Department of Computer Science

The Department of Computer Science offers a Bachelor of Science degree in Computer Science with concentrations in Cloud and Systems, Cyber Security, Data Science, and Software Engineering, and a Minor in Computer Science. The department also offers the Certificate in Pathogenic Outbreak Investigations in collaboration with the Department of Biology and the Department of Information Systems and Cyber Security in the College of Business.

Admission Policy

The goal of the Department of Computer Science is to provide undergraduate students a program of study with the highest possible standards. To achieve this goal, the admission policy of the Department of Computer Science is designed to identify those students most likely to succeed in their undergraduate computer science education.

Direct Admission Criteria for Students Admitted Under this Catalog Beginning Fall 2019

Applicants entering UTSA will be directly admitted to the Department of Computer Science if they:

- meet all UTSA undergraduate admission requirements, and
- are ranked in the top 15 percent of their high school class and a minimum 1350 SAT* or 29 ACT score, and
- are Calculus I ready (https://future.utsa.edu/ready/calculus-ready).

* New SAT scores combine Evidence-Based Reading and Writing and Math.

Transfer applicants will be directly admitted to the Department of Computer Science if they:

- meet all UTSA undergraduate transfer admission requirements, and
- are Calculus I ready (https://future.utsa.edu/ready/calculus-ready).

Students who do not meet the above requirements, but meet UTSA’s general admission requirements, will be part of “Engineering, Mathematics, and Sciences Studies” (XEMS). The student must choose a major other than computer science. A computer science minor is, however, available to all UTSA students who seek to complement a different academic major with a strong foundation in computer science.

A directly admitted computer science (CS) student who fails to complete each of the gateway courses within two attempts from the date of first admission to the Department of Computer Science will be changed from CS to undeclared (UND) in the University student record system. The student must choose a major other than computer science. A computer science minor is, however, available to all UTSA students who seek to complement a different academic major with a strong foundation in computer science.

Admission Criteria for Applicants Who Do Not Meet Direct Admission Criteria and Applicants Admitted Under this Catalog Prior to Fall 2019

Prior to Fall 2019, all applicants for admission to the Department of Computer Science will be admitted to the Department as a Pre-Computer Science (PCS) major. Beginning Fall 2019, applicants for admission to the Department of Computer Science who do not meet the direct admission requirements, but meet UTSA’s general admission requirements, will be part of “Engineering, Mathematics, and Sciences Studies” (XEMS).

All PCS or XEMS students seeking admission to the Department of Computer Science must be qualified to take MAT 1093 Precalculus or higher. In order to declare Computer Science as a major, a PCS or XEMS student must satisfy the following criteria:

- completion of CS 1083 Programming I for Computer Scientists with a grade of "C-" or better, and
- completion of CS 1713 Computer Programming II and CS 1711 Computer Programming II Recitation with a grade of "C-" or better, and
- completion of MAT 1214 Calculus I with a grade of "C-" or better, and
- have an overall GPA of 2.00 or higher on all coursework at UTSA.

A PCS or XEMS student who fails to complete the criteria to change the major to CS within two years from the date of first admission to the Department of Computer Science will be changed from PCS/XEMS to undeclared (UND) in the University student record system. The student must choose a major other than computer science. A computer science minor is, however, available to all UTSA students who seek to complement a different academic major with a strong foundation in computer science.

Bachelor of Science Degree in Computer Science

The Bachelor of Science (B.S.) degree in Computer Science is designed to prepare students with a strong technical emphasis on modern computing and systems. The degree program offers students the opportunity to prepare for advanced graduate study and for careers in high-technology companies, business, government, and teaching. The department offers concentrations in Cloud and Systems, Cyber Security, Data Science, and Software Engineering.

The B.S. degree in Computer Science requires a minimum of 120 semester credit hours, including the Core Curriculum requirements. Thirty-nine of the total semester credit hours required for the degree must be at the upper-division level.

All majors in computer science are required to complete all required and elective computer science courses with a grade of "C-" or better.

All candidates seeking this degree must fulfill the Core Curriculum requirements and the degree requirements, which are listed below.

Core Curriculum Requirements (42 semester credit hours)

Students seeking the B.S. degree in Computer Science must fulfill University Core Curriculum requirements in the same manner as other students. The course listed below will satisfy both degree requirements.
and Core Curriculum requirements; however, if this course is taken to satisfy both requirements, then students may need to take an additional course in order to meet the minimum number of semester credit hours required for this degree.

MAT 1214 may be used to satisfy the core requirement in Mathematics as well as a major requirement.

