

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, a Cyber Operations Track, a Bachelor of Arts degree in Computer Science with Teaching Track, 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

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

- Meet all UTSA undergraduate admission requirements,
- 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 (<https://future.utsa.edu/ready/calculus-ready/>) (or higher) ready

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

- Meet all UTSA undergraduate transfer admission requirements
- Are Calculus I (<https://future.utsa.edu/ready/calculus-ready/>) (or higher) ready

All applicants for admission to the Department of Computer Science must be qualified to take MAT 1214 Calculus I (or higher) and CS 1083 Programming I for Computer Scientists (or higher). Students who do not meet the requirements, but meet UTSA's general admission requirements, will be part of "Engineering, Mathematics, and Sciences Studies (XEMS)" where students will be able to work towards meeting the prerequisites needed to declare Computer Science as their major. Applicants who are not qualified should be admitted as an undeclared (UND) major.

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.

- B.S. Degree in Computer Science (p. 1)
- B.A. Degree in Computer Science with Teaching Track (p. 5)

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 department also offers the B.S. in Computer Science with a Cyber Operations Track.

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/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

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 1714	Computer Programming II	4
CS 2124	Data Structures	4

CS 4863	Distributed Computing and Systems	3
CS 4963	Advanced Topics in Systems and Cloud	3

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 1714	Computer Programming II	4
CS 2124	Data Structures	4
CS 2233	Discrete Mathematical Structures	3
CS 3333	Mathematical Foundations of Computer Science	3
CS 3343	Analysis of Algorithms	3
CS 3424	Systems Programming	4
CS 3443	Application Programming	3
CS 3723	Programming Languages	3
CS 3733	Operating Systems	3
CS 3743	Database Systems	3
CS 3844	Computer Organization	4
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 3424 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

Concentration in Cyber Security

Students may declare a Concentration in Cyber Security after completing CS 2124 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 4453	Penetration Testing	3
CS 4473	Cryptocurrencies and Bitcoins	3
CS 4493	Advanced Topics in Cyber Security	3
CS 4643	Cellular and Mobile Technologies	3
CS 4653	Software and Malware Reverse Engineering	3
CS 4663	Distributed and Cloud Systems Security	3
CS 4673	Cyber Operations	3
CS 4683	Secure Software Development and Analysis	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 4253	Machine Learning	3
CS 4263	Deep Learning	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 4413	Web Technologies	3
CS 4613	Senior Design I	3
CS 4623	Senior Design II	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

Degree Requirements for Cyber Operations Track

Cyber Operations (CO) Track is a new program option for students in the current BS in Computer Science (BSCS) degree. Students graduating with this option will have Cyber Operations Track indicated as part of their BSCS 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 Computer Architecture, which is available as an elective for this track, and the following courses:

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

CS 1083	Programming I for Computer Scientists	3
CS 1714	Computer Programming II	4
CS 2124	Data Structures	4
CS 2233	Discrete Mathematical Structures	3
CS 3333	Mathematical Foundations of Computer Science	3
CS 3343	Analysis of Algorithms	3
CS 3424	Systems Programming	4
CS 3443	Application Programming	3
CS 3723	Programming Languages	3
CS 3733	Operating Systems	3
CS 3743	Database Systems	3
CS 3844	Computer Organization	4
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. Required courses for Cyber Operations Track

CS 3113	Principles of Cyber Security	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	Cellular and Mobile 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. Elective

Choose one of the following:

CS 3853	Computer Architecture	3
CS 4673	Cyber Operations	3
CS 4853	Advanced Systems Programming	3

Any other CS upper division electives, or

IS 4523	Digital Forensic Analysis II (from Information Systems and Cybersecurity program in College of Business)	3
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Total Credit Hours 78

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 (no track) – Recommended Four-Year Academic Plan

First Year

		Credit Hours
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 (core)	3
Creative Arts core		3
Credit Hours		16

