Computer Science

Subject: Computer Science

Computer Science 1

Great Ideas in Computer Science (119953)

Henry Leitner

2020 Spring (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

An introduction to the most important discoveries and intellectual paradigms in computer science, designed for students with little or no previous background. Explores problem-solving using high and low-level programming languages; presents an integrated view of computer systems, from switching circuits up through compilers and GUI design. Examines theoretical and practical limitations related to unsolvable and intractable computational problems, and the social and ethical dilemmas presented by such issues as software unreliability and invasions of privacy.

Course Notes: **May not be taken for credit after completing Computer Science 50.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 10

Elements of Data Science (212950)

Hanspeter Pfister

Joseph Blitzstein

Xiao-Li Meng

Liberty Vittert

2020 Spring (4 Credits) **Schedule:** MWF 0300 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** 100

Data science combines data, statistical analysis, and computation to gain insights and make useful inferences and predictions. This course will take a holistic approach to helping students understand the key factors involved, from data collection and exploratory data analysis to modeling, evaluation, and communication of results. Working on case studies and a final project in teams will provide students with hands-on experience with the data science process using state-of-the-art tools. Emphasis will be given to the strengths, trade-offs, and limitations of each method to highlight the importance of merging analytical skills with critical quantitative thinking.

Course Notes: **Also offered as STAT 10. Students may not take both for credit.**

Please note that the enrollment cap of 100 is a combined total for both STAT 10 and COMPSCI 10.

Class Notes: **If you are interested in joining this course please fill out this form [https://forms.gle/CWG6j4qsiFb6gDRt5] by Wednesday, January 29, 11: 59 pm EST. We will notify you on Friday, January 31.**

Requirements: **Anti-requisite: Cannot be taken for credit if AC 209A or CS 109A or STAT10 or STAT 121A is already complete.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
Quantitative Reasoning with Data	Yes
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 20

Discrete Mathematics for Computer Science (128073)

Rebecca Nesson

2020 Spring (4 Credits) **Schedule:** MWF 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Widely applicable mathematical tools for computer science, including topics from logic, set theory, combinatorics, number theory, probability theory, and graph theory. Practice in reasoning formally and proving theorems.

Course Notes: **Covers material used in Computer Science 121 and Computer Science 124. Ordinarily, not to be taken after those courses or after courses such as Applied Mathematics 106, Applied Mathematics 107, Mathematics 101, and Mathematics 153.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS: Final Assessment Category	Three-hour Exam

Computer Science 50

Introduction to Computer Science (152514)

David Malan

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: None **Enrollment Cap:** n/a

Introduction to the intellectual enterprises of computer science and the art of programming. This course teaches students how to think algorithmically and solve problems efficiently. Topics include abstraction, algorithms, data structures, encapsulation, resource management, security, and software engineering. Languages include C, Python, and SQL plus students' choice of: HTML, CSS, and JavaScript (for web development); Java or Swift (for mobile app development); or Lua (for game development). Problem sets inspired by the arts, humanities, social sciences, and sciences. Course culminates in a final project.

Designed for concentrators and non-concentrators alike, with or without prior programming experience. Two thirds of CS50 students have never taken CS before. Among the overarching goals of this course are to inspire students to explore unfamiliar waters, without fear of failure, create an intensive, shared experience, accessible to all students, and build community among students.

Class Notes: **This course ordinarily meets for lectures in Sanders Theatre on Mondays, 3pm–5pm, but the course's first lecture will be in Sanders Theatre on Wednesday, 9/4/19, 3pm–5pm, during shopping period. Students are expected to attend the course's first eight lectures in person unless simultaneously enrolled in (or, during shopping period, shopping) another course that meets at the same or overlapping time, in which case they may watch CS50's lectures online and attend the other course in person. (The Ad Board has already granted this exception for CS50; no other steps are required.) Students with other academic or athletic conflicts should email the course's heads. After the course's eighth lecture, all students will watch their choice of lectures (on web development, mobile app development, or game development) online. CS50 is ordinarily graded SAT/UNS, though students whose concentration requires letter grades should change their grading status to letter-graded by the term's fifth Monday. Students may take CS50 SAT/UNS to fulfill the Science and Engineering and Applied Science distribution requirement or the Quantitative Reasoning with Data requirement, but not both. First years may take both CS50 and a freshman seminar SAT/UNS. Graduate students are welcome to cross-register for CS50. All students are expected to attend an orientation meeting during the second week of term; students with conflicts may watch online. Required sections to be arranged. See cs50.harvard.edu for FAQs, syllabus, and what's new for Fall 2019.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
Quantitative Reasoning with Data	Yes
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 50

