

# INFORMATION SCIENCE

**Departmental Office:** 450 Computer Science Building; 212-939-7000  
<http://www.cs.columbia.edu/>

**Director of Undergraduate Studies:** Dr. Jae Woo Lee, 715 CEPSPR;  
 212-939-7066; [jae@cs.columbia.edu](mailto:jae@cs.columbia.edu)

## Departmental Advisers:

For updated adviser information, see <http://www.cs.columbia.edu/education/undergrad/advisors>.

For administrative advising issues please contact:  
[advising@cs.columbia.edu](mailto:advising@cs.columbia.edu).

The majors in the Department of Computer Science provide students with the appropriate computer science background necessary for graduate study or a professional career. Computers impact nearly all areas of human endeavor. Therefore, the department also offers courses for students who do not plan a computer science major or concentration. The computer science majors offer maximum flexibility by providing students with a range of options for program specialization. The department offers four majors: computer science; information science; data science; and computer science-mathematics, offered jointly with the Mathematics Department.

## Computer Science Major

Students study a common core of fundamental topics, supplemented by a track that identifies specific areas for deeper study. The foundations track prepares students for advanced work in fundamental, theoretical, and mathematical aspects of computing, including analysis of algorithms, scientific computing, and security. The systems track prepares students for immediate employment in the computer industry as well as advanced study in software engineering, operating systems, computer-aided digital design, computer architecture, programming languages, and user interfaces. The intelligent systems track provides specialization for the student interested in natural language processing and systems capable of exhibiting "human-like" intelligence. The applications track is for students interested in the implementation of interactive multimedia content for the Internet and wireless applications. The vision, graphics, interaction, and robotics track exposes students to computer vision, graphics, human-computer interaction, and robotics.

A combination track is available to students who wish to pursue an interdisciplinary course of study combining computer science and another field in the arts, humanities, mathematics, natural sciences, or social sciences. A student planning a combination track should be aware that one additional course is required to complete this option.

## Information Science Major

Information science is an interdisciplinary major designed to provide a student with an understanding of how information is organized, accessed, stored, distributed, and processed in strategic segments of today's society. Recent years have seen an explosive growth of on-line information, with people of all ages and all walks of life making use of the World Wide Web and other information in digital form.

This major puts students at the forefront of the information revolution, studying how on-line access touches on all disciplines and changing the very way people communicate. Organizations have large stores of in-house information that are crucial to their daily operation. Today's systems must enable quick access to relevant information, must ensure

that confidential information is secure, and must enable new forms of communication among people and their access to information.

The information science major can choose a scientific focus on algorithms and systems for organizing, accessing, and processing information, or an interdisciplinary focus in order to develop an understanding of, and tools for, information modeling and use within an important sector of modern society such as economics or health.

## Advanced Placement

The department grants 3 points for a score of 4 or 5 on the AP Computer Science exam along with exemption from COMS W1004 Introduction to Computer Science and Programming in Java. However, we still recommend that you take COMS W1004 or W1007 even if you have credits from the CS AP exam. COMS W1007 Honors Introduction to Computer Science is recommended if you scored 5 on the AP exam, and COMS W1004 is recommended if you scored 4.

## Pre-Introductory Courses

COMS W1004 is the first course in the Computer Science major curriculum, and it does not require any previous computing experience. Before taking COMS W1004, however, students have an option to start with one of the pre-introductory courses: ENGI E1006 or COMS W1002.

ENGI E1006 Introduction to Computing for Engineers and Applied Scientist is a general introduction to computing for STEM students.

ENGI E1006 is in fact a required course for all engineering students.

COMS W1002 Computing In Context is a course primarily intended for humanities majors, but it also serves as a pre-introductory course for CS majors. ENGI E1006 and COMS W1002 do not count towards Computer Science major.

## Laboratory Facilities

The department has well-equipped lab areas for research in computer graphics, computer-aided digital design, computer vision, databases and digital libraries, data mining and knowledge discovery, distributed systems, mobile and wearable computing, natural language processing, networking, operating systems, programming systems, robotics, user interfaces, and real-time multimedia.

Research labs contain several large Linux and Solaris clusters; Puma 500 and IBM robotic arms; a UTAH-MIT dexterous hand; an Adept-1 robot; three mobile research robots; a real-time defocus range sensor; interactive 3-D graphics workstations with 3-D position and orientation trackers; prototype wearable computers, wall-sized stereo projection systems; see-through head-mounted displays; a networking testbed with three Cisco 7500 backbone routers, traffic generators; an IDS testbed with secured LAN, Cisco routers, EMC storage, and Linux servers; and a simulation testbed with several Sun servers and Cisco Catalyst routers. The department uses a SIP IP phone system. The protocol was developed in the department.

The department's computers are connected via a switched 1Gb/s Ethernet network, which has direct connectivity to the campus OC-3 Internet and internet 2 gateways. The campus has 802.11b/g wireless LAN coverage.

The research facility is supported by a full-time staff of professional system administrators and programmers.

## Professors

Alfred V. Aho  
Peter K. Allen  
Peter Belhumeur  
Steven M. Bellovin  
David Blei  
Luca Carloni  
Michael J. Collins  
Steven K. Feiner  
Luis Gravano  
Julia Hirschberg  
Gail E. Kaiser  
John R. Kender  
Kathleen R. McKeown  
Vishal Misra  
Shree K. Nayar  
Jason Nieh  
Steven M. Nowick  
Christos Papadimitriou  
Kenneth A. Ross  
Henning G. Schulzrinne  
Rocco A. Servedio  
Salvatore J. Stolfo  
Jeannette Wing  
Mihalis Yannakakis

## Associate Professors

Alexandr Andoni  
Augustin Chaintreau  
Xi Chen  
Stephen A. Edwards  
Yaniv Erlich  
Roxana Geambasu  
Eitan Grinspun  
Daniel Hsu  
Tony Jebara  
Martha Allen Kim  
Tal Malkin  
Itsik Pe'er  
Daniel S. Rubenstein  
Simha Sethumadhavan  
Junfeng Yang  
Changxi Zheng

## Assistant Professors

Lydia Chilton  
Ronghui Gu  
Suman Jana  
Baishakhi Ray  
Carl Vondrick  
Omri Weinstein  
Eugene Wu

## Senior Lecturer in Discipline

Paul Blaer  
Adam Cannon  
Jae Woo Lee

## Lecturer in Discipline

Daniel Bauer  
Tony Dear  
Ansaf Salleb-Aouissi  
Nakul Verma

## Associated Faculty Joint

Shih-Fu Chang  
Clifford Stein

## Associated Faculty

Matei Ciocarlie  
Edward G. Coffman Jr. (*emeritus*)  
Eleni Drinea  
Jonathan Gross (*emeritus*)  
Andreas Mueller  
Steven H. Unger (*emeritus*)  
Vladimir Vapnik  
Yechiam Yemini (*emeritus*)

## Senior Research Scientists

Moti Yung

## Research Scientists

Smaranda Muresan\*

## Associated Research Scientists

Allison Breton Bishop  
Giuseppe DiGuglielmo  
Paolo Mantovani  
Hiroshi Sasaki  
Eran Tromer

## Professor of Practice

Donald F. Ferguson

## Guidelines for all Computer Science Majors and Concentrators

### Courses

Students may receive credit for only one of the following two courses:

- COMS W1004 Introduction to Computer Science and Programming in Java
- COMS W1005 Introduction to Computer Science and Programming in MATLAB.

Students may receive credit for only one of the following three courses:

- COMS W3134 Data Structures in Java
- COMS W3136 Data Structures with C/C++
- COMS W3137 Honors Data Structures and Algorithms

However, COMS W1005 and COMS W3136 cannot be counted towards the Computer Science major, minor, and concentration.

### Transfer Credit

As a rule, no more than 12 transfer credits are accepted toward the major.

## Grading

A maximum of one course worth no more than 4 points passed with a grade of D may be counted toward the major or concentration.

## Major in Computer Science

Please read *Guidelines for all Computer Science Majors and Concentrators* above.

All majors should confer with their program adviser each term to plan their programs of study. Students considering a major in computer science are encouraged to talk to a program adviser during their first or second year. A typical program of study is as follows:

### Program of Study

#### Computer Science Core (22-24 points)

##### For students who declare in Spring 2014 and beyond:

ENGI E1006	Introduction to Computing for Engineers and Applied Scientists (recommended but not required)
------------	---

#### First Year

COMS W1004	Introduction to Computer Science and Programming in Java
or COMS W1007	Honors Introduction to Computer Science

#### Sophomore Year

COMS W3134	Data Structures in Java
or COMS W3137	Honors Data Structures and Algorithms
COMS W3157	Advanced Programming
COMS W3203	DISCRETE MATHEMATICS

#### Junior and Senior Year

Select the remaining required core courses:

COMS W3261	Computer Science Theory
CSEE W3827	Fundamentals of Computer Systems

Select one of the following courses:

MATH UN2010	LINEAR ALGEBRA
APMA E2101	Introduction to Applied Mathematics
APMA E3101	Linear Algebra
STAT GU4001	INTRODUCTION TO PROBABILITY AND STATISTICS

##### For students who declared prior to Spring 2014:

#### First Year

COMS W1004	Introduction to Computer Science and Programming in Java
------------	--

#### Sophomore Year

COMS W1007	Honors Introduction to Computer Science
COMS W3137	Honors Data Structures and Algorithms
COMS W3157	Advanced Programming
COMS W3203	DISCRETE MATHEMATICS

#### Junior and Senior Year

COMS W3261	Computer Science Theory
CSEE W3827	Fundamentals of Computer Systems

In addition to the CS Core (22-24 points), all CS majors must complete the Calculus Requirement (3 points) and a Track Requirement (15 or 18 points). The CS major therefore requires 40-45 points total.