Core Curriculum Component Area Requirements (http://catalog.utsa.edu/undergraduate/bachelorsdegree regulations/degreerequirements/corecurriculumcomponentarearequirements)

First Year Experience Requirement 3
Communication 6
Mathematics 3
Life and Physical Sciences 6
Language, Philosophy and Culture 3
Creative Arts 3
American History 6
Government-Political Science 6
Social and Behavioral Sciences 3
Component Area Option 3

Total Credit Hours 42

Gateway Courses

Students pursuing the B.S. degree in Computer Science must successfully complete each of the following Gateway Courses with a grade of "C-" or better in no more than two attempts. A student who is unable to successfully complete these courses within two attempts, including dropping a course with a grade of "W" or taking an equivalent course at another institution, will be required to change his or her major.

CS 1713 Computer Programming II
CS 1711 Computer Programming II Recitation
CS 2123 Data Structures
CS 2121 Data Structures Recitation

Degree Requirements

A. Required courses (this also satisfies the 3 hours of core curriculum requirement for Mathematics)

CS 1083 Programming I for Computer Scientists 3
CS 1713 Computer Programming II 4
& CS 1711 and Computer Programming II Recitation
CS 2123 Data Structures 4
& CS 2121 and Data Structures Recitation
CS 2233 Discrete Mathematical Structures 3
CS 3333 Mathematical Foundations of Computer Science 3
CS 3343 Analysis of Algorithms 3
CS 3423 Systems Programming 4
& CS 3421 and Systems Programming Recitation
CS 3443 Application Programming 3
CS 3723 Programming Languages 3
CS 3733 Operating Systems 3
CS 3743 Database Systems 3
CS 3843 Computer Organization 4
& CS 3841 and Computer Organization Recitation
CS 3853 Computer Architecture 3

MAT 1214 Calculus I (The student who is not prepared for MAT 1214 must take MAT 1093 Precalculus.) 4
MAT 1224 Calculus II 4

B. Upper-Division computer science courses

With prior written approval of the Undergraduate Advisor of Record, students may take upper-division MAT or STA courses to satisfy up to 6 hours of this requirement. A student with a cumulative grade point average of 3.0 or better may enroll in graduate courses and apply the credits earned toward satisfying this requirement. Enrollment in graduate courses requires prior written approvals as described in chapter 1 (Bachelor’s Degree Regulations) of this catalog.

C. Free electives
Electives 6

Total Credit Hours 81

Concentration in Cloud and Systems

Students may declare a Concentration in Cloud and Systems after completing CS 3423 Systems Programming with a grade of “C-” or better. All candidates for the Concentration in Cloud and Systems must fulfill the Core Curriculum requirements and the Computer Science degree requirements including, as part of the upper-division computer science electives in item B in the degree requirements, the following course:

CS 4843 Cloud Computing 3

plus three additional courses selected from the following (an elective can only be counted towards one concentration):

CS 3873 Computer Networks 3
CS 4243 Large-Scale Data Management 3
CS 4633 Simulation Techniques 3
CS 4663 Distributed and Cloud Systems Security 3
CS 4713 Compiler Construction 3
CS 4823 Parallel Programming 3
CS 4833 Embedded Systems 3
CS 4853 Advanced Systems Programming 3
CS 4863 Distributed Computing and Systems 3
CS 4963 Advanced Topics in Systems and Cloud 3

Concentration in Cyber Security

Students may declare a Concentration in Cyber Security after completing CS 2123 Data Structures with a grade of “C-” or better. All candidates for the Concentration in Cyber Security must fulfill the Core Curriculum requirements and the Computer Science degree requirements including, as part of the computer science electives in item B in the degree requirements, the following course:

CS 3113 Principles of Cyber Security 3

plus three additional courses selected from the following (an elective can only be counted towards one concentration):

CS 3433 Computer and Information Security 3
CS 4353 Unix and Network Security 3
CS 4363 Cryptography 3
CS 4643 Cellular and Mobile Technologies 3
CS 4653 Software and Malware Reverse Engineering 3
Concentration in Data Science

Students may declare a Concentration in Data Science after completing CS 3343 Analysis of Algorithms with a grade of "C-" or better. All candidates for the Concentration in Data Science must fulfill the Core Curriculum requirements and the Computer Science degree requirements including, as part of the upper-division computer science electives in item B in the degree requirements, the following course:

CS 3753 Data Science 3

plus two additional courses selected from the following (an elective can only be counted towards one concentration):

CS 3793 Artificial Intelligence 3
CS 4223 Bioinformatics and Big Data 3
CS 4233 Computational Biology and Bioinformatics 3
CS 4243 Large-Scale Data Management 3
CS 4373 Data Mining 3
CS 4973 Advanced Topics in Data Science 3

Concentration in Software Engineering

Students may declare a Concentration in Software Engineering after completing CS 3443 Application Programming with a grade of "C-" or better. All candidates for the Concentration in Software Engineering must fulfill the Core Curriculum requirements and the Computer Science degree requirements including, as part of the upper-division computer science electives in item B in the degree requirements, the following course:

CS 3773 Software Engineering 3

plus two additional courses selected from the following (an elective can only be counted towards one concentration):