Introduction to Computer Science (152514)

David Malan

Brian Yu

2020 Spring (4 Credits) **Schedule:** T 0300 PM - 0545 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Introduction to the intellectual enterprises of computer science and the art of programming. This course teaches students how to think algorithmically and solve problems efficiently. Topics include abstraction, algorithms, data structures, encapsulation, resource management, security, and software engineering. Languages include C, Python, and SQL plus HTML, CSS, and JavaScript. Problem sets inspired by the arts, humanities, social sciences, and sciences. Course culminates in a final project.

Class Notes: **This spring version of CS50 is for undergraduate concentrators who**

were unable to take the course in Fall 2019. All students, including concentrators and non-concentrators, are encouraged to take CS50 in fall term instead. See cs50.harvard.edu/spring for differences between fall term and spring term. Students must register via my.harvard for and attend weekly class meetings on Tuesdays, 3pm–5:45pm. Instructor-led tutorials to be arranged.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Not Available for Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 51

Abstraction and Design in Computation (112960)

Stuart Shieber

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: None **Enrollment Cap:** n/a

Fundamental concepts in the design of computer programs, emphasizing the crucial role of abstraction. The goal of the course is to give students insight into the difference between programming and programming well. To emphasize the differing approaches to expressing programming solutions, you will learn to program in a variety of paradigms -- including functional, imperative, and object-oriented. Important ideas from software engineering and models of computation will inform these different views of programming.

Course Notes: **Formerly Introduction to Computer Science II.**

Class Notes: **Students interested in enrolling in CS51 for spring 2020 should make sure to attend the two introductory lectures on January 28 and 30 at 10:30am in Science Center B.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 61

Systems Programming and Machine Organization (123623)

Eddie Kohler

Michael Smith

2019 Fall (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Fundamentals of computer systems programming, machine organization, and performance tuning. This course provides a solid background in systems programming and a deep understanding of low-level machine organization and design. Topics include C and assembly language programming, program

optimization, memory hierarchy and caching, virtual memory and dynamic memory management, concurrency, threads, and synchronization.

Recommended Prep: **CS50 or some experience programming in C.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Final Assessment Category	Three-hour Exam
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students

Computer Science 91R

Supervised Reading and Research (113257)

Stephen Chong

Boaz Barak

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Supervised individual study of advanced topics in computer science. A student wishing to enroll in Computer Science 91r must be accepted by a faculty member who will supervise the course work. Additional information and a form are available via https://harvardcs.info/forms/#cs-91r-form. The form must be filled out and signed by the student and faculty supervisor. Students writing theses may enroll in this course while conducting thesis research and writing.

Course Notes: **At most two terms of Computer Science 91r may be taken for academic credit. May not be taken Pass/Fail. Students wishing more information about the range of suitable projects or faculty supervisors should consult the Director of Undergraduate Studies.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students

Computer Science 91R

Supervised Reading and Research (113257)

Stephen Chong

Boaz Barak

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Supervised individual study of advanced topics in computer science. A student wishing to enroll in Computer Science 91r must be accepted by a faculty member who will supervise the course work. Additional information and a form are available via https://harvardcs.info/forms/#cs-91r-form. The form must be filled out and signed by the student and faculty supervisor. Students writing theses may enroll in

this course while conducting thesis research and writing.

Course Notes: **At most two terms of Computer Science 91r may be taken for academic credit. May not be taken Pass/Fail. Students wishing more information about the range of suitable projects or faculty supervisors should consult the Director of Undergraduate Studies.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 100

CS+X: Software Engineering in the Arts and Humanities (207609)

Douglas Lloyd

2019 Fall (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Introduction to applications of computer science (including web technologies, visualization, and database design) to domains in the arts and humanities. Emphasis on principles of software engineering and best practices, including code reviews, source control, and testing. Languages include JavaScript and SQL. Students work in teams to design and implement solutions to problems proposed by faculty from departments across campus. Offered jointly with Yale University.

