

DEPARTMENT OF COMPUTER SCIENCE

Mission Statement

The core mission is to provide an inclusive learning environment and conduct ethical and excellence-driven research in computer science to benefit departmental stakeholders including students, faculty, the university, the local community, and the society at large. To fulfill this mission, the Department will:

- Use innovative and experiential learning models and research to prepare students for careers in industry, government, and academia.
- Develop leadership in the education of underrepresented and disadvantaged groups.
- Enhance the nationally prominent research, education, and outreach programs in cybersecurity and develop the cross-cutting research thrusts of data-driven intelligence and virtual reality systems and networked and software systems.

General Information

The Department of Computer Science is engaged in cutting-edge research in cross-cutting research thrust areas of cybersecurity; data-driven intelligence and virtual reality systems, and networked and software systems, with expertise in artificial intelligence; machine learning; big data; software engineering; cloud computing; cybersecurity; bioinformatics; Internet-of-things; embedded systems; parallel, distributed, and high-performance computing; and computer graphics and virtual and augmented reality. The Department of Computer Science operates dedicated classrooms, a large instructional lab, 20 research labs, and two main research units: the Center for Infrastructure Assurance and Security (CIAS) and the Institute for Cyber Security (ICS). Its faculty members are also affiliated with UTSA's School of Data Science, National Security Collaboration Center, and AI Matrix Consortium.

The Department of Computer Science also offers research opportunities and internships to undergraduate students. Students engaged in research are able to work with state-of-the-art computing clusters and research equipment operated by the Department of Computer Science and UTSA, such as a 113-compute node cluster, as well as AI workstations with cutting-edge GPUs.

Program Outcomes

The Department of Computer Science programs provide students the opportunity to:

- Become successfully employed in the computing profession or actively pursue advanced degrees in computing or a related discipline.
- Apply mathematical foundations, algorithmic principles, and computer science theory in the design of computational systems.
- Use cutting-edge computing technologies and methods for the design and implementation of high-quality solutions.
- Create and collaborate in emergent computing technologies leading to innovative solutions for industry and academia.
- Work effectively in teams to accomplish shared computing design, evaluation, or implementation goals, while exhibiting professional

behavior and exercising appropriate leadership within their organization.

- Engage in lifelong learning while reflecting a commitment to quality, innovation, critical thinking, and continuous improvement.
- Be responsible members of their profession and communicate effectively to a variety of audiences while upholding the highest commitment to personal integrity, behavior, and ethical and professional conduct.

Degrees

The Department of Computer Science (CS) offers a Bachelor of Science (B.S.) Degree in Computer Science, a Bachelor of Arts (B.A.) Degree in Computer Science with Teaching Track, and a B.S. Degree in Software Engineering. The Department also offers a Minor in Computer Science.

The **B.S. Degree in Computer Science** is designed to prepare students with a strong technical emphasis on modern computing and systems. The 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, Cybersecurity, Data Science, and Software Engineering. The department also offers the B.S. in Computer Science with a Cyber Operations Track.

The **B.A. Degree in Computer Science with Teaching Track** is an interdisciplinary program designed for students who are interested in teaching computer science at the middle school or high school level as a certified teacher. This program integrates a cohesive set of fundamental computer science courses from the B.S. degree in Computer Science as well as the UTeachSA program so that students can gain solid foundations in the computer science and education fields to obtain the Computer Science teaching certification, thus preparing students for successful careers in secondary school education as well as in industry and government sectors.

The **B.S. Degree in Software Engineering** provides a pathway for students who are mainly interested in developing software systems and/or pursuing advanced degrees or certifications in software engineering.

UTeachSA Teacher Preparation Program

UTeachSA (<https://www.utsa.edu/uteachsa/>) is the teacher preparation program that prepares students to become secondary (middle school and high school) science and mathematics teachers. The Department of Computer Science offers one program leading to teacher certification for the state of Texas: B.A. Computer Science with Teaching Track.

Criminal History Policy and Acknowledgement for Teacher Preparation Programs

Teacher preparation programs at UTSA require fieldwork in public schools, which requires students to be able to pass a criminal background check. It is the responsibility of the student to determine if their criminal history background will present a problem before applying for admission to the teacher preparation program. Students with a problematic criminal history will encounter difficulty in completing any fieldwork requirements and may not be able to complete the program. The University of Texas at San Antonio is required to inform students of the requirements set forth by the Texas Occupation Code, Chapter 53, Sections 53.001 through 53.105 (<https://statutes.capitol.texas.gov/Docs/OC/htm/OC.53.htm>).

Signature Experiences in Computer Science

The Department of Computer Science offers experiential learning opportunities for undergraduate students in which they can gain real-world experiences while also learning about the broader impacts of their work within their fields of study. All undergraduate students have the option to participate in a Signature Experience. Students should contact the Undergraduate Advisor(s) of Record for the Computer Science or Software Engineering majors for a list of relevant signature experiences.

Degree-Specific Requirements

All program requirements should be unchanged from previous versions of the 2024-2026 Undergraduate Catalog. To confirm your degree requirements, you can visit DegreeWorks (<https://dworkswebprod.sis.utsa.edu/>) or consult your Advisor (<https://www.utsa.edu/advising/advisor/>).

All degree programs in the Department of Computer Science (p. 1) maintain the same Admission Policy and degree requirements, including UTeachSA and Signature Experience requirements, as the College of Sciences (<http://catalog.utsa.edu/undergraduate/sciences/>), in addition to any department or degree-specific requirements.

- B.S. Degree in Computer Science (p. 2)
 - Concentration in Cloud and Systems (p. 3)
 - Concentration in Cybersecurity (p.)
 - Concentration in Data Science (p.)
 - Concentration in Software Engineering (p.)
 - Cyber Operations Track (p. 4)
- B.A. Degree in Computer Science with Teaching Track (p. 6)
- B.S. Degree in Software Engineering (p. 7)

Bachelor of Science Degree in Computer Science

The Bachelor of Science (B.S.) Degree in Computer Science requires 120 credit hours (42 credit hours of university core, 42 credit hours of required CS courses, 30 credit hours of CS electives, and 6 credit hours of free electives). The B.S. degree in Computer Science includes formal concentrations in Cybersecurity, Cloud Computing and Systems, Software Engineering, and Data Science. Students can also pursue a track in Cyber Operations, which is designated by the National Security Agency as a Center of Academic Excellence in Cyber Operations (Fundamentals). Concentration requirements can be fulfilled within the standard requirements, and most students elect to complete at least one concentration.