## Mathematics (3 points)

Calculus II or Calculus III.

Note that Calculus III does NOT depend on Calculus II. You can take either Calculus II or III, but we recommend Calculus III, which covers topics that are a bit more relevant for upper-level Computer Science courses.

If you have received equivalent credits for Calculus I & II already (through a 4 or 5 on the AP Calculus exam for example), you are not required to take any more Calculus courses. But we recommend taking one more semester of Calculus, either Math UN1201 Calculus III or APAM E2000 Multivariate Calculus for Engineers and Scientists. APAM E2000 covers relevant topics from Calculus III and IV.

## Track Requirement (15 or 18 points)

Students must select one of the following six upper-level tracks. Each track, except the combination track, requires five courses consisting of required, elective breadth, and elective track courses. The combination track requires a selection of six advanced courses: three 3000- or 4000-level computer science courses and three 3000- or 4000-level courses from another field. The elective breadth requirement in each track can be fulfilled with any 3-point computer science 3000-level or higher course that is not a computer science core course or a technical elective course in that track. In addition to the breadth elective, the track requirements are as follows:

### Foundations Track (15 points)

For students interested in algorithms, computational complexity, and other areas of theoretical Computer Science.

Note: Students who declared their Computer Science major prior to Fall 2016 may also count COMS 4241, COMS 4205, COMS 4281, COMS 4444, COMS 4771, and COMS 4772 as track elective courses.

#### Required Courses

CSOR W4231	Analysis of Algorithms I
COMS W4236	Introduction to Computational Complexity

#### Track Electives

Select 2 from:

MATH UN3020	Number Theory and Cryptography
MATH UN3025	Making, Breaking Codes
COMS W4203	Graph Theory
MATH GU4032	Fourier Analysis
MATH GU4041	INTRO MODERN ALGEBRA I
MATH GU4042	INTRO MODERN ALGEBRA II
MATH GU4061	INTRO MODERN ANALYSIS I
MATH GU4155	Probability Theory
COMS W4252	Introduction to Computational Learning Theory
COMS W4261	Introduction to Cryptography
APMA E4300	Computational Math: Introduction to Numerical Methods
IEOR E4407	Game Theoretic Models of Operations
CSPH G4802	Math Logic II: Incompleteness
COMS E6232	Analysis of Algorithms, II
MATH G6238	Enumerative Combinatorics
COMS E6253	Advanced Topics in Computational Learning Theory
COMS E6261	Advanced Cryptography
EEOR E6616	Convex optimization
IEOR E6613	Optimization, I

IEOR E6614	Optimization, II
IEOR E6711	Stochastic models, I
IEOR E6712	Stochastic models, II
ELEN E6717	Information theory
ELEN E6718	Error Correcting Codes: Classical and Modern
Adviser Approved:	
COMS W3902	Undergraduate Thesis
COMS W3998	Undergraduate Projects in Computer Science
COMS W4901	Projects in Computer Science
COMS W4995	Special topics in computer science, I
COMS E6998	Topics in Computer Science

**One Breadth Course**

Any 3-point COMS 3000- or 4000-level course except those courses in the CS core or in the required or elective courses for this track

**Software Systems Track (15 points)**

For students interested in networks, programming languages, operating systems, software engineering, databases, security, and distributed systems.

**Required Courses**

COMS W4115	Programming Languages and Translators
COMS W4118	Operating Systems I
CSEE W4119	COMPUTER NETWORKS

**Track Electives**

Select 1 from:

Any COMS W41xx course	
COMS W4444	Programming and Problem Solving
Any COMS W48xx course	

Adviser Approved:

COMS W3902	Undergraduate Thesis
COMS W3998	Undergraduate Projects in Computer Science
COMS W4901	Projects in Computer Science
COMS W4995	Special topics in computer science, I
COMS W4996	Special topics in computer science, II

Any COMS E68XX course

Any COMS E61XX course

**One Breadth Course**

Any 3-point COMS 3000- or 4000-level course except those courses in the CS core or in the required or elective courses for this track

**Intelligent Systems Track (15 points)**

For students interested in machine learning, robotics, and systems capable of exhibiting "human-like" intelligence.

**Required Courses**

Select two of the following courses:

COMS W4701	Artificial Intelligence
COMS W4705	Natural Language Processing
COMS W4706	Spoken Language Processing
COMS W4731	Computer Vision I: First Principles
COMS W4733	Computational Aspects of Robotics
COMS W4771	Machine Learning

**Track Electives**

Select 2 from:

COMS W4252	Introduction to Computational Learning Theory
Any COMS W47xx course	
Any COMS E67XX course	
Adviser Approved:	
COMS W3902	Undergraduate Thesis
COMS W3998	Undergraduate Projects in Computer Science
COMS W4901	Projects in Computer Science
COMS W4995	Special topics in computer science, I
COMS E6998	Topics in Computer Science

**One Breadth Course**

Any 3-point COMS 3000- or 4000-level course except those courses in the CS core or in the required or elective courses for this track

**Applications Track (15 points)**

For students interested in the implementation of interactive multimedia applications for the internet and wireless networks.

**Required Courses**

COMS W4115	Programming Languages and Translators
COMS W4170	User Interface Design

**Track Electives**

Select 2 from:

Any COMS W41xx course	
Any COMS W47xx course	

Adviser Approved:

COMS W3902	Undergraduate Thesis
COMS W3998	Undergraduate Projects in Computer Science
COMS W4901	Projects in Computer Science
COMS W4995	Special topics in computer science, I
Any COMS E69XX course	

**One Breadth Course**

Any 3-point COMS 3000- or 4000-level course except those courses in the CS core or in the required or elective courses for this track

**Vision, Graphics, Interaction, and Robotics Track (15 points)**

For students in the vision, interaction, graphics, and robotics track. It focuses on visual information with topics in vision, graphics, human-computer interaction, robotics, modeling, and learning. Students learn about fundamental ways in which visual information is captured, manipulated, and experienced.

**Required Courses**

Select two of the following courses:

COMS W4160	Computer Graphics
COMS W4167	Computer Animation
COMS W4731	Computer Vision I: First Principles

**Track Electives**

Select 2 from:

COMS W4162	Advanced Computer Graphics
COMS W4170	User Interface Design
COMS W4172	3D User Interfaces and Augmented Reality
COMS W4701	Artificial Intelligence
COMS W4733	Computational Aspects of Robotics
COMS W4735	Visual Interfaces to Computers
COMS W4771	Machine Learning

Adviser Approved:

COMS W3902	Undergraduate Thesis
COMS W3998	Undergraduate Projects in Computer Science
COMS W4901	Projects in Computer Science
COMS W4995	Special topics in computer science, I
Any COMS E69XX course	

#### One Breadth Course

Any 3-point COMS 3000- or 4000-level course except those courses in the CS core or in the required or elective courses for this track

#### Combination Track (18 points)

For students who wish to combine computer science with another discipline in the arts, humanities, social or natural sciences. A coherent selection of six upper-level courses is required: three from computer science and three from another discipline.

The courses should be planned with and approved by the student's CS faculty advisor by the first semester of the junior year. The six courses are typically 4000-level elective courses that would count towards the individual majors. Moreover, the six courses should have a common theme. The combination track is not intended for those students who pursue double majors.

## Major in Computer Science—Mathematics

For a description of the joint major in computer science—mathematics, see the *Mathematics* section in this bulletin.

## Major in Information Science

Please read *Guidelines for all Computer Science Majors and Concentrators* above.

The major in information science requires a minimum of 33 points including a core requirement of five courses.

The elective courses must be chosen with a faculty adviser to focus on the modeling and use of information within the context of a disciplinary theme. After discussing potential selections students prepare a proposal of study that must be approved by the faculty adviser. In all cases the six courses must be at the 3000-level or above with at least three courses chosen from computer science. Following are some example programs. For more examples or templates for the program proposal, see a faculty adviser.

Note: In most cases additional courses will be necessary as prerequisites in order to take some of the elective courses. This will depend on the student's proposed program of study.

### Core Requirement

COMS W1001	Introduction to Information Science or COMS W1002 Computing in Context
COMS W1004	Introduction to Computer Science and Programming in Java
COMS W1007	Honors Introduction to Computer Science
COMS W3134	Data Structures in Java
STAT GU4001	INTRODUCTION TO PROBABILITY AND STATISTICS

Following are some suggested programs of instruction:

### Information Science and Contemporary Society

Students may focus on how humans use technology and how technology has changed society.

The requirements include:

COMS W4111	INTRODUCTION TO DATABASES
COMS W4170	User Interface Design
COMS W4701	Artificial Intelligence
COMS W3410	Computers and Society
SOCI UN3010	Methods for Social Research
SOCI UN3960	Law, Science, and Society

### Information Science and the Economy

Students may focus on understanding information modeling together with existing and emerging needs in economics and finance as well as algorithms and systems to address those needs.