Class Notes: **Enrollment limited. Apply at cs.harvard.edu/100.**

Recommended Prep: **CS50 or equivalent required.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students

Computer Science 105

Privacy and Technology (125407)

James Waldo

2019 Fall (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: Instructor **Enrollment Cap:** 36

What is privacy, and how is it affected by recent developments in technology? This course critically examines popular concepts of privacy and uses a rigorous analysis of technologies to understand the policy and ethical issues at play. Case studies: database anonymity, research ethics, wiretapping, surveillance, and others. Course relies on some technical material, but is open and accessible to all students, especially those with interest in economics, engineering, political science, computer science, sociology, biology, law, government, philosophy.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 108

Intelligent Systems: Design and Ethical Challenges (160419)

Milind Tambe

David Grant

2020 Spring (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** 20

This course explores the use of artificial intelligence to tackle difficult social problems, and considers how to address ethical challenges that arise through appropriate design techniques. Drawing on work by computer scientists, philosophers, and social scientists, we will analyze several real-world case studies featuring the application of AI methods to problems in public health, conservation and public safety, including HIV prevention, tuberculosis prevention, predictive policing, and wildlife conservation. The course will also feature guest lectures from experts in social work, anthropology, criminology, and public health.

Course Notes: **The course presumes basic programming ability, but welcomes concentrators in the humanities and social sciences as well as science and engineering.**

Recommended Prep: **CS 50**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 109A

Data Science 1: Introduction to Data Science (109899)

Pavlos Protopapas

Kevin A. Rader

Christopher Tanner

2019 Fall (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Data Science 1 is the first half of a one-year introduction to data science. The course will focus on the analysis of messy, real life data to perform predictions using statistical and machine learning methods. Material covered will integrate the five key facets of an investigation using data: (1) data collection - data wrangling, cleaning, and sampling to get a suitable data set; (2) data management - accessing data quickly and reliably; (3) exploratory data analysis – generating hypotheses and building intuition; (4) prediction or statistical learning; and (5) communication – summarizing results through visualization, stories, and

interpretable summaries. Part one of a two part series. The curriculum for this course builds throughout the academic year. Students are strongly encouraged to enroll in both the fall and spring course within the same academic year.

Course Notes: **Only one of CS 109a, AC 209a, or Stat 121a can be taken for credit. Students who have previously taken CS 109, AC 209, or Stat 121 cannot take CS 109a, AC 209a, or Stat 121a for credit.**

Recommended Prep: **Programming knowledge at the level of CS 50 or above, and statistics knowledge at the level of Stat 100 or above (Stat 110 recommended).**

Requirements: **Not to be taken in addition to Applied Computation 209, or Applied Computation 209A, or Statistics 121, or Statistics 121A.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
Full Year Course	Divisible Course
Quantitative Reasoning with Data	Yes
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 109B

Data Science 2: Advanced Topics in Data Science (203546)

Pavlos Protopapas

Mark Glickman

Christopher Tanner

2020 Spring (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Data Science 2 is the second half of a one-year introduction to data science. Building upon the material in Data Science 1, the course introduces advanced methods for data wrangling, data visualization, and statistical modeling and prediction. Topics include big data and database management, interactive visualizations, nonlinear statistical models, and deep learning. Part two of a two part series. The curriculum for this course builds throughout the academic year. Students are strongly encouraged to enroll in both the fall and spring course within the same academic year.

Course Notes: **Can only be taken after successful completion of CS 109a, AC 209a, Stat 121a, or equivalent. Students who have previously taken CS 109, AC 209, or Stat 121 cannot take CS 109b, AC 209b, or Stat 121b for credit.**

Recommended Prep: **CS 109a, AC 209a, or Stat 121a required.**

Requirements: **Requisite: (Must take CS 109A OR APCOMP 209A OR STAT 121A before taking CS 109B) AND (Not to be taken in addition to CS 109, OR APCOMP 209, OR APCOMP 209B, OR STAT 121, OR STAT 121B.)**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
Quantitative Reasoning with Data	Yes

FAS: Course Level	For Undergraduate and Graduate Students
Full Year Course	Divisible Course

Computer Science 121

Introduction to Theoretical Computer Science (119064)

Boaz Barak

Madhu Sudan

2019 Fall (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Computation occurs over a variety of substrates including silicon, neurons, DNA, the stock market, bee colonies and many others. In this course we will study the fundamental capabilities and limitations of computation, including the phenomenon of universality and the duality of code and data. Some of the questions we will touch upon include: Are there functions that cannot be computed? Are there true mathematical statements that can't be proven? Are there encryption schemes that can't be broken? Is randomness ever useful for computing? Can we use the quirks of quantum mechanics to speed up computation?