A minimum number of 120 semester credit hours is required for the B.S. in Computer Science, including Core Curriculum requirements. At least 39 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.

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 1213 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/bachelorsdegreeregulations/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

Degree Requirements

Code	Title	Credit Hours
A. Required courses (this also satisfies the 3 hours of core curriculum requirement for Mathematics)		
CS 1083	Programming I for Computer Scientists	3
CS 2113	Fundamentals of Object-Oriented Programming	3
CS 2123	Data Structures	3
CS 2233	Discrete Mathematical Structures	3
CS 2713	Computer Programming in C	3
CS 3333	Mathematical Foundations of Computer Science	3
CS 3343	Design and Analysis of Algorithms	3
CS 3423	Systems Programming	3
CS 3443	Application Programming	3
CS 3733	Operating Systems	3
CS 3843	Computer Organization	3
CS 3853	Computer Architecture	3
MAT 1213	Calculus I (The student who is not prepared for MAT 1213 must take MAT 1093 Precalculus)	3
MAT 1223	Calculus II	3
MAT 2253	Applied Linear Algebra	3

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 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:

Code	Title	Credit Hours
CS 4843	Cloud Computing	3
plus three additional courses selected from the following (an elective can only be counted toward one concentration):		
CS 3873	Computer Networks	
CS 4243	Large-Scale Data Management	
CS 4633	Simulation Techniques	
CS 4663	Distributed and Cloud Systems Security	
CS 4713	Compiler Construction	
CS 4823	Parallel Programming	
CS 4833	Embedded Systems	
CS 4853	Advanced Systems Programming	
CS 4863	Distributed Computing and Systems	
CS 4963	Advanced Topics in Systems and Cloud	
Total Credit Hours		12

Concentration in Cybersecurity

Students may declare a Concentration in Cybersecurity after completing CS 2123 with a grade of "C-" or better. All candidates for the Concentration in Cybersecurity 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:

Code	Title	Credit Hours
CS 3113	Principles of Cybersecurity	3
plus three additional courses selected from the following (an elective can only be counted toward one concentration):		
CS 3433	Computer and Information Security	
CS 4353	Unix and Network Security	
CS 4363	Cryptography	
CS 4453	Penetration Testing	
CS 4463	Steganography	
CS 4473	Cryptocurrencies and Bitcoins	
CS 4483	Cyber Security Foundations and Practice	
CS 4493	Advanced Topics in Cyber Security	
CS 4643	Mobile and Wireless Network and 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	
Total Credit Hours		12

Concentration in Data Science

Students may declare a Concentration in Data Science after completing CS 3343 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 courses:

Code	Title	Credit Hours
CS 3743	Database Systems	3
CS 3753	Data Science	3
plus two additional courses selected from the following (an elective can only be counted toward one concentration):		
CS 3793	Artificial Intelligence	
CS 4223	Bioinformatics I: Algorithms for Biological Data	
CS 4233	Bioinformatics II: Statistical Learning for Biological Data	
CS 4243	Large-Scale Data Management	
CS 4253	Machine Learning	
CS 4263	Deep Learning	
CS 4303	Introduction to Optimization	
CS 4333	Probability and Computing	
CS 4373	Data Mining	
CS 4973	Advanced Topics in Data Science	
Total Credit Hours		12

Concentration in Software Engineering

Students may declare a Concentration in Software Engineering after completing CS 3443 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:

Code	Title	Credit Hours
CS 3773	Software Engineering	3
plus two additional courses selected from the following (an elective can only be counted toward one concentration):		
CS 3723	Programming Languages	
CS 4113	Software Architecture and Design	
CS 4123	Software Maintenance and Evolution	
CS 4143	Software Modeling and Analysis	
CS 4393	User Interfaces	
CS 4413	Web Technologies	
CS 4613	Project Management and Senior Design I	
CS 4623	Project Management and Senior Design II	
CS 4683	Secure Software Development and Analysis	
CS 4723	Software Validation and Quality Assurance	
CS 4743	Enterprise Software Engineering	
CS 4773	Object-Oriented Design Patterns	
CS 4783	Advanced Software Engineering	
Total Credit Hours		9

Program Requirements for Cyber Operations Track

Cyber Operations (CO) Track is a program option for students in the current B.S. in Computer Science degree. Students graduating with this option will have Cyber Operations Track indicated as part of their B.S. in Computer Science degree. The objective of the Cyber Operations Track is to provide rigorous curriculum in Cybersecurity with a focus on offensive cyber operations, while balancing theoretical foundations and experiential learning.

All candidates for the Cyber Operations Track must fulfill the Core Curriculum requirements, the Computer Science degree requirements except CS 3853, which is available as an elective for this track, and the following courses:

Code	Title	Credit Hours
A. Required courses (this also satisfies the 3 hours of core curriculum requirement for Mathematics)		
CS 1083	Programming I for Computer Scientists	3
CS 2113	Fundamentals of Object-Oriented Programming	3
CS 2123	Data Structures	3
CS 2233	Discrete Mathematical Structures	3
CS 2713	Computer Programming in C	3
CS 3333	Mathematical Foundations of Computer Science	3
CS 3343	Design and Analysis of Algorithms	3
CS 3423	Systems Programming	3
CS 3443	Application Programming	3
CS 3733	Operating Systems	3
CS 3843	Computer Organization	3
MAT 1213	Calculus I (The student who is not prepared for MAT 1213 must take MAT 1093 Precalculus.)	3
MAT 1223	Calculus II	3
MAT 2253	Applied Linear Algebra	3
B. Required courses for Cyber Operations Track		
CS 3113	Principles of Cybersecurity	3
CS 3433	Computer and Information Security	3
CS 3873	Computer Networks	3
CS 4353	Unix and Network Security	3
CS 4363	Cryptography	3
CS 4643	Mobile and Wireless Network and Technologies	3
CS 4653	Software and Malware Reverse Engineering	3
CS 4663	Distributed and Cloud Systems Security	3
CS 4683	Secure Software Development and Analysis	3
C. Electives		12
Choose four of the following:		
CS 3853	Computer Architecture (recommended)	
CS 4673	Cyber Operations (recommended)	
CS 4853	Advanced Systems Programming (recommended)	
IS 4523	Digital Forensic Analysis II (recommended, from Information Systems and Cybersecurity program in College of Business)	

Or any other CS upper division electives.