The requirements include:

COMS W4111	INTRODUCTION TO DATABASES
COMS W4701	Artificial Intelligence
COMS W4771	Machine Learning
ECON UN3412	Introduction To Econometrics
ECON UN3025	Financial Economics
ECON UN3265	MONEY AND BANKING

### Information Science and Health Sciences

Students may focus on understanding information modeling together with existing and emerging needs in health sciences, as well as algorithms and systems to address those needs.

The requirements include:

COMS W4111	INTRODUCTION TO DATABASES
COMS W4170	User Interface Design
COMS W4701	Artificial Intelligence
BINF G4001	
BIOL W4037	Bioinformatics of Gene Expression
ECBM E3060/E4060	Introduction to genomic information science and technology

## Major in Data Science

Please read *Guidelines for all Computer Science Majors and Concentrators* above.

In response to the ever growing importance of "big data" in scientific and policy endeavors, the last few years have seen an explosive growth in theory, methods, and applications at the interface between computer science and statistics. The statistics and computer science departments have responded with a joint-major that emphasizes the interface between the disciplines.

### Prerequisites (15 points)

MATH UN1101	CALCULUS I
MATH UN1102	CALCULUS II
MATH UN1201	Calculus III
MATH UN2010	LINEAR ALGEBRA

This introductory Statistics course:

STAT UN1201 Calculus-Based Introduction to Statistics

**Statistics (12 points)**

STAT GU4203 PROBABILITY THEORY

STAT GU4204 Statistical Inference

STAT GU4205 Linear Regression Models

STAT GU4241 Statistical Machine Learning

or COMS W4771 Machine Learning

**Computer Science (12 points)**

Select one of the following courses:

COMS W1004 Introduction to Computer Science and Programming in Java

COMS W1005 Introduction to Computer Science and Programming in MATLAB

COMS W1007 Honors Introduction to Computer Science

ENGI E1006 Introduction to Computing for Engineers and Applied Scientists

Select one of the following courses:

COMS W3134 Data Structures in Java

COMS W3136 Data Structures with C/C++

COMS W3137 Honors Data Structures and Algorithms

Two required courses:

COMS W3203 DISCRETE MATHEMATICS

CSOR W4231 Analysis of Algorithms I

**Electives (15 points)**

Select two of the following courses:

STAT UN3106 Applied Data Mining

STAT GU4206 Statistical Computing and Introduction to Data Science

STAT GU4224 BAYESIAN STATISTICS

STAT GU4243 Applied Data Science

STAT Q4242 Advanced Machine Learning

Select three of the following courses:

COMS W3261 Computer Science Theory

COMS W4111 INTRODUCTION TO DATABASES

COMS W4130 Principles and Practice of Parallel Programming

COMS W4236 Introduction to Computational Complexity

COMS W4252 Introduction to Computational Learning Theory

Any COMS W47xx course EXCEPT W4771

## Concentration in Computer Science

Please read *Guidelines for all Computer Science Majors and Concentrators* above.

### For students who declare in Spring 2014 and beyond:

The concentration in computer science requires a minimum of 22-24 points, as follows:

COMS W1004 Introduction to Computer Science and Programming in Java  
or COMS W1007 Honors Introduction to Computer Science

COMS W3134 Data Structures in Java

or COMS W3137 Honors Data Structures and Algorithms

COMS W3157 Advanced Programming

COMS W3203 DISCRETE MATHEMATICS

COMS W3261 Computer Science Theory

CSEE W3827 Fundamentals of Computer Systems (or any 3 point 4000-level computer science course)

Select one of the following courses:

MATH UN2010 LINEAR ALGEBRA

MATH V2020 Honors Linear Algebra

APMA E2101 Introduction to Applied Mathematics

APMA E3101 Linear Algebra

STAT GU4001 INTRODUCTION TO PROBABILITY AND STATISTICS

SIEO W3600

### For students who declared prior to Spring 2014:

The concentration requires a minimum of 23 points, as follows:

COMS W1004 Introduction to Computer Science and Programming in Java

COMS W1007 Honors Introduction to Computer Science

COMS W3137 Honors Data Structures and Algorithms

COMS W3157 Advanced Programming

COMS W3261 Computer Science Theory

CSEE W3827 Fundamentals of Computer Systems (or any 3-point 4000-level computer science course)

## Computer Science

**COMS W1001 Introduction to Information Science. 3 points.**

Lect: 3.

Basic introduction to concepts and skills in Information Sciences: human-computer interfaces, representing information digitally, organizing and searching information on the internet, principles of algorithmic problem solving, introduction to database concepts, and introduction to programming in Python.

Fall 2021: COMS W1001

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 1001	001/12390	T Th 1:10pm - 2:25pm Room TBA	Adam Cannon	3	57/60

**COMS W1002 Computing in Context. 4 points.**

CC/GS: Partial Fulfillment of Science Requirement

Introduction to elementary computing concepts and Python programming with domain-specific applications. Shared CS concepts and Python programming lectures with track-specific sections. Track themes will vary but may include computing for the social sciences, computing for economics and finance, digital humanities, and more. Intended for nonmajors. Students may only receive credit for one of ENGI E1006 or COMS W1002.

Fall 2021: COMS W1002

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 1002	001/12391	T Th 2:40pm - 3:55pm Room TBA	Adam Cannon	4	142/300

**COMS W1004 Introduction to Computer Science and Programming in Java. 3 points.**

Lect: 3.

A general introduction to computer science for science and engineering students interested in majoring in computer science or engineering. Covers fundamental concepts of computer science, algorithmic problem-solving capabilities, and introductory Java programming skills. Assumes no prior programming background. Columbia University students may receive credit for only one of the following two courses: *1004* or *1005*.

**Spring 2021: COMS W1004**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 1004	001/11922	T Th 1:10pm - 2:25pm Online Only	Adam Cannon	3	195/250
COMS 1004	002/11923	T Th 8:10pm - 9:25pm Online Only	Adam Cannon	3	150/250

**Fall 2021: COMS W1004**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 1004	001/12392	M W 4:10pm - 5:25pm Room TBA	Paul Blaer	3	115/400

**COMS W1005 Introduction to Computer Science and Programming in MATLAB. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

A general introduction to computer science concepts, algorithmic problem-solving capabilities, and programming skills in MATLAB. Assumes no prior programming background. Columbia University students may receive credit for only one of the following two courses: *W1004* or *W1005*.

**COMS W1007 Honors Introduction to Computer Science. 3 points.**

Lect: 3.

Prerequisites: AP Computer Science with a grade of 4 or 5 or similar experience.

An honors-level introduction to computer science, intended primarily for students considering a major in computer science. Computer science as a science of abstraction. Creating models for reasoning about and solving problems. The basic elements of computers and computer programs. Implementing abstractions using data structures and algorithms. Taught in Java.

**COMS W1404 Emerging Scholars Program Seminar. 1 point.**

Pass/Fail only.

Prerequisites: the instructor's permission. Corequisites: COMS W1002 or COMS W1004 or COMS W1007

Corequisites: COMS W1004, COMS W1007, COMS W1002

Peer-led weekly seminar intended for first and second year undergraduates considering a major in Computer Science. Pass/fail only. May not be used towards satisfying the major or SEAS credit requirements.

**Spring 2021: COMS W1404**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 1404	001/20132	Th 12:30pm - 1:45pm Online Only	Adam Cannon	1	6/16
COMS 1404	002/20133	F 9:00am - 10:15am Online Only	Adam Cannon	1	4/16
COMS 1404	003/20134	F 9:30am - 10:45am Online Only	Adam Cannon	1	6/16
COMS 1404	004/20135	F 11:00am - 12:15pm Online Only	Adam Cannon	1	4/16
COMS 1404	005/20136	F 10:15am - 11:30am Online Only	Adam Cannon	1	6/16
COMS 1404	006/20137	F 11:45am - 1:00pm Online Only	Adam Cannon	1	9/16
COMS 1404	007/20138	F 12:30pm - 1:45pm Online Only	Adam Cannon	1	5/16
COMS 1404	008/20139	F 2:00pm - 3:15pm Online Only	Adam Cannon	1	7/16
COMS 1404	009/20140	F 1:45pm - 3:00pm Online Only	Adam Cannon	1	8/16
COMS 1404	010/20141	F 3:15pm - 4:30pm Online Only	Adam Cannon	1	6/16

**COMS W3101 Programming Languages. 1 point.**

Lect: 1.

Prerequisites: Fluency in at least one programming language.

Introduction to a programming language. Each section is devoted to a specific language. Intended only for those who are already fluent in at least one programming language. Sections may meet for one hour per week for the whole term, for three hours per week for the first third of the term, or for two hours per week for the first six weeks. May be repeated for credit if different languages are involved.

**COMS W3102 Development Technologies. 1-2 points.**

Lect: 2. Lab: 0-2.

Prerequisites: Fluency in at least one programming language.

Introduction to software development tools and environments. Each section devoted to a specific tool or environment. One-point sections meet for two hours each week for half a semester, and two-point sections include an additional two-hour lab.

**Spring 2021: COMS W3102**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3102	001/19893		Paul Blaer	1-2	56/200

**COMS W3107 Clean Object-Oriented Design. 3.00 points.**

Prerequisites: Intro to Computer Science/Programming in Java (COMS W1004) or instructor's permission. May not take for credit if already received credit for COMS W1007.