Course Notes: **Students may not receive credit for both CS 121 and CS 125.**

Class Notes: **Midterms will be on Thursday, October 10, 7pm and Thursday, November 14, 7pm.**

Recommended Prep: **Experience in formal mathematics at the level of CS 20. A "Homework Zero" will be posted on the course website cs121.boazbarak.org by July 1st. It is highly recommended that students complete it before the first lecture.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Computer Science 124

Data Structures and Algorithms (115384)

Michael Mitzenmacher

2020 Spring (4 Credits) **Schedule:** MW 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Design and analysis of efficient algorithms and data structures. Algorithm design methods, graph algorithms, approximation algorithms, and randomized algorithms are covered.

Course Notes: **Starting in the spring of 2013, Computer Science 124 will assume background from Computer Science 20. Students will not receive credit for both CS 124 and CS 125.**

Recommended Prep: **Computer Science 50 or equivalent; Computer Science 51 is helpful.**

Additional Course Attributes:

Attribute	Value(s)
Quantitative Reasoning with Data	Yes
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	For Undergraduate and Graduate Students

Computer Science 126

Fairness and Privacy: Perspectives of Law and Probability (204972)

Cynthia Dwork

Martha Minow

2019 Fall (4 Credits)

Schedule: W 0900 AM - 1015 AM
M 0900 AM - 1010 AM

Instructor Permissions: Instructor

Enrollment Cap: 24

Students will learn to analyze and mitigate privacy loss, unfairness, and lack of statistical validity, in data analysis. Principal techniques will come from cryptography, differential privacy, and the newly emerging areas of adaptive data analysis and fairness in machine learning.

Course Notes: **Course enrollment limited. Offered jointly by HLS and SEAS, with interwoven tracks emphasizing, respectively, law and computer science, the tracks will meet jointly and separately. Admission is by permission of instructors; applicants should submit letters of inquiry with CVs to Rachel Keeler, rkeeler@law.harvard.edu, by August 25, 2019.**

Class Notes: **Please note that we are still reviewing applications for the CS portion of this course, and final acceptance decisions may come later in shopping week. CS Applicants should submit letters of inquiry with CVs to Allison Choat, achoat@g.harvard.edu, by midnight, Wednesday, September 4. All applicants should plan to attend an opening lecture dinner for the class at 7:00 PM, Tuesday, Sept. 3rd, on HLS campus (room TBD). To attend the dinner, e-mail Allison Choat at achoat@g.harvard.edu prior to Thursday, August 29, at 3:30 PM. Whether or not you can attend the dinner, if you have not been informed of your application status, please plan to attend the first formal CS-specific class on Wednesday, September 4th, 9:00-10:15 AM, in Maxwell-Dworkin 221.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 127

Cryptography (109566)

Boaz Barak

2020 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Cryptography is as old as human communication itself, but has undergone a revolution in the last few decades. It is now about much more than "secret writing" and includes seemingly paradoxical notions such as communicating securely without a shared secret, and computing on encrypted data. In this challenging but rewarding course we will start from the basics of private and public key cryptography and go all the way up to advanced notions such as fully homomorphic encryption and software obfuscation. This is a proof-based course that will be best appreciated by mathematically mature students.

Course Notes: **This course will be offered in both an undergraduate and graduate versions. The graduate version will involve an additional project.**

Recommended Prep: **Comfort with mathematical proofs at the level of CS121, CS124 or similar. Please contact the instructor if you're unsure if your background is sufficient.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students
FAS: Final Assessment Category	Three-hour Exam
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 136

Economics and Computation (128164)

David Parkes

2019 Fall (4 Credits) **Schedule:** TR 0900 AM - 1015 AM

Instructor Permissions: None **Enrollment Cap:** n/a

The interplay between economic thinking and computational thinking as it relates to electronic commerce, social networks, collective intelligence and networked systems. Topics covered include: game theory, peer production, reputation and recommender systems, prediction markets, crowd sourcing, network influence and dynamics, auctions and mechanisms, privacy and security, matching and allocation problems, computational social choice and behavioral game theory. Emphasis will be given to core methodologies, with students engaged in theoretical, computational and empirical exercises.