Total Credit Hours

81

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

This course sequence guide is designed to assist students in completing their B.S. Degree in Computer Science. *This course sequence is only 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 (no track) – Recommended Four-Year Academic Plan

First Year

		Credit Hours
AIS 1243	AIS: Engineering, Mathematics, and Sciences	3
CS 1083	Programming I for Computer Scientists	3
MAT 1213	Calculus I	3
WRC 1013	Freshman Composition I (core)	3
Creative Arts (core)		3
Credit Hours		15

Spring

WRC 1023	Freshman Composition II	3
CS 2113	Fundamentals of Object-Oriented Programming	3
CS 2233	Discrete Mathematical Structures	3
MAT 1223	Calculus II	3
POL 1133 or POL 1213	Texas Politics and Society (core) or Civil Rights in Texas and America	3
Credit Hours		15

Second Year

Fall

CS 3333	Mathematical Foundations of Computer Science	3
CS 2123	Data Structures	3
CS 2713	Computer Programming in C	3
POL 1013	Introduction to American Politics (core)	3
Life & Physical Sciences (core)		3
Credit Hours		15

Spring

CS 3423	Systems Programming	3
CS 3443	Application Programming	3
CS 3843	Computer Organization	3
MAT 2253	Applied Linear Algebra	3
Social & Behavioral Sciences (core)		3
Credit Hours		15

Third Year**Fall**

CS 3343	Design and Analysis of Algorithms	3
Life & Physical Sciences (core)		3
Upper-division CS elective		3
Upper-division CS elective		3
Free Elective		3
Credit Hours		15

Spring

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

B.S. in Computer Science with Cyber Operations Track – Recommended Four-Year Academic Plan**First Year****Fall****Credit Hours**

AIS 1243	AIS: Engineering, Mathematics, and Sciences	3
CS 1083	Programming I for Computer Scientists	3
MAT 1213	Calculus I ((core and major))	3
WRC 1013	Freshman Composition I (core)	3
Life & Physical Sciences (core)		3
Credit Hours		15

Spring

MAT 1223	Calculus II	3
CS 2113	Fundamentals of Object-Oriented Programming	3
WRC 1023	Freshman Composition II (core)	3
Life & Physical Sciences (core)		3

Language, Philosophy & Culture (core)	3
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Credit Hours 15**Second Year****Fall**

CS 2123	Data Structures	3
CS 2233	Discrete Mathematical Structures	3
CS 2713	Computer Programming in C	3
CS 3333	Mathematical Foundations of Computer Science	3
Social & Behavioral Sciences (core)		3

Credit Hours 15**Spring**

CS 3113	Principles of Cybersecurity	3
CS 3443	Application Programming	3
CS 3423	Systems Programming	3
CS 3843	Computer Organization	3
MAT 2253	Applied Linear Algebra	3

Credit Hours 15**Third Year****Fall**

CS 3343	Design and Analysis of Algorithms	3
CS 3433	Computer and Information Security	3
CS 3733	Operating Systems	3
CS 3873	Computer Networks	3
American History (core)		3

Credit Hours 15**Spring**

CS 4353	Unix and Network Security	3
CS 4363	Cryptography	3
American History (core)		3
Upper-division CS elective (see recommended courses in degree requirements)		3
Upper-division CS elective (see recommended courses in degree requirements)		3

Credit Hours 15**Fourth Year****Fall**

CS 4643	Mobile and Wireless Network and Technologies	3
CS 4653	Software and Malware Reverse Engineering	3
CS 4663	Distributed and Cloud Systems Security	3
Creative Arts (core)		3
Government-Political Science (core)		3

Credit Hours 15**Spring**

CS 4683	Secure Software Development and Analysis	3
Upper-division CS elective (see recommended courses in degree requirements)		3
Upper-division CS elective (see recommended courses in degree requirements)		3

Component Area Option (core)	3
Government-Political Science (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.

Bachelor of Arts Degree in Computer Science with Teaching Track

The Bachelor of Arts (B.A.) Degree in Computer Science with Teaching Track is an interdisciplinary program and requires 120 credit hours (42 credit hours of university core, 39 credit hours of required CS courses, 12 credit hours of CS electives, and 30 credit hours of UTeachSA education courses). This program integrates a cohesive set of fundamental computer science courses and the UTeachSA program in pedagogy and clinical teaching, enabling students to gain a solid CS foundation and a teaching certification in CS, thus preparing students for successful careers in secondary school education, as well as in industry and government sectors. Students are encouraged to have an internship or research experience.

A minimum number of 120 semester credit hours is required for the B.A. in Computer Science with Teaching Track, including Core Curriculum requirements. At least 39 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.

Core Curriculum Requirements (42 semester credit hours)

Students seeking the B.A. degree in Computer Science with Teaching Track 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 1213 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/bachelorsdegreeregulations/degree requirements/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

Course Sequence Guide for B.A. Degree in Computer Science with Teaching Track

This course sequence guide is designed to assist students in completing their B.A. Degree in Computer Science with Teaching Track. *This course sequence is only 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.A. in Computer Science with Teaching Track - Recommended Four-Year Academic Plan

First Year

Fall		Credit Hours
AIS 1243	AIS: Engineering, Mathematics, and Sciences	3
CS 1083	Programming I for Computer Scientists	3
WRC 1013	Freshman Composition I (core)	3
MAT 1213	Calculus I (core and major)	3
UTE 1111	Introduction to STEM Teaching Step 1	1
Credit Hours		13

Spring

CS 2113	Fundamentals of Object-Oriented Programming	3
POL 1133 or POL 1213	Texas Politics and Society (core) or Civil Rights in Texas and America	3
WRC 1023	Freshman Composition II (core)	3
UTE 1122	Introduction to STEM Teaching Step 2	2
MAT 1223	Calculus II	3
Life & Physical Sciences (core)		3
Credit Hours		17

Second Year

Fall

CS 2123	Data Structures	3
CS 2233	Discrete Mathematical Structures	3
CS 2713	Computer Programming in C	3
POL 1013	Introduction to American Politics (core)	3
UTE 3203	Knowing and Learning in Mathematics and Science	3
Credit Hours		15

Spring

CS 3333	Mathematical Foundations of Computer Science	3
CS 3443	Application Programming	3
UTE 3023	Perspectives on Science and Mathematics	3
Life & Physical Sciences (core)		3
Social & Behavioral Sciences (core)		3

MAT 2253	Applied Linear Algebra	3
Credit Hours		18
Third Year		
Fall		
CS 3423	Systems Programming	3
CS 3843	Computer Organization	3
ESL 3083	Second Language Teaching and Learning for Grades 7-12	3
Component Area Option (core)		3
Creative Arts (core)		3
Credit Hours		15
Spring		
CS 3343	Design and Analysis of Algorithms	3
SPE 3603	Introduction to Special Education	3
UTE 3213	Classroom Interactions	3
American History (core)		3
Language, Philosophy & Culture (core)		3
Credit Hours		15
Fourth Year		
Fall		
LTED 3773	Reading and Writing Across the Disciplines-Grades 7-12	3
UTE 4203	Project-Based Instruction	3
Upper-division CS elective		3
Upper-division CS elective		3
American History (core)		3
Credit Hours		15
Spring		
UTE 4646	Clinical Teaching	6
Upper-division CS elective		3
Upper-division CS elective		3
Credit Hours		12
Total Credit Hours		120

Bachelor of Science Degree in Software Engineering

The Bachelor of Science (B.S.) in Software Engineering provides a pathway for students who are mainly interested in developing software systems and/or pursuing advanced degrees or certifications in software engineering.

