSE 347 and CSE 447.
**Prerequisites:** CSE 326

**CSE 449 Big Data Analytics 3 Credits**
Provides working knowledge of large-scale data analysis using open source frameworks such as Apache Spark and Waikato Environment for Knowledge Analysis (Weka). Includes patterns employed in big data analytics, including classification, collaborative filtering, recommender systems, natural language processing, simulation, deep learning, and anomaly detection. Project-oriented software course; students should have substantial programming experience in one or more high-level languages. Past experience in data mining and/or machine learning expected. Credit will not be given for both 349 and 449.
**Prerequisites:** CSE 109 and (CSE 326 or CSE 347)

**CSE 450 Special Topics 3 Credits**
Selected topics in computer science not included in other courses.
**Repeat Status:** Course may be repeated.

**CSE 451 Iterative Methods 3 Credits**
Commonly used iterative methods for efficiently solving large, sparse linear systems. Review of basic numeric analysis, direct methods, iterative methods, Krylov subspace methods, preconditioning techniques, and multigrid methods. Analysis of theoretical properties, including convergence behavior and computational and memory demands. Evaluation of performance using numerical experimentation on various real-world applications using Matlab. Credit will not be given for both CSE 351 and CSE 451.

**CSE 460 Mobile Robotics 3 Credits**
Algorithms employed in mobile robotics for navigation, sensing, and estimation. Common sensor systems, motion planning, robust estimation, Bayesian estimation techniques, Kalman and particle filters, localization and mapping. This course, a version of CSE 360 for graduate students will require an independent project to be presented in class. Credit will not be given for both CSE 360 and CSE 460.

**CSE 467 Blockchain Projects 0,3 Credits**
Independent or small-group graduate-level unique projects related to blockchain-systems and/or applications. While pursuing their own project, students serve as consultants to the other teams via a once-weekly class meeting in which each team presents updates on status, progress, and open problems, and one student gives a longer prepared presentation on current research or development results in the blockchain field. Each project team has its own separate second weekly meeting with the instructor for a more in-depth project review and discussion.
**Repeat Status:** Course may be repeated.

**CSE 471 Principles of Mobile Computing 3 Credits**
Course topics include fundamental concepts and technology underlying mobile computing and current research in these areas. Examples drawn from a variety of application domains such as health monitoring, energy management, commerce, and travel. Issues of system efficiency will be studied, including efficient handling of large data such as images and effective use of cloud storage. Recent research papers will be discussed. The graduate version of CSE 371 requires additional effort. Credit will not be given for both CSE371 and CSE471.
**Prerequisites:** CSE 109 and CSE 202 or CSE 303

**CSE 475 Principles and Practice of Parallel Computing 3 Credits**
Parallel computer architectures, parallel languages, parallelizing compilers and operating systems. Design, implementation, and analysis of parallel algorithms for scientific and data-intensive computing. This is a graduate version of CSE 375. As such, it will require additional assignments. Credit is not given for both CSE 375 and CSE 475.

**CSE 476 Distributed Systems 3 Credits**
Exploration of theoretical and practical aspects of topics in distributed systems through a combination of readings, programming assignments, and projects. The main focal point is large distributed systems, in particular protocols to synchronize the activities of machines when operating over shared data. Techniques to ensure fault-tolerance and service-availability will also be discussed. Using distributed systems as a foundation, students gain skills in the design of complex, multilayered systems. Credit will not be given for both CSE 376 and CSE 476.
**Prerequisites:** (CSE 303 or CSE 403) and (CSE 340 or CSE 440) and (CSE 241 or CSE 242 or CSE 341 or CSE 375 or CSE 404 or ECE 404 or CSE 475)

**CSE 490 Thesis 1-6 Credits**
Thesis.
**Repeat Status:** Course may be repeated.

**CSE 491 Research Seminar 1-3 Credits**
Regular meetings focused on specific topics related to the research interests of department faculty. Current research will be discussed. Students may be required to present and review relevant publications. Consent of instructor required.
**Repeat Status:** Course may be repeated.

**CSE 492 Independent Study 1-3 Credits**
An intensive study, with report of a topic in computer science that is not treated in other courses. Consent of instructor required.
**Repeat Status:** Course may be repeated.

**CSE 499 Dissertation 1-15 Credits**