Course Notes: **Formerly Computer Science 186**

Recommended Prep: **Applied Math 21b, Computer Science 51 or equivalent, Statistics 110, and one of Computer Science 181, Computer Science 182, Economics 1011a, Economics 1052, or Economics 1056.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 141

Computing Hardware (113856)

Vijay Janapa Reddi

2020 Spring (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This course introduces fundamentals in designing and building modern information devices and systems that interface with the real world. It focuses on *digital* devices and systems, and it complements ENG-SCI 152, which focuses on devices and systems that use analog electronics. Topics include: combinational and sequential logic; computer architecture; machine code; and altogether the infrastructure and computational framework composing a MIPS processor. Consideration is given in design to interactions between hardware and software systems. Students will design application specific hardware for an embedded system.

Recommended Prep: **CS50 or programming experience required.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 143

Computer Networks (118418)

H. Kung

2019 Fall (4 Credits) **Schedule:** MW 0430 PM - 0545 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Computer networking has enabled the emergence of mobile and cloud computing, creating two of the most important technological breakthroughs in computing of the past decade. We expect three major focuses in the next ten years. First, we will witness the emergence of 5G wireless mobile networks, which will begin to replace the current 4G networks as early as 2020, enabling new applications and paradigm shifts in edge computing, such as uploading sensor data for AI applications everywhere. Second, cyber security, and in particular its relation to networking and supply chain security for 5G network infrastructure, will receive unprecedented attention from industry. Third, blockchain technology, which has powered Bitcoin, is creating a new trusted network infrastructure that will allow information to be distributed but not copied. While these areas are each rich in intellectual content on their own, they will also interplay with one other, creating interesting opportunities for those versed in all three. In order to play a role in this era of network-based computing, students must have a thorough understanding of these networking technologies and applications. Beyond teaching the basic networking protocols, which have become very mature and can be treated as a black box, in CS 143, we will teach new networking issues and topics of significance. This focus on upcoming wireless, cyber security as it relates to networks, network infrastructure, and the broader supply chain, and blockchain advancements is the motivation for CS 143 this semester. Students in the course will read and discuss basic material as well as the latest literature, work on homework assignments, gain hands-on experience through network programming, and have the opportunity to present the concepts and insights learned through a final project.

Recommended Prep: **CS50 (or programming experience) and a strong interest in the subject matter. Lab sessions will be provided to give extra support.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students

All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 145

Networking at Scale (208314)

Minlan Yu

2020 Spring (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Clouds have become critical infrastructures for many applications in business and society (e.g., social media, public health, and entertainment). In this course, we will take a look inside the cloud infrastructure and learn critical technology trends and challenges in the networking and computing layers. We will discuss the design choices of performance, scalability, manageability, and cost in various cloud companies such as Amazon, Google, Microsoft, and Facebook. This course includes lectures and system programming projects.
More information can be found at https://github.com/minlanyu/cs145spring20.

Recommended Prep: **System programming at the level of CS 61 or CS 143**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 146

Computer Architecture (113270)

David Brooks

2019 Fall (4 Credits) **Schedule:** F 0900 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Review of the fundamental structures in modern processor design. Topics include computer organization, memory system design, pipelining, and other techniques to exploit parallelism. Emphasis on a quantitative evaluation of design alternatives and an understanding of timing issues.

Recommended Prep: **Computer Science 61**

Requirements: **Prerequisite: Computer Science 141**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 148

Design of VLSI Circuits and Systems (110990)

Gu-Yeon Wei

2020 Spring (4 Credits) **Schedule:** WF 0300 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** 16

Presentation of concepts and techniques for the design and fabrication of VLSI systems and digital MOS integrated circuits. Topics include: basic semiconductor theory; MOS transistors and digital MOS circuits design; synchronous machines, clocking, and timing issues; high-level description and modeling of VLSI systems; synthesis and place and route design flows; and testing of VLSI circuits and systems. Various CAD tools for design, simulation, and verification are extensively used.

Course Notes: **Offered in alternate years.**

Recommended Prep: **Computer Science 141 or permission of instructor.**

Requirements: **Prerequisite: Computer Science 141**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 152

Programming Languages (119629)

Nada Amin

2020 Spring (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Comprehensive introduction to the principal features and overall design of both traditional and modern programming languages, including syntax, formal semantics, abstraction mechanisms, modularity, type systems, naming, polymorphism, closures, continuations, and concurrency. Provides the intellectual tools needed to design, evaluate, choose, and use programming languages.