A minimum number of 120 semester credit hours is required for the B.S. in Software Engineering, including Core Curriculum requirements. At least 39 of the total semester credit hours required for the degree must be at the upper-division level.

All major and support work courses and the required prerequisites must be completed with a grade of "C-" or better.

Core Curriculum Requirements (42 semester credit hours)

Students seeking the B.S. Degree in Software Engineering must fulfill University Core Curriculum requirements in the same manner as other students. If courses are taken to satisfy both degree requirements and Core Curriculum requirements, then students may need to take additional

courses to meet the minimum number of semester credit hours required for this degree.

MAT 1073, MAT 1093, or MAT 1213 may be used to satisfy the core requirement in Mathematics as well as a major requirement.

The following courses are recommended to satisfy 6 credits for the core curriculum requirements.

EGR 1343 may be used to satisfy the core requirement in Social and Behavioral Sciences.

EGR 1403, ENG 2413, or PHI 2043 may be used to satisfy the core requirement in the Component Area Option.

Core Curriculum Component Area Requirements (<http://catalog.utsa.edu/undergraduate/bachelorsdegreeregulations/degree/requirements/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

Degree Requirements

A. Required Foundational Courses

CS 1083	Programming I for Computer Scientists	3
CS 2113	Fundamentals of Object-Oriented Programming	3
CS 2123	Data Structures	3
CS 2233	Discrete Mathematical Structures	3
CS 2713	Computer Programming in C	3
CS 3333	Mathematical Foundations of Computer Science	3
CS 3343	Design and Analysis of Algorithms	3
CS 3423	Systems Programming	3
CS 3443	Application Programming	3
CS 3733	Operating Systems	3
CS 3843	Computer Organization	3
MAT 1073	Algebra for Scientists and Engineers (core or major) ¹	3
MAT 1093	Precalculus (core or major) ¹	3
MAT 1213	Calculus I (core or major)	3
MAT 2253	Applied Linear Algebra	3

B. Required Upper-Division Courses

CS 3743	Database Systems	3
CS 3773	Software Engineering	3
CS 4393	User Interfaces	3
CS 4413	Web Technologies	3
CS 4743	Enterprise Software Engineering	3
or CS 4783	Advanced Software Engineering	

C. Upper-Division Support Courses (Software Engineering Electives) 6

Select any two upper-division Computer Science (CS) courses to fulfill this elective requirement. The following courses are recommended:

CS 3783	Software Requirements Engineering
CS 4113	Software Architecture and Design
CS 4123	Software Maintenance and Evolution
CS 4143	Software Modeling and Analysis
CS 4683	Secure Software Development and Analysis
CS 4723	Software Validation and Quality Assurance
CS 4773	Object-Oriented Design Patterns

D. Experiential Learning

CS 4613	Project Management and Senior Design I	3
Students may select one additional course from the following:		
CS 4623	Project Management and Senior Design II ²	3
CS 4913	Independent Study	
CS 4923	Undergraduate Research	
CS 4933	Internship in Computer Science ³	
CS 4883	Senior Thesis I	

E. Free Electives 6-12

Students must select enough free electives (usually 6-12) to reach the minimum of 120 hours required for the degree. A maximum of 12 semester credit hours from a combination of Internship, Independent Study, Undergraduate Research, Senior Design, and Senior Thesis courses can be applied toward the Bachelor of Science degree in Software Engineering.

Recommended courses for fulfilling the Free Electives:

MAT 1223	Calculus II ⁴
The following courses are recommended if CS 4623 was taken to fulfill Experiential Learning credit.	
CS 4913	Independent Study
CS 4923	Undergraduate Research
CS 4933	Internship in Computer Science ³
CS 4883	Senior Thesis I

Total Credit Hours 81

¹ Students who pass the ALEKS Math Placement Exam may substitute MAT 1073 and/or MAT 1093 with free elective courses.

² Students are strongly encouraged to take CS 4623 Project Management and Senior Design II to form a two-semester capstone sequence.

³ Only 3 credits of internship may apply to this degree.

⁴ Per the U.S. Office of Personnel Management's Computer Science Series 1550 document (<https://www.opm.gov/policy-data-oversight/classification-qualifications/general-schedule-qualification-standards/1500/computer-science-series-1550/>), Computer Science bachelor's degree holders must have at least 15 credit hours with "any combination of statistics and mathematics that included differential and integral calculus." Therefore, students who wish to pursue 1550 Series jobs are advised to take MAT 1223 Calculus II as an elective.

Course Sequence Guides for B.S. Degree in Software Engineering

This course sequence guide is designed to assist students in completing their B.S. Degree in Software Engineering. *This course sequence is only 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 Software Engineering – Recommended Four-Year Academic Plan

First Year

Fall		Credit Hours
AIS 1243	AIS: Engineering, Mathematics, and Sciences (core)	3
MAT 1073	Algebra for Scientists and Engineers (core or major) ¹	3
POL 1133 or POL 1213	Texas Politics and Society (core) or Civil Rights in Texas and America	3
WRC 1013	Freshman Composition I (core)	3
Language, Philosophy & Culture (core)		3
Credit Hours		15

Spring

CS 1083	Programming I for Computer Scientists	3
EGR 1343	The Impact of Modern Technologies on Society (core)	3
MAT 1093	Precalculus ¹	3
WRC 1023	Freshman Composition II	3
Life & Physical Sciences (core)		3
Credit Hours		15

Second Year**Fall**

CS 2113	Fundamentals of Object-Oriented Programming	3
CS 2233	Discrete Mathematical Structures	3
POL 1013	Introduction to American Politics	3
Life & Physical Sciences (core)		3
American History (core)		3
Credit Hours		15