CS 4393 User Interfaces 3
CS 4683 Secure Software Development and Analysis 3
CS 4723 Software Validation and Quality Assurance 3
CS 4743 Enterprise Software Engineering 3
CS 4773 Object-Oriented Systems 3
CS 4783 Advanced Software Engineering 3

Course Sequence Guide for B.S. Degree in Computer Science

This course sequence guide is designed to assist students in completing their UTSA undergraduate Computer Science degree requirements. This is merely a guide and students must satisfy other requirements of this catalog and meet with their academic advisor for individualized degree plans. Progress within this guide depends upon such factors as course availability, individual student academic preparation, student time management, work obligations, and individual financial considerations. Students may choose to take courses during Summer terms to reduce course loads during long semesters.

B.S. in Computer Science – Recommended Four-Year Academic Plan

First Year

Fall
AIS 1203 Academic Inquiry and Scholarship (core) 3
CS 1083 Programming I for Computer Scientists 3
MAT 1214 Calculus I (core and major) 4
WRC 1013 Freshman Composition I (Q) (core) 3
Creative Arts core 3
Credit Hours 16

Spring
CS 1713 Computer Programming II 3
CS 1711 Computer Programming II Recitation 1
MAT 1224 Calculus II 4
POL 1133 or POL 1213 Texas Politics and Society (core) or Civil Rights in Texas and America 3
WRC 1023 Freshman Composition II (Q) (core) 3
Credit Hours 14

Second Year

Fall
CS 2123 Data Structures 3
CS 2121 Data Structures Recitation 1
CS 2233 Discrete Mathematical Structures 3
CS 3333 Mathematical Foundations of Computer Science 3
POL 1013 Introduction to American Politics (core) 3
Life & Physical Sciences core 3
Credit Hours 16

Spring
CS 3423 Systems Programming 3
CS 3421 Systems Programming Recitation 1
CS 3443 Application Programming 3
CS 3843 Computer Organization 3
CS 3841 Computer Organization Recitation 1
Social & Behavioral Sciences core 3
Credit Hours 14

Third Year

Fall
CS 3343 Analysis of Algorithms 3
CS 3723 Programming Languages 3
CS 3743 Database Systems 3
Life & Physical Sciences core 3
Free Elective 3
Credit Hours 15

Spring
CS 3733 Operating Systems 3
CS 3853 Computer Architecture 3
Upper-division CS elective 3
Upper-division CS elective | 3
Free Elective | 3

Credit Hours | 15

Fourth Year
Fall
Upper-division CS elective | 3
Upper-division CS elective | 3
Upper-division CS elective | 3
Component Area Option core | 3
American History core | 3

Credit Hours | 15

Spring
Upper-division CS elective | 3
Upper-division CS elective | 3
Upper-division CS elective | 3
Language, Philosophy & Culture core | 3
American History core | 3

Credit Hours | 15

Total Credit Hours | 120

Note: Some courses are only offered once a year; Fall or Spring. Check with the Department of Computer Science for scheduling of courses.

Minor in Computer Science

All students pursuing the Minor in Computer Science must complete 20 semester credit hours. All required and elective courses must be completed with a grade of "C-" or better.

A. Required courses
CS 1083 Programming I for Computer Scientists | 3
CS 1713 Computer Programming II | 4
& CS 1711 and Computer Programming II Recitation | 4
CS 2123 Data Structures | 4
& CS 2121 and Data Structures Recitation

B. CS core courses or approved CS electives
Select 9 hours of additional CS core courses or approved CS electives, at least 6 hours of which must be at the upper-division level | 9

Total Credit Hours | 20

To declare a Minor in Computer Science, obtain advice, or seek approval of substitutions for course requirements, students should consult with their academic advisor.

Certificate in Pathogenic Outbreak Investigations

This interdisciplinary certificate program is designed for students in biology, information systems and cyber security, computer science and computer engineering disciplines to investigate biological and digital pathogen identification, propagation prediction, and mitigation. The required capstone project reinforces the cross-disciplinary learning fostered by the program and provides real-world practice.

This certificate is open only to biology, information systems and cyber security, computer science, and computer engineering majors. To apply for the Pathogenic Outbreak Investigations certificate, students should consult with the Director of the Office of Undergraduate Research for specific information about certificate requirements and consult with their academic advisors to verify that they have met all University requirements. All courses used to satisfy the requirements of this undergraduate certificate program must be college-level courses taken at UTSA. Students must fulfill all prerequisite requirements for elective courses.