Spring

CS 1714	Computer Programming II	4
CS 2233	Discrete Mathematical Structures	3
MAT 1224	Calculus II	4
POL 1133 or POL 1213	Texas Politics and Society (core) or Civil Rights in Texas and America	3
Credit Hours		14

Second Year

Fall

CS 2124	Data Structures	4
CS 3333	Mathematical Foundations of Computer Science	3
POL 1013	Introduction to American Politics (core)	3
WRC 1023	Freshman Composition II (core)	3
Life & Physical Sciences core		3
Credit Hours		16

Spring

CS 3424	Systems Programming	4
CS 3443	Application Programming	3
CS 3844	Computer Organization	4
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.

B.S. in Computer Science with Cyber Operations Track – Recommended Four-Year Academic Plan

First Year

Fall		Credit Hours
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 (core)	3
Life & Physical Sciences core		3
Credit Hours		16

Spring		
CS 1714	Computer Programming II	4
MAT 1224	Calculus II	4
WRC 1023	Freshman Composition II (core)	3
Life & Physical Sciences core		3
Credit Hours		14

Second Year

Fall		
CS 2124	Data Structures	4
CS 2233	Discrete Mathematical Structures	3
CS 3333	Mathematical Foundations of Computer Science	3
Language, Philosophy & Culture core		3
Social & Behavioral Sciences core		3
Credit Hours		16

Spring		
CS 3113	Principles of Cyber Security	3
CS 3424	Systems Programming	4
CS 3443	Application Programming	3
CS 3844	Computer Organization	4
Credit Hours		14

Third Year

Fall		
CS 3343	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 3723	Programming Languages	3
CS 3743	Database Systems	3
CS 4353	Unix and Network Security	3
CS 4363	Cryptography	3
American History core		3
Credit Hours		15

Fourth Year

Fall		
CS 4643	Cellular and Mobile 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 Cyber Security elective (must be approved by CS department)		3
Upper-division Cyber Security elective (must be approved by CS department)		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 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 Bachelor of Science 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.

The B.A. 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.A. 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/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

Gateway Courses

Students pursuing the B.A. 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 1714	Computer Programming II	4
CS 2124	Data Structures	4

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 1714	Computer Programming II	4
CS 2124	Data Structures	4
CS 2233	Discrete Mathematical Structures	3
CS 3333	Mathematical Foundations of Computer Science	3
CS 3343	Analysis of Algorithms	3
CS 3424	Systems Programming	4
CS 3443	Application Programming	3
CS 3743	Database Systems	3
CS 3844	Computer Organization	4
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 electives 12

Any of upper division computer science electives in the B.S. in Computer Science program

C. Education courses (27 hours)

UTE 1111	Introduction to STEM Teaching Step 1	1
UTE 1122	Introduction to STEM Teaching Step 2	2
UTE 3023	Perspectives on Science and Mathematics	3
UTE 3203	Knowing and Learning in Mathematics and Science	3
UTE 3213	Classroom Interactions	3
UTE 4203	Project-Based Instruction	3
ESL 3083	Second Language Teaching and Learning for Grades 7-12	3
LTED 3773	Reading and Writing Across the Disciplines-Grades 7-12	3
UTE 4646	Clinical Teaching	6

Total Credit Hours 81

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 UTSA undergraduate B.A. in 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.A. in Computer Science with Teaching Track - Recommended Four-Year Academic Plan

First Year

Fall		Credit Hours
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 (core)	3
UTE 1111	Introduction to STEM Teaching Step 1	1
Credit Hours		14

Spring

CS 1714	Computer Programming II	4
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	3
UTE 1122	Introduction to STEM Teaching Step 2	2
Credit Hours		16

Second Year

Fall

CS 2124	Data Structures	4
CS 2233	Discrete Mathematical Structures	3
POL 1013	Introduction to American Politics	3
Life & Physical Sciences core		3
UTE 3203	Knowing and Learning in Mathematics and Science	3
Credit Hours		16