Recommended Prep: **Computer Science 51; Computer Science 121 is recommended. Students must have good programming skills, be very comfortable with recursion, proofs, basic mathematical ideas and notations, including sets, relations, functions, and induction.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS: Final Assessment Category	Three-hour Exam

Computer Science 153

Compilers (131493)

Stephen Chong

2019 Fall (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Implementation of efficient interpreters and compilers for programming languages. Associated algorithms and pragmatic issues. Emphasizes practical applications including those outside of programming languages proper. Also shows relationships to programming-language theory and design. Participants build a working compiler including lexical analysis, parsing, type checking, code generation, and register allocation. Exposure to run-time issues and optimization.

Recommended Prep: **Computer Science 51 or 61.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students

Computer Science 161

Operating Systems (113847)

James Mickens

2020 Spring (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This course focuses on the design and implementation of modern operating systems. The course discusses threads, processes, virtual memory, schedulers, and the other fundamental primitives that an OS uses to represent active computations. An exploration of the system call interface explains how applications interact with hardware and other programs which are concurrently executing. Case studies of popular file systems reveal how an OS makes IO efficient and robust in the midst of crashes and unexpected reboots. Students also learn how virtualization allows a physical machine to partition its resources across multiple virtual machines. Class topics are reinforced through a series of intensive programming assignments which use a real operating system.

Recommended Prep: **Computer Science 61.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 165

Data Systems (119249)

Stratos Idreos

2019 Fall (4 Credits) **Schedule:** MW 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

We are in the big data era and data systems sit in the critical path of everything we do. We are going through major transformations in businesses, sciences, as well as everyday life - collecting and analyzing data changes everything and data systems provide the means to store and analyze a massive amount of data. This course is a comprehensive introduction to modern data systems. The primary focus of the course is on the modern trends that are shaping the data management industry right now: column-store and hybrid systems, shared nothing architectures, cache conscious algorithms, hardware/software co-design, main-memory systems, adaptive indexing, stream processing, scientific data management, and key-value stores. We also study the history of data systems, traditional and seminal concepts and ideas such as the relational model, row-store database systems, optimization, indexing, concurrency control, recovery and SQL. In this way, we discuss both how and why data systems evolved over the years, as well as how these concepts apply today and how data systems might evolve in the future. We focus on understanding concepts and trends rather than specific techniques that will soon be outdated - as such the class relies largely on recent research material and on a semi-flipped class model with a lot of hands-on interaction in each class.

Recommended Prep: **Computer Science 51 and Computer Science 61.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 171

Visualization (124364)

Hanspeter Pfister

2019 Fall (4 Credits) **Schedule:** MW 0300 PM - 0545 PM

Instructor Permissions: Instructor **Enrollment Cap:** 80

An introduction to key design principles and techniques for visualizing data. Covers design practices, data and image models, visual perception, interaction principles, visualization tools, and applications. Introduces programming of web-based interactive visualizations.

Course Notes: **Enrollment limited to 80 students.**

Recommended Prep: **Students are required to have basic programming experience (e.g., Computer Science 50). Web programming experience (HTML, CSS, JS) is a plus.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 175

Computer Graphics (113410)

Steven Gortler

2020 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This course covers the fundamentals of 3D computer graphics using a modern shader-based version of OpenGL. Main topics include: geometric coordinate systems and transformations, keyframe animation and interpolation, camera simulation, triangle rasterization, material simulation, texture mapping, image sampling and color theory. The course also touches on ray tracing, geometric modeling and simulation-based animation.

Recommended Prep: **Computer Science 51 or 61, Applied Mathematics 22a or Mathematics 21b.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 179

Design of Useful and Usable Interactive Systems (123971)

Elena Glassman

2020 Spring (4 Credits) **Schedule:** MW 1030 AM - 1145 AM

Instructor Permissions: Instructor **Enrollment Cap:** 71

The course covers skills and techniques necessary to design innovative interactive products that are useful, usable and that address important needs of people other than yourself. You will learn how to uncover needs that your customers cannot even articulate. You will also learn a range of design principles, effective creativity-related practices, and techniques for rapidly creating and evaluating product prototypes. You will also have several opportunities to formally communicate your design ideas to a variety of audiences. You will complete two large team-based design projects.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students
GSD: MDS/MDE Rec. Elec.	MDE recommended elective

Computer Science 181

Machine Learning (148156)

Finale Doshi-Velez

2020 Spring (4 Credits) **Schedule:** MW 0900 AM - 1015 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Introduction to machine learning, providing a probabilistic view on artificial intelligence and reasoning under uncertainty. Topics include: supervised learning, ensemble methods and boosting, neural networks, support vector machines, kernel methods, clustering and unsupervised learning, maximum likelihood, graphical models, hidden Markov models, inference methods, and computational learning theory. Students should feel comfortable with multivariate calculus, linear algebra, probability theory, and complexity theory.