Spring

CS 2123	Data Structures	3
CS 2713	Computer Programming in C	3
EGR 1403 or ENG 2413 or PHI 2043	Technical Communication (core) or Technical Writing or Introductory Logic	3
MAT 1213	Calculus I	3
Creative Arts (core)		3
Credit Hours		15

Third Year**Fall**

CS 3333	Mathematical Foundations of Computer Science	3
CS 3423	Systems Programming	3
CS 3443	Application Programming	3
CS 3843	Computer Organization	3

MAT 2253	Applied Linear Algebra	3
Credit Hours		15
Spring		
CS 3743	Database Systems	3
CS 3773	Software Engineering	3
CS 3733	Operating Systems	3
CS 3343	Design and Analysis of Algorithms	3
American History (core)		3
Credit Hours		15
Fourth Year		
Fall		
CS 4413	Web Technologies	3
CS 4613	Project Management and Senior Design I	3
Software Engineering Elective		3
Free Elective		3
Free Elective		3
Credit Hours		15
Spring		
CS 4743 or CS 4783	Enterprise Software Engineering or Advanced Software Engineering	3
CS 4393	User Interfaces	3
Software Engineering Elective		3
Experiential Learning Course		3
Free Elective		3
Credit Hours		15
Total Credit Hours		120

¹ Students who pass the ALEKS Math Placement Exam may substitute MAT 1073 and/or MAT 1093 with free elective courses.

² Students are strongly encouraged to take CS 4623 Project Management and Senior Design I to form a two-semester capstone sequence.

³ Only 3 credits of internship may apply to this degree.

⁴ Per the U.S. Office of Personnel Management's Computer Science Series 1550 document (<https://www.opm.gov/policy-data-oversight/classification-qualifications/general-schedule-qualification-standards/1500/computer-science-series-1550/>), Computer Science bachelor's degree holders must have at least 15 credit hours with "any combination of statistics and mathematics that included differential and integral calculus." Therefore, students who wish to pursue 1550 Series jobs are advised to take MAT 1223 Calculus II as an elective.

Minor in Computer Science

All students pursuing the Minor in Computer Science must complete 18 semester credit hours. The purpose of the minor in Computer Science is to provide students with strong computational thinking and software development skills that can help them solve problems from their major program of study and better collaborate with interdisciplinary teams when working on computationally-intensive projects.

All required and elective courses must be completed with a grade of "C-" or better.

Code	Title	Credit Hours
A. Required courses		
CS 1083	Programming I for Computer Scientists	3
CS 2113	Fundamentals of Object-Oriented Programming	3
CS 2123	Data Structures	3
CS 2713	Computer Programming in C	3
B. CS core courses or approved CS electives		
Select 6 hours of additional CS core courses or approved CS electives, at least 3 hours of which must be at the upper-division level. The "CS electives" should be organized CS courses other than internship or independent study.		6
Total Credit Hours		18

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

Computer Science (CS) Courses

CS 1063. Introduction to Computer Programming I. (3-0) 3 Credit Hours.

Prerequisite: Completion of or concurrent enrollment in 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 Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60; DL01 \$75.

CS 1083. Programming I for Computer Scientists. (3-0) 3 Credit Hours. (TCCN = COSC 1336)

Prerequisite: Completion of or concurrent enrollment in MAT 1073 or the equivalent. An introduction to computer programming emphasizing structured programming, problem-solving, and algorithmic thinking. Topics include assignments, decisions, loops, methods, and arrays. Students intending to major or minor in Computer Science should take this course instead of CS 1063. Generally offered: Fall, Spring, Summer. Course Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60; DL01 \$75.

CS 1153. Game Programming. (3-0) 3 Credit Hours.

Prerequisite: Computer literacy. Introduction to game design and programming. Common practices used in the video game industry today will also be introduced. Students will learn the basics of creating a PC game through lecture material, hands-on laboratories, and a final project in which the students will build a simple game. Generally offered: Fall. Course Fees: IUCS \$45; LRS1 \$46.20; STSI \$21.60.

CS 1173. Data Analysis and Visualization. (3-0) 3 Credit Hours.

Prerequisite: MAT 1023. Introduction to computation for 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 Mathematics Core Curriculum requirement. (Formerly titled "Computation for Scientists and Engineers.") Generally offered: Fall, Spring, Summer. Course Fee: DL01 \$75; IUCS \$45; LRC1 \$12; LRS1 \$46.20; STSI \$21.60.

CS 2073. Computer Programming with Engineering Applications. (3-0) 3 Credit Hours. (TCCN = ENGR 2304)

Prerequisite: MAT 1213 (or MAT 1214 in previous catalogs), and completion of or concurrent enrollment in MAT 1223 (or MAT 1224 in previous catalogs). 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. Course Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60.

CS 2113. Fundamentals of Object-Oriented Programming. (3-0) 3 Credit Hours. (TCCN = COSC 1337)

Prerequisite: CS 1083. Extended programming concepts, including multidimensional arrays, file input/output, and recursion. Applies the object-oriented programming paradigm, focusing on the definition and use of classes along with the fundamentals of object-oriented design. Includes basic analysis of algorithms, searching and sorting techniques, and an introduction to software engineering. Course Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60; DL01 \$75.

CS 2123. Data Structures. (3-0) 3 Credit Hours. (TCCN = COSC 2336)

Prerequisite: CS 2113. 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. The course includes 3 hours of lecture per week. (Formerly CS 1723 and CS 2124. Credit can only be earned for one of the following courses: #CS 2124, CS 1723, or CS 2123.) Generally offered: Fall, Spring, Summer. Course Fee: LRS1 \$46.20; STSI \$21.60; DL01 \$75; IUCS \$45.

CS 2233. Discrete Mathematical Structures. (3-0) 3 Credit Hours. (TCCN = MATH 2305)

Prerequisites: MAT 1093 and one of the following: CS 1083, CS 1063, CS 2073, CPE 2073. Survey and development of theoretical tools suitable for describing algorithmic applications. Propositional and predicate calculus, proofs, induction, order notation, recurrences, and discrete structures. (Formerly CS 3233. Credit cannot be earned for both CS 2233 and CS 3233.) Generally offered: Fall, Spring. Course Fees: IUCS \$45; LRS1 \$46.20; STSI \$21.60; DL01 \$75.

CS 2713. Computer Programming in C. (3-0) 3 Credit Hours.

Prerequisite: CS 2113. Extended programming concepts, including multidimensional arrays, pointers, dynamic memory allocation/deallocation, and recursion. Problem-solving methods, algorithm development, and implementation. The course includes 3 hours of lecture per week. (Formerly CS 1714 and CS 1713. Credit can only be earned for one of the following: CS 2713, #CS#1714, #or CS 1713.) Generally offered: Fall, Spring, Summer. Course Fee: LRS1 \$46.20; STSI \$21; DL01 \$75; IUCS \$45.