Spring

CS 3333	Mathematical Foundations of Computer Science	3
CS 3443	Application Programming	3
Life & Physical Sciences core		3
Social & Behavioral Sciences core		3
UTE 3023	Perspectives on Science and Mathematics	3
Credit Hours		15

Third Year

Fall

CS 3424	Systems Programming	4
CS 3844	Computer Organization	4
Component Area Option core		3
Creative Arts core		3
ESL 3083	Second Language Teaching and Learning for Grades 7-12	3
Credit Hours		17

Spring

CS 3343	Analysis of Algorithms	3
CS 3743	Database Systems	3
Language, Philosophy & Culture core		3

American History core		3
UTE 3213	Classroom Interactions	3
Credit Hours		15

Fourth Year

Fall

Upper-division CS elective		3
Upper-division CS elective		3
American History core		3
LTED 3773	Reading and Writing Across the Disciplines-Grades 7-12	3
UTE 4203	Project-Based Instruction	3
Credit Hours		15

Spring

Upper-division CS elective		3
Upper-division CS elective		3
UTE 4646	Clinical Teaching	6
Credit Hours		12
Total Credit Hours		120

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 1714	Computer Programming II	4
CS 2124	Data Structures	4

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 the Certificate Program Advisor 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:

BIO 3713 Microbiology	3
CS 4593 Topics in Computer Science (Cloud Computing)	
IS 4533 Malware Analysis	

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

Biology elective options¹

BIO 3513 Biochemistry	
BIO 3743 Bacteriology	
BIO 4743 Immunology	
BIO 5762 Fundamentals of Immunology for Biotechnology	
BIO 6973 Special Problems (Comparative Genomics)	
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 \$45; STSI \$21.

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: IUCS \$45; LRS1 \$45; STSI \$21.

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: IUCS \$45; LRS1 \$45; STSI \$21.

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

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: IUCS \$45; LRS1 \$45; STSI \$21.

CS 1093. Programming for Data Science. (3-0) 3 Credit Hours.

Prerequisite: MAT 1073 or the equivalent. An introduction to computer programming emphasizing structured programming, problem solving, and algorithmic thinking. Topics include assignment, decisions, loops, functions, arrays/lists, and use of objects and math/stat packages. Course Fees: IUCS \$45; LRS1 \$45; STSI \$21.

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 \$45; STSI \$21.

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 Fees: DL01 \$75; IUUCS \$45; LRC1 \$12; LRS1 \$45; STSI \$21.

CS 1714. Computer Programming II. (4-0) 4 Credit Hours. (TCCN = COSC 1437)

Prerequisite: CS 1083. 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 and a mandatory 1-hour recitation per week. (Formerly CS 1711/1713. Credit cannot be earned for both CS 1714 and CS 1711/1713.) Course Fees: IUUCS \$60; LRS1 \$60; STSI \$28.

CS 1793. Data Computation. (3-0) 3 Credit Hours.

Prerequisite: CS 1093. Extended programming concepts including multidimensional arrays, references, dynamic memory allocation/deallocation, list-like structures and recursion. Problem solving methods, algorithm development and implementation. Course Fees: IUUCS \$45; LRS1 \$45; STSI \$21.

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. Course Fees: IUUCS \$45; LRS1 \$45; STSI \$21.

CS 2124. Data Structures. (4-0) 4 Credit Hours.

Prerequisites: CS 1714 and completion of or concurrent enrollment in MAT 1214. 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 and a mandatory 1-hour recitation per week. (Formerly CS 1723 and CS 2121/2123. Credit cannot be earned for both CS 2124 and CS 1723 or CS 2121/2123.) Course Fees: IUUCS \$60; LRS1 \$60; STSI \$28.

CS 2173. Programming Fundamentals and Data Structures. (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 programming fundamentals and basic data structures such as arrays, stack, linked-lists, trees, graphs. Only one of the following may be applied towards a degree: CS 2173, CS 2193, or CS 2124 (previously CS 2121/2123). Course Fees: IUUCS \$45; LRS1 \$45; STSI \$21.