Prerequisites: see notes re: points

A course in designing, documenting, coding, and testing robust computer software, according to object-oriented design patterns and clean coding practices. Taught in Java. Object-oriented design principles include: use cases; CRC; UML; javadoc; patterns (adapter, builder, command, composite, decorator, facade, factory, iterator, lazy evaluation, observer, singleton, strategy, template, visitor); design by contract; loop invariants; interfaces and inheritance hierarchies; anonymous classes and null objects; graphical widgets; events and listeners; Java's Object class; generic types; reflection; timers, threads, and locks

Fall 2021: COMS W3107

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3107	001/12480	M W 4:10pm - 5:25pm Room TBA	John Kender	3.00	42/70

**COMS W3134 Data Structures in Java. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W1004) or knowledge of Java.

Data types and structures: arrays, stacks, singly and doubly linked lists, queues, trees, sets, and graphs. Programming techniques for processing such structures: sorting and searching, hashing, garbage collection.

Storage management. Rudiments of the analysis of algorithms. Taught in Java. Note: Due to significant overlap, students may receive credit for only one of the following three courses: *COMS W3134*, *COMS W3136*, *COMS W3137*.

Spring 2021: COMS W3134

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3134	001/11924	M W 5:40pm - 6:55pm Online Only	Paul Blaer	3	324/400

Fall 2021: COMS W3134

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3134	001/12481	M W 2:40pm - 3:55pm Room TBA	Daniel Bauer	3	190/200

**COMS W3136 Data Structures with C/C++. 4 points.**

Prerequisites: (COMS W1004) or (COMS W1005) or (COMS W1007) or (ENGI E1006)

A second programming course intended for nonmajors with at least one semester of introductory programming experience. Basic elements of programming in C and C++, arraybased data structures, heaps, linked lists, C programming in UNIX environment, object-oriented programming in C++, trees, graphs, generic programming, hash tables. Due to significant overlap, students may only receive credit for either COMS W3134, W3136, or W3137.

**COMS W3137 Honors Data Structures and Algorithms. 4 points.**

Prerequisites: (COMS W1004) or (COMS W1007)

Corequisites: COMS W3203

An honors introduction to data types and structures: arrays, stacks, singly and doubly linked lists, queues, trees, sets, and graphs. Programming techniques for processing such structures: sorting and searching, hashing, garbage collection. Storage management. Design and analysis of algorithms. Taught in Java. Note: Due to significant overlap, students may receive credit for only one of the following three courses: *COMS W3134*, *W3136*, or *W3137*.

Spring 2021: COMS W3137

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3137	001/15971	T Th 4:10pm - 5:25pm Online Only	Paul Blaer	4	47/75

**COMS W3157 Advanced Programming. 4 points.**

Lect: 4.

Prerequisites: (COMS W3134) or (COMS W3137)

C programming language and Unix systems programming. Also covers Git, Make, TCP/IP networking basics, C++ fundamentals.

Spring 2021: COMS W3157

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3157	001/11925	T Th 4:10pm - 5:25pm Online Only	Jae Lee	4	268/500
COMS 3157	002/14850	F 2:10pm - 4:00pm 301 Pupin Laboratories	Jae Lee	4	41/75

Fall 2021: COMS W3157

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3157	001/12482	T Th 4:10pm - 5:25pm Room TBA	Jae Lee	4	362/400

**COMS W3203 DISCRETE MATHEMATICS. 4.00 points.**

Lect: 3.

Prerequisites: Any introductory course in computer programming.

Prerequisites: Any introductory course in computer programming. Logic and formal proofs, sequences and summation, mathematical induction, binomial coefficients, elements of finite probability, recurrence relations, equivalence relations and partial orderings, and topics in graph theory (including isomorphism, traversability, planarity, and colorings)

Spring 2021: COMS W3203

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3203	001/13030	M W 10:10am - 11:25am Online Only	Ansaf Salleb-Aouissi	4.00	159/165

Fall 2021: COMS W3203

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3203	001/12483	M W 4:10pm - 5:25pm Room TBA	Yining Liu	4.00	120/120
COMS 3203	002/12484	T Th 5:40pm - 6:55pm Room TBA	Antonio Moretti	4.00	115/150



**COMS W3210 Scientific Computation. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: two terms of calculus.

Introduction to computation on digital computers. Design and analysis of numerical algorithms. Numerical solution of equations, integration, recurrences, chaos, differential equations. Introduction to Monte Carlo methods. Properties of floating point arithmetic. Applications to weather prediction, computational finance, computational science, and computational engineering.

**COMS W3251 COMPUTATIONAL LINEAR ALGEBRA. 4.00 points.**

Spring 2021: COMS W3251

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3251	001/13032	T Th 11:40am - 12:55pm Online Only	Tony Dear	4.00	199/230

Fall 2021: COMS W3251

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3251	001/12485	T Th 2:40pm - 3:55pm Room TBA	Tony Dear	4.00	123/150

**COMS W3261 Computer Science Theory. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3203)

Corequisites: COMS W3134, COMS W3136, COMS W3137

Regular languages: deterministic and non-deterministic finite automata, regular expressions. Context-free languages: context-free grammars, push-down automata. Turing machines, the Chomsky hierarchy, and the Church-Turing thesis. Introduction to Complexity Theory and NP-Completeness.

Spring 2021: COMS W3261

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3261	001/12483	M W 4:10pm - 5:25pm Online Only	Xi Chen	3	189/235

Fall 2021: COMS W3261

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3261	001/13344	M W 2:40pm - 3:55pm Room TBA	Xi Chen	3	150/150
COMS 3261	002/13345	M W 4:10pm - 5:25pm Room TBA	Xi Chen	3	132/150

**COMS W3410 Computers and Society. 3 points.**

Lect: 3.

Broader impact of computers. Social networks and privacy. Employment, intellectual property, and the media. Science and engineering ethics. Suitable for nonmajors.

**COMS W3902 Undergraduate Thesis. 1-6 points.**

Prerequisites: Agreement by a faculty member to serve as thesis adviser. An independent theoretical or experimental investigation by an undergraduate major of an appropriate problem in computer science carried out under the supervision of a faculty member. A formal written report is mandatory and an oral presentation may also be required. May be taken over more than one term, in which case the grade is deferred until all 6 points have been completed. Consult the department for section assignment.

Fall 2021: COMS W3902

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3902	000/14021			1-6	0/0

**COMS W3995 Special Topics in Computer Science. 3 points.**

Lect: 3.

Prerequisites: the instructor's permission.

Consult the department for section assignment. Special topics arranged as the need and availability arise. Topics are usually offered on a one-time basis. Since the content of this course changes each time it is offered, it may be repeated for credit.

**COMS W3998 Undergraduate Projects in Computer Science. 1-3 points.**

Prerequisites: Approval by a faculty member who agrees to supervise the work.

Independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit, but not for a total of more than 3 points of degree credit. Consult the department for section assignment.

Fall 2021: COMS W3998

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 3998	000/14022			1-3	0/0

**COMS E3999 Fieldwork. 1 point.**

Prerequisites: Obtained internship and approval from faculty advisor. May be repeated for credit, but no more than 3 total points may be used toward the 128-credit degree requirement. Only for SEAS computer science undergraduate students who include relevant off-campus work experience as part of their approved program of study. Final report and letter of evaluation required. May not be used as a technical or non-technical elective. May not be taken for pass/fail credit or audited.

**COMS W4111 INTRODUCTION TO DATABASES. 3.00 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: COMS W3134, COMS W3136, or COMS W3137; or the instructor's permission.

Prerequisites: (COMS W3134) or (COMS W3136) or (COMS W3137) or Prerequisites: (COMS W3134) or (COMS W3137) or (COMS W3136) and fluency in Java); or the instructor's permission. The fundamentals of database design and application development using databases: entity-relationship modeling, logical design of relational databases, relational data definition and manipulation languages, SQL, XML, query processing, physical database tuning, transaction processing, security. Programming projects are required

**Spring 2021: COMS W4111**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4111	001/11926	M W 1:10pm - 2:25pm Online Only	Kenneth Ross	3.00	162/175
COMS 4111	002/11927	F 10:10am - 12:40pm 417 International Affairs Bldg	Donald Ferguson	3.00	232/250
COMS 4111	003/13636	Th 10:10am - 12:40pm Online Only	Alexandros Biliris	3.00	61/100
COMS 4111	V03/17897		Alexandros Biliris	3.00	21/99

**Fall 2021: COMS W4111**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4111	001/12406	T Th 1:10pm - 2:25pm Room TBA	Luis Gravano	3.00	134/150
COMS 4111	002/12423	F 10:10am - 12:40pm Room TBA	Donald Ferguson	3.00	67/200
COMS 4111	003/12452	Th 10:10am - 12:40pm Room TBA	Alexandros Biliris	3.00	11/100

**COMS W4112 Database System Implementation. 3 points.**

Lect: 2.5.

Prerequisites: (COMS W4111) and fluency in Java or C++. CSEE W3827 is recommended.

The principles and practice of building large-scale database management systems. Storage methods and indexing, query processing and optimization, materialized views, transaction processing and recovery, object-relational databases, parallel and distributed databases, performance considerations. Programming projects are required.

**COMS W4113 Fundamentals of Large-Scale Distributed Systems. 3 points.**

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and (COMS W3157 or COMS W4118 or CSEE W4119)

Design and implementation of large-scale distributed and cloud systems.