CS 3113. Principles of Cybersecurity. (3-0) 3 Credit Hours.

Prerequisite: CS 2713 and completion of or concurrent enrollment in CS 2123. An introductory course in Cybersecurity, including an examination of the fundamental principles underlying cybersecurity, 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.) Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3333. Mathematical Foundations of Computer Science. (3-0) 3 Credit Hours.

Prerequisite: CS 2233 and MAT 1213 (or MAT 1214 in previous catalogs). Survey and development of mathematical and statistical tools suitable for describing algorithmic applications. Probability, statistical models, number theory, and combinatorics. Generally offered: Fall, Spring, Summer. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3343. Design and Analysis of Algorithms. (3-0) 3 Credit Hours.

Prerequisite: 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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3423. Systems Programming. (3-0) 3 Credit Hours.

Prerequisite: CS 2123 and CS 2713. 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. The course includes 3 hours of lecture per week. (Formerly CS 2413 and CS 3424. Credit can only be earned for one of the following courses: #CS 3424, CS 2413, and CS 3423.) Generally offered: Fall, Spring, Summer. This course has Differential Tuition. Course Fee: DL01 \$75; IUCS \$45.

CS 3433. Computer and Information Security. (3-0) 3 Credit Hours.

Prerequisite: CS 3423 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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

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

Prerequisite: CS 2123. Advanced application development in a current object-oriented language. Introduction to the software life cycle, best programming practices, and modern development tools. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3523. Windows Systems Programming. (3-0) 3 Credit Hours.

Prerequisite: CS 2123 and CS 2713. A study of systems-level programming in the Windows Operating System. Focus on concepts and tools to support the construction of Windows systems programs. Learn and use tools like Powershell, Python, and command prompt. Understand in detail how the registry works, how to audit and log system changes, how to create new users, how to manipulate access control lists, etc. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3723. Programming Languages. (3-0) 3 Credit Hours.

Prerequisite: CS 2713, 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, scoping and activation records, control structures, and data abstraction. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3733. Operating Systems. (3-0) 3 Credit Hours.

Prerequisite: CS 3423, CS 3443, and CS 3843 (formerly CS 3844).
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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3743. Database Systems. (3-0) 3 Credit Hours.

Prerequisite: CS 2123 and CS 2233. 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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3753. Data Science. (3-0) 3 Credit Hours.

Prerequisite: CS 2123 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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3783. Software Requirements Engineering. (3-0) 3 Credit Hours.

Prerequisite: CS 3443. This course covers the process of eliciting, analyzing, specifying, validating, and managing software requirements. It introduces techniques to capture user stories, requirements traceability, and requirements process management to accurately capture and manage requirements to ensure meeting the needs of stakeholders. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 3793. Artificial Intelligence. (3-0) 3 Credit Hours.

Prerequisite: CS 3753 and MAT 2253. This course covers the construction of programs that use knowledge representation and reasoning to solve problems. Major topics include informed search, logical and probabilistic inference, machine learning, planning, and natural language processing. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 3843. Computer Organization. (3-0) 3 Credit Hours.

Prerequisite: CS 2713 or equivalent. 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 and CS 3844. Credit can only be earned for one of the following: CS 2733, CS 3844, or CS 3843.) Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3853. Computer Architecture. (3-0) 3 Credit Hours.

Prerequisite: CS 3843 and CS 2123. 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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 3873. Computer Networks. (3-0) 3 Credit Hours.

Prerequisite: CS 3423 and CS 3443. 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. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 4013. Fundamentals of Software. (3-0) 3 Credit Hours.

Prerequisite: Consent of instructor. This course is a bridge course for non-Computer Science students. It cannot be applied to the undergraduate degrees in computer science. Topics include discrete math; advanced data structure and basic algorithms, such as binary tree and stack; system programming basics; and concepts of compilation. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4023. Fundamentals of Systems. (3-0) 3 Credit Hours.

Prerequisite: Consent of instructor. This course is a bridge course for non-Computer Science students. It cannot be applied to the undergraduate degrees in computer science. Topics include basic concepts and knowledge in computer organization, architecture, operating systems, and compilers. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fees: IUCS \$45.

CS 4113. Software Architecture and Design. (3-0) 3 Credit Hours.

Prerequisite: CS 3773. This course introduces software architecture and design concepts and practices. Topics covered in this course include software design principles, software architecture design styles, software design patterns, etc. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4123. Software Maintenance and Evolution. (3-0) 3 Credit Hours.

Prerequisite: CS 4113. This course covers the principles and techniques of software maintenance and evolution. It will introduce topics on software maintainability, evolvability, and release planning. It also explores the best practices and tools for software maintenance, such as reverse engineering, refactoring, and measurement. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4143. Software Modeling and Analysis. (3-0) 3 Credit Hours.

Prerequisite: CS 3773 and CS 3343. This course covers various techniques for modeling and analyzing software systems. The course introduces students to the topics of software modeling, static analysis, and dynamic analysis to ensure the quality of software systems. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4223. Bioinformatics I: Algorithms for Biological Data. (3-0) 3 Credit Hours.

Prerequisite: CS 3343. Study of algorithmic techniques in modeling and analyzing large-scale biological data such as biological sequences, gene expression, and biological networks. Topics include, but are not limited to, dynamic programming and string pre-processing for sequence comparison, heuristic search algorithms for pattern discovery, and graph algorithms for biological network analysis. Some fundamental concepts of molecular biology will also be introduced. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4233. Bioinformatics II: Statistical Learning for Biological Data. (3-0) 3 Credit Hours.

Prerequisites: CS 3753 or CS 4223. Study of statistical techniques in modeling and analyzing large-scale biological data with emphasis on integrating information and tools from publicly available biological databases to address complex problems. Topics include, but are not limited to, statistical significance testing, clustering, classification, and dimension reduction. Basic biological concepts related to the applications will also be covered. Generally offered: Spring. This course has Differential Tuition. Course Fees: IUCS \$45.

CS 4243. Large-Scale Data Management. (3-0) 3 Credit Hours.

Prerequisite: CS 3423. This course presents an introduction to research and enterprise data management. Students will learn about scalable approaches to managing large-scale datasets. Application of High-Performance Computing, High-Throughput Computing, and AI for managing large-scale datasets will be covered. An overview of the SQL and NoSQL database management systems will also be included. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 4253. Machine Learning. (3-0) 3 Credit Hours.