Students pursuing the Certificate in Pathogenic Outbreak Investigations must complete a minimum of 15 semester credit hours:

A. Courses required by all majors:

Topic: Introduction to Pathogenic Outbreak Investigations: | 3
BIO 4953 Special Studies in Biology
or CS 4593 Topics in Computer Science
or IS 3313 Introduction to Pathogenic Outbreak Investigations

Topic: Advanced Research in Pathogenic Outbreak Investigations: | 3
BIO 4953 Special Studies in Biology
or CS 4913 Independent Study
or IS 4953 Special Studies in Information Systems

B. Required course according to major: | 3
BIO 3713 Microbiology
CS 4593 Topics in Computer Science (Cloud Computing)
IS 4953 Special Studies in Information Systems (Topic: Malware Agent Analysis)

C. Elective courses for each major. Select 6 hours from one of the following groups depending on major:

Biology elective options
1. BIO 3513 Biochemistry
2. BIO 3743 Bacteriology
3. BIO 4743 Immunology
4. BIO 5762 Fundamentals of Immunology for Biotechnology
5. BIO 6973 Special Problems (Comparative Genomics)
6. BIO 6973 Special Problems (Microbial Genomics)

Information Systems/Cyber Security elective options
IS 3523 Intrusion Detection and Incident Response
IS 4463 Web Application Security
IS 4483 Digital Forensic Analysis I
IS 4513 Industrial Control Systems
IS 4523 Digital Forensic Analysis II

Computer Science elective options
CS 3113 Principles of Cyber Security
CS 3433 Computer and Information Security
CS 3753 Data Science
CS 3873 Computer Networks
CS 4223 Bioinformatics and Big Data
CS 4353 Unix and Network Security
CS 4363 Cryptography
CS 4373 Data Mining
CS 4593 Topics in Computer Science
CS 4633 Simulation Techniques
CS 4643 Cellular and Mobile Technologies
CS 4653 Software and Malware Reverse Engineering
CS 4663 Distributed and Cloud Systems Security
CS 4673 Cyber Operations
CS 4683  Secure Software Development and Analysis
CS 4713  Compiler Construction
CS 4823  Parallel Programming
CS 4833  Embedded Systems
CS 4843  Cloud Computing
CS 4853  Advanced Systems Programming
CS 4863  Distributed Computing and Systems
CS 4933  Internship in Computer Science
CS 4963  Advanced Topics in Systems and Cloud
CS 4973  Advanced Topics in Data Science

Total Credit Hours 15

1 Undergraduate biology students are permitted to take graduate courses based on need, student background/capability, and instructor consent.

Computer Science (CS) Courses

CS 1023. Cultural Implications of the Information Society. (3-0) 3 Credit Hours.
This course offers an examination of the modern information society and the influences of technological advances on society and culture. The emphasis is on information and its management from ethical, social, and legal perspectives. Students will make extensive use of the World Wide Web. Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

CS 1033. Microcomputer Applications. (3-0) 3 Credit Hours.
Study of the uses of the computer and the organization and visualization of data. Topics will be selected from library searching, networking, e-mail, spreadsheets, databases, authoring packages, multimedia and hypertext applications, presentation graphics, and legal/ethical issues. May not be applied toward a major in computer science. (Formerly CS 2083. Credit cannot be earned for both CS 1033 and CS 2083.) Generally offered: Spring. Course Fees: LRS1 $15; STSI $15.

CS 1063. Introduction to Computer Programming I. (3-0) 3 Credit Hours.
Prerequisite: MAT 1073 or the equivalent. An introduction to computer programming using a modern object-oriented computer language. Topics include assignment, decisions, loops, methods and arrays using objects. Generally offered: Fall, Spring, Summer. Course Fees: LRS1 $15; STSI $15.

CS 1083. Programming I for Computer Scientists. (3-0) 3 Credit Hours. (TCCN = COSC 1437)
Prerequisite: MAT 1073 or the equivalent. An introduction to computer programming emphasizing structured programming, problem solving, and algorithmic thinking. Topics include assignment, decisions, loops, methods, arrays, and use of objects. Students intending to major or minor in Computer Science should take this course instead of CS 1063. Course Fees: LRS1 $15; STSI $15.

CS 1173. Data Analysis and Visualization. (3-0) 3 Credit Hours.
Prerequisite: MAT 1023. Introduction to data analysis and visualization in a programming language such as MATLAB or R. Programming concepts including functions, scripting, loops and logic, handling of vectors and structured data are explored in the context of working with and plotting real data. May be applied toward the Core Curriculum requirement in the Component Area Option. (Formerly titled "Computation for Scientists and Engineers.") Generally offered: Fall, Spring, Summer. Course Fees: LRC1 $12; LRS1 $15; STSI $15.

CS 2073. Computer Programming with Engineering Applications. (3-0) 3 Credit Hours. (TCCN = ENGR 2304)
Prerequisites: MAT 1214 and completion of or concurrent enrollment in MAT 1224. Algorithmic approaches to problem solving and computer program design for engineers. Engineering and mathematically-oriented problem sets will be emphasized, including nonnumeric applications. Searching, sorting, linked lists, and data typing will be introduced. May not be applied toward a major in computer science. Generally offered: Fall, Spring, Summer. Course Fees: LRS1 $15; STSI $15.