Teaches abstractions, design and implementation techniques that enable the building of fast, scalable, fault-tolerant distributed systems. Topics include distributed communication models (e.g., sockets, remote procedure calls, distributed shared memory), distributed synchronization (clock synchronization, logical clocks, distributed mutex), distributed file systems, replication, consistency models, fault tolerance, distributed transactions, agreement and commitment, Paxos-based consensus, MapReduce infrastructures, scalable distributed databases. Combines concepts and algorithms with descriptions of real-world implementations at Google, Facebook, Yahoo, Microsoft, LinkedIn, etc.

**COMS W4115 Programming Languages and Translators. 3 points.**

Lect: 3.

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and (COMS W3261) and (CSEE W3827) or equivalent, or the instructor's permission.

Modern programming languages and compiler design. Imperative, object-oriented, declarative, functional, and scripting languages. Language syntax, control structures, data types, procedures and parameters, binding, scope, run-time organization, and exception handling. Implementation of language translation tools including compilers and interpreters. Lexical, syntactic and semantic analysis; code generation; introduction to code optimization. Teams implement a language and its compiler.

**Spring 2021: COMS W4115**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4115	001/13902	M W 5:40pm - 6:55pm Online Only	Stephen Edwards	3	192/300
COMS 4115	V01/17792		Stephen Edwards	3	3/99

**Fall 2021: COMS W4115**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4115	001/12547	M W 1:10pm - 2:25pm Room TBA	Baishakhi Ray	3	127/120

**COMS W4117 Compilers and Interpreters. 3 points.**

Lect: 3. **Not offered during 2021-22 academic year.**

Prerequisites: (COMS W4115) or instructor's permission.

Continuation of *COMS W4115*, with broader and deeper investigation into the design and implementation of contemporary language translators, be they compilers or interpreters. Topics include parsing, semantic analysis, code generation and optimization, run-time environments, and compiler-compilers. A programming project is required.

**COMS W4118 Operating Systems I. 3 points.**

Lect: 3.

Prerequisites: (CSEE W3827) and knowledge of C and programming tools as covered in COMS W3136, W3157, or W3101, or the instructor's permission.

Design and implementation of operating systems. Topics include process management, process synchronization and interprocess communication, memory management, virtual memory, interrupt handling, processor scheduling, device management, I/O, and file systems. Case study of the UNIX operating system. A programming project is required.

**Spring 2021: COMS W4118**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4118	001/11928	M W 8:40am - 9:55am 501 Northwest Corner	Jason Nieh	3	99/150

**Fall 2021: COMS W4118**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4118	001/12539	W 4:10pm - 6:40pm Room TBA	Jae Lee	3	113/150

**COMS W4119 COMPUTER NETWORKS. 3.00 points.****COMS W4121 Computer Systems for Data Science. 3 points.**

Prerequisites: background in Computer System Organization and good working knowledge of C/C++

Corequisites: CSOR W4246, STAT GU4203

An introduction to computer architecture and distributed systems with an emphasis on warehouse scale computing systems. Topics will include fundamental tradeoffs in computer systems, hardware and software techniques for exploiting instruction-level parallelism, data-level parallelism and task level parallelism, scheduling, caching, prefetching, network and memory architecture, latency and throughput optimizations, specialization, and an introduction to programming data center computers.

**COMS W4130 Principles and Practice of Parallel Programming. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3137 or COMS W3136 and experience in Java) and basic understanding of analysis of algorithms. Principles of parallel software design. Topics include task and data decomposition, load-balancing, reasoning about correctness, determinacy, safety, and deadlock-freedom. Application of techniques through semester-long design project implementing performant, parallel application in a modern parallel programming language.

**COMS W4156 Advanced Software Engineering. 3 points.**

Lect: 3.

Prerequisites: (COMS W3157) or equivalent.

Software lifecycle using frameworks, libraries and services. Major emphasis on software testing. Centers on a team project.

**Spring 2021: COMS W4156**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4156	001/11929	T Th 8:40am - 9:55am Online Only	Junfeng Yang	3	117/120

**Fall 2021: COMS W4156**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4156	001/12531	T Th 10:10am - 11:25am Room TBA	Gail Kaiser	3	129/120

**COMS W4160 Computer Graphics. 3 points.**

Lect: 3.

Prerequisites: (COMS W3134) or (COMS W3136) or (COMS W3137) COMS W4156 is recommended. Strong programming background and some mathematical familiarity including linear algebra is required.

Introduction to computer graphics. Topics include 3D viewing and projections, geometric modeling using spline curves, graphics systems such as OpenGL, lighting and shading, and global illumination. Significant implementation is required: the final project involves writing an interactive 3D video game in OpenGL.

**Spring 2021: COMS W4160**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4160	001/15972	T Th 4:10pm - 5:25pm Online Only	Changxi Zheng	3	51/75
COMS 4160	V01/19157		Changxi Zheng	3	3/99

**COMS W4162 Advanced Computer Graphics. 3 points.**

Lect: 3.

Prerequisites: (COMS W4160) or equivalent, or the instructor's permission.

A second course in computer graphics covering more advanced topics including image and signal processing, geometric modeling with meshes, advanced image synthesis including ray tracing and global illumination, and other topics as time permits. Emphasis will be placed both on implementation of systems and important mathematical and geometric concepts such as Fourier analysis, mesh algorithms and subdivision, and Monte Carlo sampling for rendering. Note: Course will be taught every two years.

**COMS W4167 Computer Animation. 3 points.**

Lect: 3.

Prerequisites: Multivariable calculus, linear algebra, C++ programming proficiency. COMS W4156 recommended.

Theory and practice of physics-based animation algorithms, including animated clothing, hair, smoke, water, collisions, impact, and kitchen sinks. Topics covered: Integration of ordinary differential equations, formulation of physical models, treatment of discontinuities including collisions/contact, animation control, constrained Lagrangian Mechanics, friction/dissipation, continuum mechanics, finite elements, rigid bodies, thin shells, discretization of Navier-Stokes equations. General education requirement: quantitative and deductive reasoning (QUA).

**Fall 2021: COMS W4167**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4167	001/13531	T Th 4:10pm - 5:25pm Room TBA	Changxi Zheng	3	37/65

**COMS W4170 User Interface Design. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137)

Introduction to the theory and practice of computer user interface design, emphasizing the software design of graphical user interfaces. Topics include basic interaction devices and techniques, human factors, interaction styles, dialogue design, and software infrastructure. Design and programming projects are required.

**Spring 2021: COMS W4170**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4170	001/17520	M W 5:40pm - 6:55pm Online Only	Celeste Layne	3	75/80
COMS 4170	V01/17976		Celeste Layne	3	9/99

**Fall 2021: COMS W4170**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4170	001/12528	T Th 2:40pm - 3:55pm Room TBA	Brian Smith	3	0/100

**COMS W4172 3D User Interfaces and Augmented Reality. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W4160) or (COMS W4170) or the instructor's permission.

Design, development, and evaluation of 3D user interfaces. Interaction techniques and metaphors, from desktop to immersive. Selection and manipulation. Travel and navigation. Symbolic, menu, gestural, and multimodal interaction. Dialogue design. 3D software support. 3D interaction devices and displays. Virtual and augmented reality. Tangible user interfaces. Review of relevant 3D math.

Spring 2021: COMS W4172

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4172	001/11930	T Th 1:10pm - 2:25pm Online Only	Steven Feiner	3	33/40

**COMS W4181 Security I. 3 points.****Not offered during 2021-22 academic year.**

Prerequisites: COMS W3157 or equivalent.

Introduction to security. Threat models. Operating system security features. Vulnerabilities and tools. Firewalls, virtual private networks, viruses. Mobile and app security. Usable security.

Fall 2021: COMS W4181

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4181	001/12523	T Th 1:10pm - 2:25pm Room TBA	Steven Bellovin	3	81/100

**COMS W4182 Security II. 3 points.****Not offered during 2021-22 academic year.**

Prerequisites: COMS W4181, COMS W4118, COMS W4119

Advanced security. Centralized, distributed, and cloud system security. Cryptographic protocol design choices. Hardware and software security techniques. Security testing and fuzzing. Blockchain. Human security issues.

Spring 2021: COMS W4182

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4182	001/11931	T Th 1:10pm - 2:25pm Online Only	Suman Jana	3	15/60
COMS 4182	V01/17795		Suman Jana	3	1/99

**COMS W4186 Malware Analysis and Reverse Engineering. 3 points.****Not offered during 2021-22 academic year.**

Prerequisites: COMS W3157 or equivalent. COMS W3827

Hands-on analysis of malware. How hackers package and hide malware and viruses to evade analysis. Disassemblers, debuggers, and other tools for reverse engineering. Deep study of Windows Internals and x86 assembly.

Fall 2021: COMS W4186

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4186	001/13799	Th 4:10pm - 6:40pm Room TBA	Michael Sikorski	3	16/35

**COMS W4203 Graph Theory. 3 points.**

Lect: 3.

Prerequisites: (COMS W3203)

General introduction to graph theory. Isomorphism testing, algebraic specification, symmetries, spanning trees, traversability, planarity, drawings on higher-order surfaces, colorings, extremal graphs, random graphs, graphical measurement, directed graphs, Burnside-Polya counting, voltage graph theory.

**COMS W4205 Combinatorial Theory. 3 points.****Lect: 3. Not offered during 2021-22 academic year.**

Prerequisites: (COMS W3203) and course in calculus.