Prerequisite: CS 3793. Study of fundamental concepts and methods of machine learning. Topics include unsupervised learning, supervised learning, reinforcement learning, and other advanced topics selected by the instructor. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4263. Deep Learning. (3-0) 3 Credit Hours.

Prerequisite: CS 3793. Study of advanced techniques for learning models. Algorithmic and hands-on introduction to deep neural networks and adversarial learning. Topics include convolutional models, generative networks, neural network vulnerabilities, and attention models, with applications in natural language understanding and computer vision. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4303. Introduction to Optimization. (3-0) 3 Credit Hours.

Prerequisite: MAT 2213 (or MAT 2214 in previous catalogs) and MAT 2233, or EGR 3323, or MAT 1223 (or MAT 1224 in previous catalogs) and CS 3333. May include Discrete, Continuous, Linear, and non-Linear optimization. Optimality conditions, Lagrange multipliers, duality theory. Applications of linear programming in computer science and discrete optimization. Gradient descent and Newton iteration (i.e., RST and second order methods), trust region methods, and conjugate gradient. Applications of RST and second order methods to engineering. (Same as MAT 4343. Credit cannot be earned for both CS 4303 and MAT 4343.) Generally offered in Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

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. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4333. Probability and Computing. (3-0) 3 Credit Hours.

Prerequisites: CS 3333 or MAT 2313. May include moments of random variables: randomized mincut algorithm, Chebyshev and Markov inequalities, sampling estimator for mean. Basic Concentration Inequalities: Chernoff and Hoeffding inequalities; parameter estimation and set balancing. Discrete probabilistic structures: Bucket sort algorithm, Poisson approximation, Lovasz local Lemma, independent set search. The Gaussian: Moment Generating Functions, Central Limit Theorem, JL dimensionality reduction lemma. Markov Chains and Random Walks: Stationary Distributions, and randomized 3-SAT algorithm, Entropy Function: Information and Compression. (Cross-listed with MAT 4333. Credit cannot be earned for both CS 4333 and MAT 4333.) Generally offered in Springs. This course has Differential Tuition. Course fees: IUCS \$45.

CS 4353. 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. This course has Differential Tuition. Course Fee: IUCS \$45.

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. Generally offered: Spring. This course has Differential Tuition. Course Fees: IUCS \$45; DL01 \$75.

CS 4373. Data Mining. (3-0) 3 Credit Hours.

Prerequisites: CS 3343 and CS 3753. 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. Generally offered: Fall. This course has Differential Tuition. Course Fees: IUCS \$45.

CS 4383. Computer Graphics. (3-0) 3 Credit Hours.

Prerequisite: CS 2713, CS 3343, and MAT 2253. 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. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

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

Prerequisite: CS 3443. Study of advanced user interface issues. User interface design, human factors, usability, GUI programming models, and the psychological aspects of human-computer interaction. Generally offered: Fall. This course has Differential Tuition. Course Fees: IUCS \$45; DL01 \$75.

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

Prerequisite: CS 3423 and CS 3743. Fundamentals of Web and component technology: markup languages, layout design, client and server side programming, database, and Web integration. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fees: IUCS \$45; DL01 \$75.

CS 4453. Penetration Testing. (3-0) 3 Credit Hours.

Prerequisite: CS 3873. Introduction to the principles and techniques associated with the cyber security practice known as penetration testing or ethical hacking. The course covers planning, reconnaissance, scanning, exploitation, post-exploitation, and result reporting. Students learn how to use penetration testing tools, how to discover system vulnerabilities, and how to avoid exploitation of vulnerabilities. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4463. Steganography. (3-0) 3 Credit Hours.

Prerequisite: CS 3423. Steganography literally means "covered writing" and is the science of hiding secret data within innocuous data. This course covers a broad set of background topics including data compression, encryption, hashing, number theory, and human perception. Then we delve into the aspects and techniques for data hiding using image and audio files for data hiding. This includes bitmaps, jpegs, and wave files. We also explore steganalysis—the detection of hidden data—in the various file types. We also discuss the use of steganography in practice, particularly use by malware. There is a course project where a team of students develop and test their own steganography program. Generally offered: Spring, Summer. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 4473. Cryptocurrencies and Bitcoins. (3-0) 3 Credit Hours.

Prerequisite: CS 3113. This course introduces the concept of public permission-less blockchains and discusses the various applications that it enables. It specifically focuses on the cryptocurrency application of such distributed systems, with an emphasis on Bitcoins. This course will cover the following topics: blockchain fundamentals, operation of the Bitcoin cryptocurrency, Bitcoin security, user privacy and anonymity in Bitcoin, Bitcoin as a distributed application platform, Bitcoin and cryptocurrency regulation, future of Bitcoins and cryptocurrencies, Ethereum and Smart Contracts. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4483. Cyber Security Foundations and Practice. (3-0) 3 Credit Hours.

Prerequisite: CS 3113. Advanced study of fundamental cyber security and privacy technologies and their applications in modern and emerging cyber systems such as social media, cloud computing, internet of things, cyber-physical systems, and cryptocurrencies. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4493. Advanced Topics in Cyber Security. (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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

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. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4613. Project Management and Senior Design I. (3-0) 3 Credit Hours.

Prerequisite: CS 3443 and CS 3773. Students will self-organize into teams, prepare/propose project scope, gather requirements, produce specifications, analyze security and other risk factors, and present their designs. Industrial collaboration and/or faculty sponsorship of these projects is encouraged. Not more than a total of 6 semester credit hours of Internship, Independent Study, Senior Design, and Senior Thesis courses may count toward the Bachelor of Science degree in Computer Science. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4623. Project Management and Senior Design II. (3-0) 3 Credit Hours.

Prerequisite: CS 4613. Students continue the development of an instructor-approved design project, testing of the design project, and present their findings, along with social and ethical impact considerations. Students who own their intellectual property are required to compete in CITE. Industrial collaboration and/or faculty sponsorship of these projects is encouraged. Not more than a total of 6 semester credit hours of Internship, Independent Study, Senior Design, and Senior Thesis courses may count toward the Bachelor of Science degree in Computer Science. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

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. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4643. Mobile and Wireless Network and Technologies. (3-0) 3 Credit Hours.