CS 2121. Data Structures Recitation. (1-0) 1 Credit Hour.
Prerequisites: CS 1713 and MAT 1214. Concurrent enrollment in CS 2123 is required. Recitation to accompany CS 2123. (Formerly titled "Introduction to Data Structures.") Generally offered: Fall, Spring, Summer. Course Fees: LRS1 $15; STSI $15.

CS 2123. Data Structures. (3-0) 3 Credit Hours.
Prerequisites: CS 1713 and MAT 1214. Concurrent enrollment in CS 2121 is required. Abstract data structures (stacks, queues, lists, trees), recursion, sorting, and searching. Implementation of data structures using explicit memory management, and introduction to abstract data type design and encapsulation. (Formerly CS 1723. Credit cannot be earned for both CS 2123 and CS 1723.) Generally offered: Fall, Spring, Summer. Course Fees: LRS1 $15; STSI $15.

CS 2153. Game Design. (3-0) 3 Credit Hours.
Prerequisites: CS 1153. This course builds upon the lessons learned in CS 1153 Game Programming to examine in more detail the design and development of electronic games. The fundamentals of game design and development of electronic games. The fundamentals of game design will be examined in detail and the students will be responsible for building a game using a popular game engine. Course Fees: LRS1 $15; STSI $15.
**CS 2233. Discrete Mathematical Structures. (3-0) 3 Credit Hours.**
(TCCN = MATH 2305)
Prerequisites: CS 1713 and MAT 1214. Survey and development of theoretical tools suitable for describing algorithmic applications. Propositional and predicate calculus, proofs, induction, order notation, recurrences and discrete structures. (Formerly 3233. Credit cannot be earned for both CS 2233 and CS 3233.) Generally offered: Fall, Spring. Summer. Course Fees: LRS1 $15; STSI $15.

**CS 3113. Principles of Cyber Security. (3-0) 3 Credit Hours.**
Prerequisite: CS 2123. An introductory course in Cyber Security including an examination of the fundamental principles underlying cyber security, how these principles interrelate and how they are typically employed to secure computer systems and networks. The course will also examine how failures in fundamental security design principles can lead to system vulnerabilities that can be exploited and will also examine the legal issues governing cyber law and cyber operations. (Formerly CS 2433. Credit cannot be earned for both CS 3113 and CS 2433.) Course Fees: LRS1 $15; STSI $15.

**CS 3333. Mathematical Foundations of Computer Science. (3-0) 3 Credit Hours.**
Prerequisites: CS 1713 and MAT 1224. Survey and development of mathematical and statistical tools suitable for describing algorithmic applications. Vectors, matrices, combinatorics, probability and statistical models. Generally offered: Fall, Spring, Summer. Course Fees: LRS1 $15; STSI $15.

**CS 3343. Analysis of Algorithms. (3-0) 3 Credit Hours.**
Prerequisites: CS 2123, CS 2233, and CS 3333. Analysis of the performance of algorithms; discussion of programming techniques and data structures used in the writing of effective algorithms. Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

**CS 3421. Systems Programming Recitation. (1-0) 1 Credit Hour.**
Prerequisite: CS 2123. Concurrent enrollment in CS 3423 is required. Recitation to accompany CS 3423. (Formerly CS 2411. Credit cannot be earned for both CS 3421 and CS 2411.) Generally offered: Fall, Spring. Course Fees: LRS1 $5; STSI $5.

**CS 3423. Systems Programming. (3-0) 3 Credit Hours.**
Prerequisite: CS 2123. Concurrent enrollment in CS 3421. A study of systems-level programming in a specific system (at present, Unix). Focus on concepts and tools to support the construction of systems programs. (Formerly CS 2413. Credit cannot be earned for both CS 3423 and CS 2413.) Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

**CS 3433. Computer and Information Security. (3-0) 3 Credit Hours.**
Prerequisites: CS 2433 and consent of instructor. An introduction to the protection of computer systems and networks. Topics will include authentication, access controls, malicious software, formal security methods, firewalls, intrusion detection, cryptography and information hiding, risk management, computer forensics, and ethics. Generally offered: Fall. Course Fees: LRS1 $15; STSI $15.