Students will be required to produce non-trivial programs in Python.

Recommended Prep: **Computer Science 51, Statistics 110, Math 21a and 21b (or equivalent).**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
Quantitative Reasoning with Data	Yes
GSD: MDS/MDE Rec. Elec.	MDE recommended elective
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 183

Foundations of Machine Learning (215691)

Yaron Singer

2020 Spring (4 Credits) **Schedule:** R 0300 PM - 0545 PM

Instructor Permissions: None **Enrollment Cap:** n/a

The course provides an extensive account of the fundamental ideas underlying machine learning and the basic algorithms used in practice. The course first formalizes basic concepts used to establish the theory and language of machine learning. These concepts include PAC learnability, sample complexity, and the VC dimension. The course then covers the concepts of convexity, regularization, and stability as well as important algorithmic paradigms including stochastic gradient descent, boosting, support vector machines, kernel methods, feature selection, and neural networks.

Course Notes: **Students cannot take both CS 181 and CS 183 for credit.**

Recommended Prep: **Math23a, 25a, or 55a; OR Math 21b and either CS121 or CS124.**

Requirements: **Cannot be taken for credit if COMPSCI 181 already complete.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 189

Autonomous Robot Systems (127551)

Radhika Nagpal

2020 Spring (4 Credits) **Schedule:** F 0900 AM - 1145 AM

Instructor Permissions: Instructor **Enrollment Cap:** 20

Building autonomous robotic systems requires understanding how to make robots that observe, reason, and act. Each component uses many engineering principles: how to fuse, multiple, noisy sensors; how to balance short-term versus long-term goals; how to control one's actions and how to coordinate with others. This year theme will be "Robots Roam the Halls", where we will focus on kinect-based robots that move in the SEAS buildings, to do applications like navigating, map building, and interacting with people. The class format will have a mixed lecture and lab format, and have a final project component.

Recommended Prep: **The only prerequisites are CS51 or CS61, or experience with programming and using APIs. This class is appropriate for CS, EE, and ME students interested in robotics.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 205

Computing Foundations for Computational Science (128104)

David Sondak

2020 Spring (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Computational science has become a third partner, together with theory and experimentation, in advancing scientific knowledge and practice, and an essential tool for product and process development and manufacturing in industry. Big data science adds the 'fourth pillar' to scientific advancements, providing the methods and algorithms to extract knowledge or insights from data. The course is a journey into the foundations of Parallel Computing at the intersection of large-scale computational science and big data analytics. Many science communities are combining high performance computing and high-end data analysis platforms and methods in workflows that orchestrate large-scale simulations or incorporate them into the stages of large-scale analysis pipelines for data generated by simulations, experiments, or observations. This is an applications course highlighting the use of modern computing platforms in solving computational and data science problems, enabling simulation, modeling and real-time analysis of complex natural and social phenomena at unprecedented scales. The class emphasizes on making effective use of the diverse landscape of programming models, platforms, open-source tools, computing architectures and cloud services for high performance computing and high-end data analytics.

Recommended Prep: **Students are expected to have basic programming experience and understanding of algorithms (e.g. CS50/CS51/CS207), familiarity with Python, C or similar, and basic knowledge of Linux including using the command line.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 207

Systems Development for Computational Science (128105)

David Sondak

2019 Fall (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This is a project-based course emphasizing designing, building, testing, maintaining and modifying

software for scientific computing. Students will work in groups on a number of projects, ranging from small data-transformation utilities to large-scale systems. Students will learn to use a variety of tools and languages, as well as various techniques for organizing teams. Most important, students will learn to fit tools and approaches to the problem being solved.

Recommended Prep: **Students are expected to have basic programming experience (Computer Science 50).**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 223

Probabilistic Analysis and Algorithms (114806)

Michael Mitzenmacher

2019 Fall (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Probabilistic techniques and tools for the design and analysis of algorithms. Designed for all first-year graduate students in all areas.