Prerequisite: CS 3873 or consent of instructor. Introduces the latest mobile and wireless networking technologies and network software architectures as well as the application of IoT fundamentals for mobile/wireless computing systems. Students will be able to describe user associations and traffic routing in a mobile/wireless network, interaction of elements within the mobile/wireless core, and end-to-end delivery of a packet and/or signal and what happens with the hand-off at each step along the communications path. They will be able to explain architecture differences between different generations of mobile/wireless network technologies and design and build a mobile/wireless IoT application from ground up to demonstrate their understandings. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 4653. Software and Malware Reverse Engineering. (3-0) 3 Credit Hours.

Prerequisite: CS 3843 (formerly CS 3844), and CS 3113 or CS 3433. An introduction to the basic procedures to reverse engineering of software, hardware and malware. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

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. This course has Differential Tuition. Course Fee: IUCS \$45.

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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fees: IUCS \$45; DL01 \$75.

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. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4713. Compiler Construction. (3-0) 3 Credit Hours.

Prerequisite: CS 3723 and CS 3843 (formerly CS 3844). 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."). Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

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. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4743. Enterprise Software Engineering. (3-0) 3 Credit Hours.

Prerequisite: CS 3773 and CS 4413. 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.") Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4773. Object-Oriented Design Patterns. (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. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4783. Advanced Software Engineering. (3-0) 3 Credit Hours.

Prerequisite: CS 3773 and CS 4413. This course covers modern software development technology. Students utilize Swagger and JavaScript or Python to build a database-enabled RESTful web service component. Using a DevOps pipeline, students test and deploy their project using tools like Gitlab, CI/CD, OWASP ZAP, Docker, and Kubernetes. Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4823. Parallel Programming. (3-0) 3 Credit Hours.

Prerequisite: CS 3423. Parallel programming concepts (partitioning, synchronization and communication, programming models-shared memory-based and message-based), programming tools and languages, performance issues. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75.

CS 4833. Embedded Systems. (3-0) 3 Credit Hours.

Prerequisite: CS 3843 (formerly CS 3844). 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. Generally offered: Fall. This course has Differential Tuition. Course Fee: IUCS \$45.

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. Generally offered: Fall, Spring, Summer. This course has Differential Tuition. Course Fee: IUCS \$45; DL01 \$75; STSE \$30.

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.") Generally offered: Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60.

CS 4883. Senior Thesis I. (3-0) 3 Credit Hours.

Prerequisite: Consent of Instructor. The student learns how to conduct independent research. The student selects a thesis topic, conducts a literature review, plans and executes an experiment, and gathers and analyzes data. Faculty sponsorship of the thesis is required, and a faculty member should agree to sponsor the student before Senior Thesis I begins. Not more than a total of 6 semester credit hours of Internship, Independent Study, Senior Design, and Senior Thesis courses may count toward the Bachelor of Science degree in Computer Science. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4893. Senior Thesis II. (3-0) 3 Credit Hours.

Prerequisite: Consent of Instructor. The student writes the thesis through a series of assignments. The student also prepares a presentation of their research and presents the thesis to the public during a Computer Science undergraduate research symposium. Faculty sponsorship of the thesis is required and should be the same faculty member from Thesis I (special exceptions are possible). Not more than a total of 6 semester credit hours of Internship, Independent Study, Senior Design, and Senior Thesis courses may count toward the Bachelor of Science degree in Computer Science. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4911. Independent Study. (0-0) 1 Credit Hour.

Prerequisite: Approval from the instructor, the Department Chair, and the Associate Dean of Undergraduate Studies in the College for which this course is offered; registration form available on the UTSA OneStop website. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but no more than 6 semester credit hours of Independent Study (CS 4911, CS 4912, CS 4913), Undergraduate Research (CS 4923), Senior Design (CS 4613, CS 4623), and Internship (CS 4933), regardless of discipline, will apply to a bachelor's degree. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$15.

CS 4912. Independent Study. (0-0) 2 Credit Hours.

Prerequisite: Approval from the instructor, the Department Chair, and the Associate Dean of Undergraduate Studies in the College for which this course is offered; registration form available on the UTSA OneStop website. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but no more than 6 semester credit hours of Independent Study (CS 4911, CS 4912, CS 4913), Undergraduate Research (CS 4923), Senior Designs (CS 4613, CS 4623), and Internship (CS 4933), regardless of discipline, will apply to a bachelor's degree. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$30.

CS 4913. Independent Study. (0-0) 3 Credit Hours.

Prerequisite: Approval from the instructor, the Department Chair, and the Associate Dean of Undergraduate Studies in the College for which this course is offered; the registration form is available on the UTSA OneStop website. 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 of Independent Study (CS 4911, CS 4912, CS 4913), Undergraduate Research (CS 4923), Senior Design (CS 4613, CS 4623), and Internship (CS 4933), regardless of discipline, will apply to a bachelor's degree. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4923. Undergraduate Research. (0-0) 3 Credit Hours.

Prerequisite: Restricted to students majoring in Computer Science. Approval from the instructor, the Department Chair, and the Associate Dean of Undergraduate Studies in the College for which this course is offered. This course should involve a laboratory and experimental and/or a theoretical problem. May be repeated for credit, but no more than 6 semester credit hours of Independent Study (CS 4911, CS 4912, CS 4913), Undergraduate Research (CS 4923), Senior Design (CS 4613, CS 4623), and Internship (CS 4933), regardless of discipline, will apply to a bachelor's degree. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4933. Internship in Computer Science. (0-0) 3 Credit Hours.

Prerequisite: Junior or Seniors with a 2.5+ Overall GPA, and approval from the employer, the instructor, the Department Chair, and the Associate Dean for Undergraduate Studies, registration form available on the College of Sciences website. The opportunity for a semester-long work experience in a private business or public agency in a computer science-related position. No more than 3 semester credit hours of CS 4933, and no more than 6 semester credit hours of Independent Study (CS 4911, CS 4912, CS 4913), Undergraduate Research (CS 4923), and Senior Design (CS 4613, CS 4623) may count toward the Bachelor of Science degree in Computer Science. Generally offered: Fall, Summer. This course has Differential Tuition. Course Fee: IUCS \$45.

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. This course has Differential Tuition. Course Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60.

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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45; LRS1 \$46.20; STSI \$21.60.

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. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.

CS 4993. Directed Research. (0-0) 3 Credit Hours.

Prerequisite: Approval from the instructor, the Department Chair, and the Associate Dean of Undergraduate Studies in the College for which this course is offered; form available on the College of Sciences website. Supervised research mentored by a faculty member engaged in active research within the student's designated area of concentration. Students may produce a thesis in addition to active research. May be repeated. This course can also be used for students pursuing the COS Undergraduate Thesis Option. Generally offered: Fall, Spring. This course has Differential Tuition. Course Fee: IUCS \$45.