**CS 3443. Application Programming. (3-0) 3 Credit Hours.**

**CS 3723. Programming Languages. (3-0) 3 Credit Hours.**
Prerequisites: CS 2233 and CS 3443. An introduction to high-level procedural, functional, and object-oriented programming languages, their theoretical foundations, organization, and implementation. Topics include formal syntax, compilers and interpreters, type systems, scopeing and activation records, control structures, and data abstraction. Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

**CS 3733. Operating Systems. (3-0) 3 Credit Hours.**
Prerequisites: CS 3423, CS 3443, and CS 3843. An introduction to the functions and major techniques of a modern multiprogramming operating system. Includes exposure to the fundamentals of processor management, process synchronization, memory management, and peripheral management. Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

**CS 3743. Database Systems. (3-0) 3 Credit Hours.**
Prerequisites: CS 2233 and CS 3423. Study of fundamentals of database systems. Topics include basic concepts, various data models, database design, storage systems, indexing and hashing, database application design and implementation, and commercially available database systems. Course Fees: LRS1 $15; STSI $15.

**CS 3753. Data Science. (3-0) 3 Credit Hours.**
Prerequisites: CS 2123, CS 2233, and CS 3333. Study of fundamental methods and models of data science. Topics include data management, Extract-Transform-Loading methods, machine learning models, and data visualization. Use of a specialized programming language is emphasized. Course Fees: LRS1 $15; STSI $15.

**CS 3773. Software Engineering. (3-0) 3 Credit Hours.**
Prerequisite: CS 3443. Introduction to different aspects of software engineering with the concentration on processes, methods, and tools for developing reliable software-centered systems. Study of software development process models, project management, a variety of modeling notations, requirement analysis, architecture design methods, and testing techniques. Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

**CS 3793. Artificial Intelligence. (3-0) 3 Credit Hours.**
Prerequisites: CS 3343 and CS 3423. Discussion of theorem-proving by machine; includes computational linguistics, psychological modeling, and computer games. Course Fees: LRS1 $15; STSI $15.

**CS 3841. Computer Organization Recitation. (1-0) 1 Credit Hour.**
Prerequisite: CS 2123. Concurrent enrollment in CS 3843 is required. Recitation to accompany CS 3843. (Formerly CS 2731. Credit cannot be earned for both CS 3841 and CS 2731.) Generally offered: Fall, Spring. Course Fees: LRS1 $5; STSI $5.

**CS 3843. Computer Organization. (3-0) 3 Credit Hours.**
Prerequisite: CS 2123. Concurrent enrollment in CS 3843 is required. Organization of a computer system is introduced at block diagram level. Programming in assembly language and understanding the macroarchitecture of a computer is emphasized. Fundamentals of digital systems are introduced and the designs of various components used are investigated. (Formerly CS 2733. Credit cannot be earned for both CS 3843 and CS 2733.) Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.
CS 3853. Computer Architecture. (3-0) 3 Credit Hours.
Prerequisites: CS 3423 and CS 3433. Instruction set architecture, datapath and control unit design, advanced computer arithmetic, pipelining, memory hierarchy and I/O subsystem, performance issues. (Formerly CS 4753. Credit cannot be earned for both CS 3853 and CS 4753.) Generally offered: Fall, Spring. Course Fees: LRS1 $15; STSI $15.

CS 3873. Computer Networks. (3-0) 3 Credit Hours.
Prerequisite: CS 3843. Network architecture, TCP/IP protocol suite, routing, data-link layer protocols, medium access control protocols, error detection and recovery, local area networks, wireless and mobile networks. (Formerly CS 4873. Credit cannot be earned for both CS 3873 and CS 4873.) Generally offered: Spring. Course Fees: LRS1 $15; STSI $15.

CS 4223. Bioinformatics and Big Data. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. Hands-on introduction to large-scale analysis of heterogeneous data with emphasis on integrating information and tools from publicly available biological databases to address complex problems. Course Fees: LRS1 $15; STSI $15.

CS 4233. Computational Biology and Bioinformatics. (3-0) 3 Credit Hours.
Prerequisite: CS 3343. Study of algorithmic and statistical techniques in modeling and analyzing large-scale biological data such as DNA sequences, gene expression, and gene networks. Topics include fast string matching, sequence alignment, frequent pattern mining, clustering, classification, and significance testing. Course Fees: LRS1 $15; STSI $15.

CS 4243. Large-Scale Data Management. (3-0) 3 Credit Hours.
Prerequisites: CS 3423 and CS 3443. Modern big data systems managing the three Vs of big data (variety, volume, and velocity). Topics include, but not limited to classic data management (overview), web search, information retrieval, map/reduce, data integration, natural language processing at scale. Course Fees: LRS1 $15; STSI $15.

CS 4313. Automata, Computability, and Formal Languages. (3-0) 3 Credit Hours.
Prerequisite: CS 3343. Discussion of abstract machines (finite state automata, pushdown automata, and Turing machines), formal grammars (regular, context-free, and type 0), and the relationship among them. Course Fees: LRS1 $15; STSI $15.

CS 4335. Unix and Network Security. (3-0) 3 Credit Hours.
Prerequisite: CS 3433. A technical survey of the fundamentals of computer and information security. Issues include cryptography, authentication, attack techniques at both the OS and network level, defense techniques, intrusion detection, scan techniques and detection, forensics, denial of service techniques and defenses, libpcap, libdnet and libnet programming. Generally offered: Spring. Course Fees: LRS1 $15; STSI $15.