CS 2193. Data Organization. (3-0) 3 Credit Hours.

Prerequisites: CS 1793 and MAT 1214. 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. Only one of the following may be applied towards a degree: CS 2173, CS 2193, or CS 2124 (previously CS 2121/2123). Course Fees: IUUCS \$45; LRS1 \$45; STSI \$21.

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

Prerequisites: CS 1083 and MAT 1093. 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: IUUCS \$45; LRS1 \$45; STSI \$21.

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

Prerequisite: CS 2124. 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.) Differential Tuition: \$150. Course Fees: DL01 \$75; IUUCS \$45.

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

Prerequisites: CS 1714 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisites: CS 2124, 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

CS 3424. Systems Programming. (4-0) 4 Credit Hours.

Prerequisite: CS 2124. 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 and a mandatory 1-hour recitation per week. (Formerly CS 2413 and CS 3421/3423. Credit cannot be earned for both CS 3424 and CS 2413 or CS 3421/3423.) Differential Tuition: \$200. Course Fee: IUUCS \$60.

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

Prerequisites: CS 3424 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisite: CS 2124. 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisite: CS 2124. 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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, scoping and activation records, control structures, and data abstraction. Generally offered: Fall, Spring. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 3424, CS 3443, and 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 2233 and CS 3424. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 2124, 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 3343 and CS 3424. Discussion of theorem-proving by machine; includes computational linguistics, psychological modeling, and computer games. Differential Tuition: \$150. Course Fee: IUCS \$45.

CS 3844. Computer Organization. (4-0) 4 Credit Hours.

Prerequisite: CS 2124. 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. The course includes 3 hours of lecture and a mandatory 1-hour recitation per week. (Formerly CS 2733 and CS 3841/3843. Credit cannot be earned for both CS 3844 and CS 2733 or CS 3841/3843.) Differential Tuition: \$200. Course Fees: IUCS \$60.

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

Prerequisites: CS 3424 and CS 3844. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 3424 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 3424 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisite: CS 3343. Study of fundamental concepts and methods of machine learning. Topics include unsupervised learning, supervised learning, reinforcement learning and other advanced topics selected by instructor. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisite: One of the following: CS 3753, CS 3793, CS 4233, CS 4253. 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. Differential Tuition: \$150. 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. Differential Tuition: \$150. Course Fee: 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. Differential Tuition: \$150. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 2124 and CS 3343. 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. Differential Tuition: \$150. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisite: CS 3424. Fundamentals of Web and component technology: markup languages, layout design, client and server side programming, database and Web integration. Generally offered: Fall. Differential Tuition: \$150. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisite: CS 3424. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. 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. Differential Tuition: \$150. 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. Differential Tuition: \$150. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

CS 4623. 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. Differential Tuition: \$150. 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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUCS \$45.

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

Prerequisites: CS 3844, and CS 3113 or CS 3433. An introduction to the basic procedures to reverse engineering of software, hardware and malware. Differential Tuition: \$150. Course Fee: IUUCS \$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. Differential Tuition: \$150. Course Fee: IUUCS \$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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisites: CS 3723 and 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.") Differential Tuition: \$150. Course Fee: IUUCS \$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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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.") Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisites: CS 3343 and CS 3424. Parallel programming concepts (partitioning, synchronization and communication, programming models-shared memory based and message based), programming tools and languages, performance issues. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisite: 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

CS 4843. Cloud Computing. (3-0) 3 Credit Hours.

Prerequisite: CS 3424. 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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.") Differential Tuition: \$150. Course Fee: IUUCS \$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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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

Prerequisite: Consent of Instructor. The student learns how to conduct independent research. He/she 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. Differential Tuition: \$150. Course Fee: IUUCS \$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 his/her 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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$50. Course Fee: IUUCS \$15.

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. Differential Tuition: \$100. Course Fee: IUUCS \$30.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.

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. Differential Tuition: \$150. Course Fee: IUUCS \$45.