Sequences and recursions, calculus of finite differences and sums, elementary number theory, permutation group structures, binomial coefficients, Stirling numbers, harmonic numbers, generating functions.

**COMS W4232 Advanced Algorithms. 3 points.**

Prerequisite: Analysis of Algorithms (COMS W4231).

Prerequisites: see notes re: points

Introduces classic and modern algorithmic ideas that are central to many areas of Computer Science. The focus is on most powerful paradigms and techniques of how to design algorithms, and how to measure their efficiency. The intent is to be broad, covering a diversity of algorithmic techniques, rather than be deep. The covered topics have all been implemented and are widely used in industry. Topics include: hashing, sketching/streaming, nearest neighbor search, graph algorithms, spectral graph theory, linear programming, models for large-scale computation, and other related topics.

**COMS W4236 Introduction to Computational Complexity. 3 points.**

Lect: 3.

Prerequisites: (COMS W3261)

Develops a quantitative theory of the computational difficulty of problems in terms of the resources (e.g. time, space) needed to solve them. Classification of problems into complexity classes, reductions, and completeness. Power and limitations of different modes of computation such as nondeterminism, randomization, interaction, and parallelism.

**COMS W4241 Numerical Algorithms and Complexity. 3 points.**

Lect: 3.

Prerequisites: Knowledge of a programming language. Some knowledge of scientific computation is desirable.

Modern theory and practice of computation on digital computers. Introduction to concepts of computational complexity. Design and analysis of numerical algorithms. Applications to computational finance, computational science, and computational engineering.

**COMS W4242 Numerical Algorithms and Their Complexity II. 3 points.**

Prerequisites: COMS W4241.

A continuation of COMS W4241.

**COMS W4252 Introduction to Computational Learning Theory. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (CSOR W4231) or (COMS W4236) or *COMS W3203* and the instructor's permission, or *COMS W3261* and the instructor's permission. Possibilities and limitations of performing learning by computational agents. Topics include computational models of learning, polynomial time learnability, learning from examples and learning from queries to oracles. Computational and statistical limitations of learning. Applications to Boolean functions, geometric functions, automata.

**Spring 2021: COMS W4252**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4252	001/11932	M W 8:40am - 9:55am 309 Havemeyer Hall	Rocco Servedio	3	91/100
COMS 4252	V01/17948		Rocco Servedio	3	7/99

**Fall 2021: COMS W4252**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4252	001/13518	M W 8:40am - 9:55am Room TBA	Rocco Servedio	3	34/100

**COMS W4261 Introduction to Cryptography. 3 points.**

Lect: 2.5.

Prerequisites: Comfort with basic discrete math and probability.

Recommended: COMS W3261 or CSOR W4231.

An introduction to modern cryptography, focusing on the complexity-theoretic foundations of secure computation and communication in adversarial environments; a rigorous approach, based on precise definitions and provably secure protocols. Topics include private and public key encryption schemes, digital signatures, authentication, pseudorandom generators and functions, one-way functions, trapdoor functions, number theory and computational hardness, identification and zero knowledge protocols.

**COMS W4281 Introduction to Quantum Computing. 3 points.**

Lect: 3.

Prerequisites: Knowledge of linear algebra. Prior knowledge of quantum mechanics is not required although helpful.

Introduction to quantum computing. Shor's factoring algorithm, Grover's database search algorithm, the quantum summation algorithm. Relationship between classical and quantum computing. Potential power of quantum computers.

**Spring 2021: COMS W4281**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4281	001/13318	M W 2:40pm - 3:55pm Online Only	Henry Yuen	3	49/70
COMS 4281	V01/18002		Henry Yuen	3	8/99

**COMS W4419 Internet Technology, Economics, and Policy. 3 points.****Not offered during 2021-22 academic year.**

Technology, economic and policy aspects of the Internet. Summarizes how the Internet works technically, including protocols, standards, radio spectrum, global infrastructure and interconnection. Micro-economics with a focus on media and telecommunication economic concerns, including competition and monopolies, platforms, and behavioral economics. US constitution, freedom of speech, administrative procedures act and regulatory process, universal service, role of FCC. Not a substitute for CSEE4119. Suitable for non-majors. May not be used as a track elective for the computer science major.

**Fall 2021: COMS W4419**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4419	001/12512	M W 10:10am - 11:25am Room TBA	Henning Schulzrinne	3	25/50

**COMS W4444 Programming and Problem Solving. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and (CSEE W3827)

Hands-on introduction to solving open-ended computational problems. Emphasis on creativity, cooperation, and collaboration. Projects spanning a variety of areas within computer science, typically requiring the development of computer programs. Generalization of solutions to broader problems, and specialization of complex problems to make them manageable. Team-oriented projects, student presentations, and in-class participation required.

**Fall 2021: COMS W4444**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4444	001/12504	M W 1:10pm - 2:25pm Room TBA	Kenneth Ross	3	0/30

**COMS W4460 Principles of Innovation and Entrepreneurship. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) or the instructor's permission.

Team project centered course focused on principles of planning, creating, and growing a technology venture. Topics include: identifying and analyzing opportunities created by technology paradigm shifts, designing innovative products, protecting intellectual property, engineering innovative business models.

**COMS W4560 Introduction to Computer Applications in Health Care and Biomedicine. 3 points.**

Lect: 3.

Prerequisites: Experience with computers and a passing familiarity with medicine and biology. Undergraduates in their senior or junior years may take this course only if they have adequate background in mathematics and receive the instructor's permission.

An overview of the field of biomedical informatics, combining perspectives from medicine, computer science and social science. Use of computers and information in health care and the biomedical sciences, covering specific applications and general methods, current issues, capabilities and limitations of biomedical informatics. Biomedical Informatics studies the organization of medical information, the effective management of information using computer technology, and the impact of such technology on medical research, education, and patient care. The field explores techniques for assessing current information practices, determining the information needs of health care providers and patients, developing interventions using computer technology, and evaluating the impact of those interventions.

**COMS W4701 Artificial Intelligence. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) and any course on probability. Prior knowledge of Python is recommended. Provides a broad understanding of the basic techniques for building intelligent computer systems. Topics include state-space problem representations, problem reduction and and-or graphs, game playing and heuristic search, predicate calculus, and resolution theorem proving, AI systems and languages for knowledge representation, machine learning and concept formation and other topics such as natural language processing may be included as time permits.

**Spring 2021: COMS W4701**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4701	001/13031	T Th 10:10am - 11:25am Online Only	Ansaf Salleb-Aouissi	3	154/150
COMS 4701	V01/17797		Ansaf Salleb-Aouissi	3	13/99

**Fall 2021: COMS W4701**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4701	001/12503	T Th 10:10am - 11:25am Room TBA	Ansaf Salleb-Aouissi	3	155/150
COMS 4701	002/13267	T Th 11:40am - 12:55pm Room TBA	Ansaf Salleb-Aouissi	3	127/150

**COMS W4705 Natural Language Processing. 3 points.**

Lect: 3.

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) or the instructor's permission.

Computational approaches to natural language generation and understanding. Recommended preparation: some previous or concurrent exposure to AI or Machine Learning. Topics include information extraction, summarization, machine translation, dialogue systems, and emotional speech. Particular attention is given to robust techniques that can handle understanding and generation for the large amounts of text on the Web or in other large corpora. Programming exercises in several of these areas.

**Spring 2021: COMS W4705**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4705	001/11933	M W 4:10pm - 5:25pm Online Only	Kathleen McKeown	3	126/155
COMS 4705	V01/17800		Kathleen McKeown	3	14/99

**Fall 2021: COMS W4705**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4705	001/12502	M W 4:10pm - 5:25pm Room TBA	Kathleen McKeown	3	113/110

**COMS W4706 Spoken Language Processing. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) or the instructor's permission.

Computational approaches to speech generation and understanding. Topics include speech recognition and understanding, speech analysis for computational linguistics research, and speech synthesis. Speech applications including dialogue systems, data mining, summarization, and translation. Exercises involve data analysis and building a small text-to-speech system.

**COMS W4725 Knowledge representation and reasoning. 3 points.**Lect: 3. **Not offered during 2021-22 academic year.**

Prerequisites: (COMS W4701)

General aspects of knowledge representation (KR). The two fundamental paradigms (semantic networks and frames) and illustrative systems. Topics include hybrid systems, time, action/plans, defaults, abduction, and case-based reasoning. Throughout the course particular attention is paid to design trade-offs between language expressiveness and reasoning complexity, and issues relating to the use of KR systems in larger applications.

**COMS W4731 Computer Vision I: First Principles. 3.00 points.**

Lect: 3.

Prerequisites: Fundamentals of calculus, linear algebra, and C programming. Students without any of these prerequisites are advised to contact the instructor prior to taking the course.