CS 4363. Cryptography. (3-0) 3 Credit Hours.
Prerequisites: CS 3343, and CS 3113 or CS 3433. A course in pure and applied cryptography, with emphasis on theory. Topics may include conventional and public-key cryptosystems, signatures, pseudo-random sequences, hash functions, key management, and threshold schemes. Course Fees: LRS1 $15; STSI $15.

CS 4373. Data Mining. (3-0) 3 Credit Hours.
Prerequisite: CS 3343 or consent of instructor. Principles, techniques, systems and evaluation of data mining. Topics may include data preprocessing, frequent pattern mining, association mining, classification and prediction, cluster analysis, and advanced topics such as mining streams, time-Series, texts, and graphs. Course Fees: LRS1 $15; STSI $15.

CS 4383. Computer Graphics. (3-0) 3 Credit Hours.
Prerequisites: CS 2123 and CS 3443. An introduction to two- and three-dimensional generative computer graphics. Display devices, data structures, mathematical transformations, and algorithms used in picture generation, manipulation, and display. Course Fees: LRS1 $15; STSI $15.

CS 4393. User Interfaces. (3-0) 3 Credit Hours.

CS 4413. Web Technologies. (3-0) 3 Credit Hours.

CS 4423. Game Development. (3-0) 3 Credit Hours.
Prerequisite: CS 3443. A study of the major topics in game development, such as game mechanics, rendering, scripting, user interfaces, animation, asset management, and physics, with a focus on team-based development practices. By the end of the course students will have developed a full game with a group and several mini-games individually. Course Fees: LRS1 $15; STSI $15.

CS 4593. Topics in Computer Science. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. Advanced topics in an area of computer science. May be repeated for credit when topics vary. Generally offered: Spring. Course Fees: LRS1 $15; STSI $15.

CS 4633. Simulation Techniques. (3-0) 3 Credit Hours.
Prerequisite: CS 3343. Design, execution, and analysis of simulation models, discrete event simulation techniques, input and output analysis, random numbers, and simulation tools and languages. Course Fees: LRS1 $15; STSI $15.

CS 4643. Cellular and Mobile Technologies. (3-0) 3 Credit Hours.
Prerequisite: CS 3733. A study of cellular and mobile infrastructure, networks, and applications. Focus on concepts and tools related to the major cellular and mobile protocols. Course Fees: LRS1 $15; STSI $15.

CS 4653. Software and Malware Reverse Engineering. (3-0) 3 Credit Hours.
Prerequisites: CS 3433, and CS 3113 or CS 3433. An introduction to the basic procedures to reverse engineering of software, hardware and malware. Course Fees: LRS1 $15; STSI $15.

CS 4663. Distributed and Cloud Systems Security. (3-0) 3 Credit Hours.
Prerequisite: CS 3733. A study of the uses and security issues of virtualization, distributed systems and cloud systems. Course Fees: LRS1 $15; STSI $15.
CS 4673. Cyber Operations. (3-0) 3 Credit Hours.
Prerequisite: CS 3113 or CS 3433. A study of both offensive and defensive cyber operations, risk management, social engineering, perception management, and the international legal issues and considerations surrounding cyber operations, conflict, and war. Course Fees: LRS1 $15; STSI $15.

CS 4683. Secure Software Development and Analysis. (3-0) 3 Credit Hours.
Prerequisite: CS 3443. Analysis of software for vulnerabilities. Development of robust, secure software. Topics include source and binary code analysis, static and dynamic code analysis techniques, testing methodologies, secure programming principles and practices. Course Fees: LRS1 $15; STSI $15.

CS 4713. Compiler Construction. (3-0) 3 Credit Hours.
Prerequisites: CS 3723 and CS 3843. An introduction to implementation of translators. Topics include formal grammars, scanners, parsing techniques, syntax-directed translation, symbol table management, code generation, and code optimization. (Formerly titled "Compiler Writing.") Course Fees: LRS1 $15; STSI $15.

CS 4723. Software Validation and Quality Assurance. (3-0) 3 Credit Hours.
Prerequisite: CS 3773. Study of software validation techniques. Introduction to static analysis and software testing approaches (functional testing, structural testing, integration testing and regression testing). Overview of test planning and test case design. Review of topics in quality assurance. Generally offered: Spring. Course Fees: LRS1 $15; STSI $15.

CS 4743. Enterprise Software Engineering. (3-0) 3 Credit Hours.
Prerequisites: CS 3743 and CS 3773. Providing a hands-on introduction to principles and best practices for the development of enterprise-level software systems. Topics include architectural patterns, database models, remote deployment and execution, and concurrency management. (Formerly titled "Applied Software Engineering.") Course Fees: LRS1 $15; STSI $15.

CS 4773. Object-Oriented Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 3773. An introduction of principles and methodologies of good software design. Study of object-oriented concepts and techniques, encapsulation, inheritance mechanisms, polymorphism, and programming in one or more object-oriented languages. Examination of design patterns that provide reusable solutions to problems in object-oriented design. Course Fees: LRS1 $15; STSI $15.

CS 4783. Advanced Software Engineering. (3-0) 3 Credit Hours.
Prerequisites: CS 3743 and CS 3773. Application of software engineering principles to develop a working, security-hardened software product as a team project. Real-world case studies and perspectives will accompany lecture to provide students with an industry-level viewpoint. Course Fees: LRS1 $15; STSI $15.

CS 4823. Parallel Programming. (3-0) 3 Credit Hours.
Prerequisites: CS 3343 and CS 3423. Parallel programming concepts (partitioning, synchronization and communication, programming models-shared memory based and message based), programming tools and languages, performance issues. Course Fees: LRS1 $15; STSI $15.

CS 4833. Embedded Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 3843. Concepts and design principles of embedded systems. Microprocessor and hardware architecture, sensors and actuators, basic feedback control theory, Real-time scheduling, programming in embedded systems. Course Fees: LRS1 $15; STSI $15.

CS 4843. Cloud Computing. (3-0) 3 Credit Hours.
Prerequisite: CS 3423. The general trend of modern computing in cloud. Cloud computing paradigm and associate key technologies. Programming in cloud environment (e.g., Hadoop, MapReduce, and OpenStack APIs). Privacy and security in Cloud. Course Fees: LRS1 $15; STSI $15.

CS 4853. Advanced Systems Programming. (3-0) 3 Credit Hours.
Prerequisite: CS 3733. Concepts and knowledge on system booting, memory management, process and scheduling, interrupt handling, system calls, file systems, networking, device drivers and module programming. Runtime systems. Programming kernel modules in Linux. (Formerly titled "Systems Development and Programming.") Course Fees: LRS1 $15; STSI $15.

CS 4863. Distributed Computing and Systems. (3-0) 3 Credit Hours.
Prerequisite: CS 3733. A distributed system comprises computers working together as a single unit. These systems are essential to the understanding of present and future computer applications. This course will include the following topics: concurrent processing, threads, network programming, distributed file systems, remote procedure calls, distributed objects, client-server models, and Internet protocols. Course Fees: LRS1 $15; STSI $15.

CS 4911. Independent Study. (0-0) 1 Credit Hour.
Prerequisites: Permission in writing (form available) from the instructor, the student’s advisor, the Department Chair, and the Dean of the College in which the course is offered. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor’s degree. Course Fees: LRS1 $5; STSI $5.

CS 4912. Independent Study. (0-0) 2 Credit Hours.
Prerequisites: Permission in writing (form available) from the instructor, the student’s advisor, the Department Chair, and the Dean of the College in which the course is offered. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor’s degree. Course Fees: LRS1 $10; STSI $10.

CS 4913. Independent Study. (0-0) 3 Credit Hours.
Prerequisites: Permission in writing (form available) from the instructor, the student’s advisor, the Department Chair, and the Dean of the College in which the course is offered. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor’s degree. Generally offered: Fall, Spring, Summer. Course Fees: LRS1 $15; STSI $15.

CS 4933. Internship in Computer Science. (0-0) 3 Credit Hours.
Prerequisites: Junior or senior standing, an overall 2.5 grade point average, and permission in writing from the instructor, the Department Chair, and the Dean of the College of Sciences. The opportunity for a semester-long work experience in a private business or public agency in a computer science-related position. Not more than 3 semester credit hours of CS 4933, and not more than a total of 6 semester credit hours of CS 4933 and independent study courses may count toward the Bachelor of Science degree in Computer Science. The grade report for this course is either “CR” (satisfactory participation in the internship) or “NC” (unsatisfactory participation in the internship). Generally offered: Fall, Summer. Course Fees: LRS1 $15; STSI $15.
CS 4953. Special Studies in Computer Science. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Studies may be repeated for credit when topics vary, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor’s degree. Generally offered: Summer. Course Fees: LRS1 $15; STSI $15.

CS 4963. Advanced Topics in Systems and Cloud. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. Advanced topics in an area of systems and cloud. May be repeated for credit when topics vary. Course Fees: LRS1 $15; STSI $15.

CS 4973. Advanced Topics in Data Science. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. Advanced topics in an area of data science. May be repeated for credit when topics vary. Course Fees: LRS1 $15; STSI $15.

CS 4993. Honors Research. (0-0) 3 Credit Hours.
Prerequisites: Enrollment limited to candidates for College Honors during their last two semesters; approval by the College Honors Committee. Supervised research and preparation of an honors thesis. May be repeated once with approval. Course Fees: LRS1 $15; STSI $15.