Prerequisites: Fundamentals of calculus, linear algebra, and C programming. Students without any of these prerequisites are advised to contact the instructor prior to taking the course. Introductory course in computer vision. Topics include image formation and optics, image sensing, binary images, image processing and filtering, edge extraction and boundary detection, region growing and segmentation, pattern classification methods, brightness and reflectance, shape from shading and photometric stereo, texture, binocular stereo, optical flow and motion, 2D and 3D object representation, object recognition, vision systems and applications

**Spring 2021: COMS W4731**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4731	001/11953	M W 10:10am - 11:25am Online Only	Shree Nayar	3.00	91/100

**Fall 2021: COMS W4731**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4731	001/12749	M W 10:10am - 11:25am Room TBA	Shree Nayar	3.00	100/100

**COMS W4732 Computer Vision II: Learning. 3.00 points.**

Advanced course in computer vision. Topics include convolutional networks and back-propagation, object and action recognition, self-supervised and few-shot learning, image synthesis and generative models, object tracking, vision and language, vision and audio, 3D representations, interpretability, and bias, ethics, and media deception

**COMS W4733 Computational Aspects of Robotics. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (COMS W3134 or COMS W3136COMS W3137)

Introduction to robotics from a computer science perspective. Topics include coordinate frames and kinematics, computer architectures for robotics, integration and use of sensors, world modeling systems, design and use of robotic programming languages, and applications of artificial intelligence for planning, assembly, and manipulation.

**Spring 2021: COMS W4733**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4733	001/16699	F 2:10pm - 4:40pm 309 Havemeyer Hall	Tony Dear	3	114/130

**COMS 4733 V01/18034**

			Tony Dear	3	3/3
--	--	--	-----------	---	-----

**Fall 2021: COMS W4733**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4733	001/12501	T Th 4:10pm - 5:25pm Room TBA	Tony Dear	3	0/110

**COMS W4735 Visual Interfaces to Computers. 3 points.**

Lect: 3.

Prerequisites: (COMS W3134 or COMS W3136 or COMS W3137) Visual input as data and for control of computer systems. Survey and analysis of architecture, algorithms, and underlying assumptions of commercial and research systems that recognize and interpret human gestures, analyze imagery such as fingerprint or iris patterns, generate natural language descriptions of medical or map imagery. Explores foundations in human psychophysics, cognitive science, and artificial intelligence.

**COMS W4737 Biometrics. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: a background at the sophomore level in computer science, engineering, or like discipline.

In this course. we will explore the latest advances in biometrics as well as the machine learning techniques behind them. Students will learn how these technologies work and how they are sometimes defeated. Grading will be based on homework assignments and a final project. There will be no midterm or final exam. This course shares lectures with COMS E6737. Students taking COMS E6737 are required to complete additional homework problems and undertake a more rigorous final project. Students will only be allowed to earn credit for COMS W4737 or COMS E6737 and not both.

**COMS W4762 Machine Learning for Functional Genomics. 3 points.**

Prerequisites: Proficiency in a high-level programming language (Python/ R/Julia). An introductory machine learning class (such as COMS 4771 Machine Learning) will be helpful but is not required.

Prerequisites: see notes re: points

This course will introduce modern probabilistic machine learning methods using applications in data analysis tasks from functional genomics, where massively-parallel sequencing is used to measure the state of cells: e.g. what genes are being expressed, what regions of DNA ("chromatin") are active ("open") or bound by specific proteins.

**COMS E4762 Machine Learning for Functional Genomics. 3.00 points.**

This course will introduce modern probabilistic machine learning methods using applications in data analysis tasks from functional genomics, where massively-parallel sequencing is used to measure the state of cells: e.g. what genes are being expressed, what regions of DNA ("chromatin") are active ("open") or bound by specific proteins

**Spring 2021: COMS E4762**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4762	001/12573	M W 4:10pm - 5:25pm Online Only	David Knowles	3.00	59/100
COMS 4762	V01/17896		David Knowles	3.00	4/99

**COMS W4771 Machine Learning. 3 points.**

Lect: 3.

Prerequisites: Any introductory course in linear algebra and any introductory course in statistics are both required. Highly recommended: COMS W4701 or knowledge of Artificial Intelligence.

Topics from generative and discriminative machine learning including least squares methods, support vector machines, kernel methods, neural networks, Gaussian distributions, linear classification, linear regression, maximum likelihood, exponential family distributions, Bayesian networks, Bayesian inference, mixture models, the EM algorithm, graphical models and hidden Markov models. Algorithms implemented in MATLAB.

**Spring 2021: COMS W4771**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4771	001/11934	T Th 1:10pm - 2:25pm Online Only	Nakul Verma	3	95/110
COMS 4771	002/11935	T Th 2:40pm - 3:55pm Online Only	Nakul Verma	3	74/110
COMS 4771	V01/17804		Nakul Verma	3	7/99

**Fall 2021: COMS W4771**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4771	001/12498	T Th 2:40pm - 3:55pm Room TBA	Nakul Verma	3	0/110
COMS 4771	002/12499	T Th 1:10pm - 2:25pm Room TBA	Daniel Hsu	3	70/110

**COMS W4772 Advanced Machine Learning. 3 points.**

Lect: 3.

Prerequisites: (COMS W4771) or instructor's permission; knowledge of linear algebra & introductory probability or statistics is required. An exploration of advanced machine learning tools for perception and behavior learning. How can machines perceive, learn from, and classify human activity computationally? Topics include appearance-based models, principal and independent components analysis, dimensionality reduction, kernel methods, manifold learning, latent models, regression, classification, Bayesian methods, maximum entropy methods, real-time tracking, extended Kalman filters, time series prediction, hidden Markov models, factorial HMMS, input-output HMMs, Markov random fields, variational methods, dynamic Bayesian networks, and Gaussian/Dirichlet processes. Links to cognitive science.

**COMS W4773 Machine Learning Theory. 3 points.**

Prerequisites: Machine Learning (COMS W4771). Background in probability and statistics, linear algebra, and multivariate calculus. Ability to program in a high-level language, and familiarity with basic algorithm design and coding principles.

Prerequisites: see notes re: points

Core topics from unsupervised learning such as clustering, dimensionality reduction and density estimation will be studied in detail. Topics in clustering: k-means clustering, hierarchical clustering, spectral clustering, clustering with various forms of feedback, good initialization techniques and convergence analysis of various clustering procedures. Topics in dimensionality reduction: linear techniques such as PCA, ICA, Factor Analysis, Random Projections, non-linear techniques such as LLE, IsoMap, Laplacian Eigenmaps, tSNE, and study of embeddings of general metric spaces, what sorts of theoretical guarantees can one provide about such techniques. Miscellaneous topics: design and analysis of data structures for fast Nearest Neighbor search such as Cover Trees and LSH. Algorithms will be implemented in either Matlab or Python.

**COMS W4774 Unsupervised Learning. 3 points.**

Prerequisites: Solid background in multivariate calculus, linear algebra, basic probability, and algorithms.

Prerequisites: see notes re: points

Theoretical study of algorithms for machine learning and high-dimensional data analysis. Topics include high-dimensional probability, theory of generalization and statistical learning, online learning and optimization, spectral analysis.

**Spring 2021: COMS W4774**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4774	001/11936	T Th 1:10pm - 2:25pm Online Only	Daniel Hsu	3	34/45

**Fall 2021: COMS W4774**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4774	001/12500	T Th 1:10pm - 2:25pm Room TBA	Nakul Verma	3	0/50

**COMS W4775 Causal Inference. 3.00 points.**

Prerequisites: Discrete Math, Calculus, Statistics (basic probability, modeling, experimental design), some programming experience.

Prerequisites: see notes re: points

Causal Inference theory and applications. The theoretical topics include the 3-layer causal hierarchy, causal bayesian networks, structural learning, the identification problem and the do-calculus, linear identifiability, bounding, and counterfactual analysis. The applied part includes intersection with statistics, the empirical-data sciences (social and health), and AI and ML

**Fall 2021: COMS W4775**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4775	001/14070	M W 4:10pm - 5:25pm Room TBA	Elias Bareinboim	3.00	0/40

**COMS E4775 Causal Inference. 3 points.**

Prerequisites: (COMS4711W) and Discrete Math, Calculus, Statistics (basic probability, modeling, experimental design), Some programming experience

Causal Inference theory and applications. The theoretical topics include the 3-layer causal hierarchy, causal bayesian networks, structural learning, the identification problem and the do-calculus, linear identifiability, bounding, and counterfactual analysis. The applied part includes intersection with statistics, the empirical-data sciences (social and health), and AI and ML.

**COMS W4776 Machine Learning for Data Science. 3 points.**

Lect.: 3

Prerequisites: (STAT GU4001 or IEOR E4150) and linear algebra.

Introduction to machine learning, emphasis on data science.

Topics include least square methods, Gaussian distributions, linear classification, linear regression, maximum likelihood, exponential family distributions, Bayesian networks, Bayesian inference, mixture models, the EM algorithm, graphical models, hidden Markov models, support vector machines kernel methods. Emphasizes methods and problems relevant to big data. Students may not receive credit for both COMS W4771 and W4776.



**COMS W4901 Projects in Computer Science. 1-3 points.**

Prerequisites: Approval by a faculty member who agrees to supervise the work.

A second-level independent project involving laboratory work, computer programming, analytical investigation, or engineering design. May be repeated for credit, but not for a total of more than 3 points of degree credit. Consult the department for section assignment.

**Fall 2021: COMS W4901**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4901	000/14024			1-3	0/0

**COMS W4910 Curricular Practical Training. 1 point.**

Prerequisites: obtained internship and approval from faculty advisor.

Only for M.S. students in the Computer Science department who need relevant work experience as part of their program of study. Final report required. This course may not be taken for pass/fail credit or audited.

**COMS W4995 Special topics in computer science, I. 3 points.**

Lect: 3.

Prerequisites: Instructor's permission.

Special topics arranged as the need and availability arises. Topics are usually offered on a one-time basis. Since the content of this course changes each time it is offered, it may be repeated for credit. Consult the department for section assignment.

**Spring 2021: COMS W4995**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4995	001/13033	M W 10:10am - 11:25am Online Only	Daniel Bauer	3	44/50
COMS 4995	002/17129	Th 6:10pm - 8:00pm Online Only	Tristan Boutros	3	54/60
COMS 4995	003/14430	T Th 11:40am - 12:55pm Online Only	Augustin Chaintreau	3	28/60
COMS 4995	004/14178	T Th 11:40am - 12:55pm Online Only	Andrew Blumberg	3	21/60
COMS 4995	005/11937	F 10:10am - 12:40pm Online Only	Smaranda Muresan, Isabelle Zaugg	3	30/38
COMS 4995	006/11938	F 10:10am - 12:00pm Online Only	Bjarne Stroustrup	3	31/30
COMS 4995	007/12252	M 10:10am - 12:40pm Online Only	Elias Bareinboim	3	13/30
COMS 4995	008/13315	T Th 4:10pm - 5:25pm Online Only	Alexandr Andoni	3	38/70
COMS 4995	009/17101	T 6:10pm - 8:00pm Online Only	Agnes Chang	3	36/40
COMS 4995	010/16379	Th 7:00pm - 9:30pm Online Only	Joshua Gordon	3	176/185
COMS 4995	011/16382	T 7:00pm - 9:30pm Online Only	Adam Kelleher	3	45/100
COMS 4995	V01/17814		Daniel Bauer	3	2/99
COMS 4995	V03/19311		Augustin Chaintreau	3	1/99
COMS 4995	V08/17812		Alexandr Andoni	3	3/99
COMS 4995	V10/17977		Joshua Gordon	3	9/99

**Fall 2021: COMS W4995**

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
COMS 4995	001/12495	T 4:10pm - 6:40pm Room TBA	Paul Blaer	3	0/35
COMS 4995	002/12496	M W 5:40pm - 6:55pm Room TBA	Stephen Edwards	3	56/60
COMS 4995	003/12497	T Th 8:40am - 9:55am Room TBA	Junfeng Yang	3	21/120
COMS 4995	004/13363	F 10:10am - 12:40pm Room TBA	Augustin Chaintreau	3	18/40
COMS 4995	005/14028	T Th 2:40pm - 3:55pm Room TBA		3	0/50
COMS 4995	006/13800	T Th 2:40pm - 3:55pm Room TBA	Peter Belhumeur	3	13/60
COMS 4995	010/13929	M 7:00pm - 9:30pm Room TBA	Bryan Gibson	3	23/120

**COMS W4996 Special topics in computer science, II. 3 points.**

Lect: 3. Not offered during 2021-22 academic year.

Prerequisites: Instructor's permission.

A continuation of COMS W4995 when the special topic extends over two terms.

## Computer Science - English

## Computer Science - Electrical Engineering

### CSEE W3827 Fundamentals of Computer Systems. 3 points.

Lect: 3.

Prerequisites: an introductory programming course.

Fundamentals of computer organization and digital logic. Boolean algebra, Karnaugh maps, basic gates and components, flipflops and latches, counters and state machines, basics of combinational and sequential digital design. Assembly language, instruction sets, ALU's, single-cycle and multi-cycle processor design, introduction to pipelined processors, caches, and virtual memory.

#### Spring 2021: CSEE W3827

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
CSEE 3827	001/16180	T Th 10:10am - 11:25am 301 Pupin Laboratories	Daniel Rubenstein	3	111/320
CSEE 3827	002/17382	T Th 11:40am - 12:55pm 214 Pupin Laboratories	Daniel Rubenstein	3	86/320

#### Fall 2021: CSEE W3827

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
CSEE 3827	001/12486	T Th 10:10am - 11:25am Room TBA	Martha Kim	3	88/150
CSEE 3827	002/12487	T Th 11:40am - 12:55pm Room TBA	Martha Kim	3	70/150

### CSEE W4119 COMPUTER NETWORKS. 3.00 points.

Lect: 3.

Prerequisites: Comfort with basic probability. Programming fluency in Python, C++, Java, or Ruby (please see section course page for specific language requirements).

Prerequisites: Comfort with basic probability. Programming fluency in Python, C, Java, or Ruby (please see section course page for specific language requirements). Introduction to computer networks and the technical foundations of the Internet, including applications, protocols, local area networks, algorithms for routing and congestion control, security, elementary performance evaluation. Several written and programming assignments required.

#### Spring 2021: CSEE W4119

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
CSEE 4119	001/11947	M W 1:10pm - 2:25pm Online Only	Henning Schulzrinne	3.00	128/160
CSEE 4119	V01/19945		Henning Schulzrinne	3.00	2/99

### CSEE W4121 COMPUTER SYSTEMS FOR DATA SCIENCE. 3 points.

Prerequisites: Background in Computer System Organization and good working knowledge of C/C++. Corequisites: CSOR W4246 Algorithms for Data Science, STAT W4203 Probability Theory, or equivalent as approved by faculty advisor.

An introduction to computer architecture and distributed systems with an emphasis on warehouse scale computing systems. Topics will include fundamental tradeoffs in computer systems, hardware and software techniques for exploiting instruction-level parallelism, data-level parallelism and task level parallelism, scheduling, caching, prefetching, network and memory architecture, latency and throughput optimizations, specialization, and an introduction to programming data center computers.

### CSEE W4140 Networking Laboratory. 3 points.

Lect: 3.

Prerequisites: (CSEE W4119) or equivalent.

In this course, students will learn how to put "principles into practice," in a hands-on-networking lab course. The course will cover the technologies and protocols of the Internet using equipment currently available to large internet service providers such as CISCO routers and end systems. A set of laboratory experiments will provide hands-on experience with engineering wide-area networks and will familiarize students with the Internet Protocol (IP), Address Resolution Protocol (ARP), Internet Control Message Protocol (ICMP), User Datagram Protocol (UDP) and Transmission Control Protocol (TCP), the Domain Name System (DNS), routing protocols (RIP, OSPF, BGP), network management protocols (SNMP, and application-level protocols (FTP, TELNET, SMTP).

### CSEE W4823 Advanced Logic Design. 3 points.

Lect: 3.

Prerequisites: (CSEE W3827) or a half semester introduction to digital logic, or the equivalent.

An introduction to modern digital system design. Advanced topics in digital logic: controller synthesis (Mealy and Moore machines); adders and multipliers; structured logic blocks (PLDs, PALs, ROMs); iterative circuits. Modern design methodology: register transfer level modelling (RTL); algorithmic state machines (ASMs); introduction to hardware description languages (VHDL or Verilog); system-level modelling and simulation; design examples.

#### Fall 2021: CSEE W4823

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
CSEE 4823	001/12057	T Th 2:40pm - 3:55pm Room TBA	Mingoo Seok	3	27/80

### CSEE W4824 Computer Architecture. 3 points.

Lect: 3.

Prerequisites: (CSEE W3827) or equivalent.

Focuses on advanced topics in computer architecture, illustrated by case studies from classic and modern processors. Fundamentals of quantitative analysis. Pipelining. Memory hierarchy design. Instruction-level and thread-level parallelism. Data-level parallelism and graphics processing units. Multiprocessors. Cache coherence. Interconnection networks. Multi-core processors and systems-on-chip. Platform architectures for embedded, mobile, and cloud computing.

#### Fall 2021: CSEE W4824

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
CSEE 4824	001/12488	M W 10:10am - 11:25am Room TBA	Simha Sethumadhavan	3	27/60

### CSEE W4840 Embedded Systems. 3 points.

Lect: 3.

Prerequisites: (CSEE W4823)

Embedded system design and implementation combining hardware and software. I/O, interfacing, and peripherals. Weekly laboratory sessions and term project on design of a microprocessor-based embedded system including at least one custom peripheral. Knowledge of C programming and digital logic required.

**CSEE W4868 System-on-chip platforms. 3 points.**

Prerequisites: (COMS W3157) and (CSEE W3827)

Design and programming of System-on-Chip (SoC) platforms. Topics include: overview of technology and economic trends, methodologies and supporting CAD tools for system-level design, models of computation, the SystemC language, transaction-level modeling, software simulation and virtual platforms, hardware-software partitioning, high-level synthesis, system programming and device drivers, on-chip communication, memory organization, power management and optimization, integration of programmable processor cores and specialized accelerators. Case studies of modern SoC platforms for various classes of applications.

Fall 2021: CSEE W4868

Course Number	Section/Call Number	Times/Location	Instructor	Points	Enrollment
CSEE 4868	001/12489	T Th 11:40am - 12:55pm Room TBA	Luca Carloni	3	21/60

## Computer Science - Biomedical Engineering

**CBMF W4761 Computational Genomics. 3 points.**

Lect: 3.

Prerequisites: Working knowledge of at least one programming language, and some background in probability and statistics.

Computational techniques for analyzing genomic data including DNA, RNA, protein and gene expression data. Basic concepts in molecular biology relevant to these analyses. Emphasis on techniques from artificial intelligence and machine learning. String-matching algorithms, dynamic programming, hidden Markov models, expectation-maximization, neural networks, clustering algorithms, support vector machines. Students with life sciences backgrounds who satisfy the prerequisites are encouraged to enroll.