Recommended Prep: **Computer Science 124. Preferably additional probability, such as in Computer Science 226r, Statistics 110, or Mathematics 191.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 226R

Topics in Theory for Society: Fairness and Validity (214483)

Cynthia Dwork

2020 Spring (4 Credits) **Schedule:** MW 0900 AM - 1015 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Topics from the literature on theoretical computer science addressing technical problems of societal concern. Focus for 2019-2020: Algorithmic Fairness and Statistical Validity in Adaptive (Exploratory) Data Analysis.

Recommended Prep: **Computer Science 124, 125, or 127.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Final Assessment Category	Three-hour Exam

FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 227

Cryptography (213331)

Boaz Barak

2020 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Cryptography is as old as human communication itself, but has undergone a revolution in the last few decades. It is now about much more than "secret writing" and includes seemingly paradoxical notions such as communicating securely without a shared secret, and computing on encrypted data. In this challenging but rewarding course we will start from the basics of private and public key cryptography and go all the way up to advanced notions such as fully homomorphic encryption and software obfuscation. This is a proof-based course that will be best appreciated by mathematically mature students.

Course Notes: **This course will be offered in both an undergraduate and graduate versions. The graduate version will involve an additional project.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam

Computer Science 228

Computational Learning Theory (113296)

Leslie Valiant

2020 Spring (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Possibilities of and limitations to performing learning by a computational process. Computationally feasible generalization and its limits. Topics include computational models of learning, polynomial time learnability, learning from examples and from queries to oracles. Applications to Boolean functions, languages and geometric functions. Darwinian evolution as learning.

Recommended Prep: **Computer Science 121 or equivalent.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 229R

Topics in Theoretical Computer Science: Essential Coding Theory (120237)

Madhu Sudan

2020 Spring (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Introduces essential elements the theory of error-correcting codes. Focuses on the basic results in the area, taught from first principles. Special focus will be given on results of asymptotic or algorithmic significance. Principal topics include 1. Construction and existence results for error-correcting codes; 2. Limitations on the combinatorial performance of error-correcting codes; 3. Decoding algorithms 4. Applications to other areas of mathematics and computer science. Lecture notes for this course from previous offerings give further details on the material covered. These may be found at http://madhu.seas.harvard.edu/courses/Spring2017.

Course Notes: **Instructor permission needed for undergraduates. Undergraduates planning to take the class must write to the instructor indicating (1) what they hope to learn from the class and (2) their level of preparation in math and CS theory (e.g., CS 121, CS 124).**

Recommended Prep: **CS 121/124/125 or equivalents.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 236R

Topics at the Interface between Computer Science and Economics (116531)

Yiling Chen

2020 Spring (4 Credits) **Schedule:** TR 0900 AM - 1015 AM

Instructor Permissions: Instructor **Enrollment Cap:** 20

Interplay between computation and economics. Topics in electronic commerce, computational social choice, computational mechanism design, peer production, prediction markets and reputation systems. Readings in AI, theoretical CS, multi-agent systems, economic theory, and operations research.

Recommended Prep: **Mathematics 21b, Applied Mathematics 21b, or equivalent; Economics 1011a, or equivalent; or permission of instructor.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 242

Computing at Scale (160624)

H. Kung

2020 Spring (4 Credits) **Schedule:** MW 0430 PM - 0545 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Scaling computation over parallel and distributed computing systems is a rapidly advancing area of research receiving high levels of interest from both academia and industry. The objective can be for high---performance computing and energy---efficient computing ("green" data center servers as well as small embedded devices). In this course, students will learn principled methods of mapping prototypical computations used in machine learning, the Internet of Things, and scientific computing onto parallel and distributed compute nodes of various forms. These techniques will lay the foundation for future computational libraries and packages for both high---performance computing and energy---efficient devices. To master the subject, students will need to appreciate the close interactions between computational algorithms, software abstractions, and computer organizations. After having successfully taken this course, students will acquire an integrated understanding of these issues. The class will be organized into the following modules: Big picture: use of parallel and distributed computing to achieve high performance and energy efficiency; End---to---end example 1: mapping nearest neighbor computation onto parallel computing units in the forms of CPU, GPU, ASIC and FPGA; Communication and I/O: latency hiding with prediction, computational intensity, lower bounds; Computer architectures and implications to computing: multi---cores, CPU, GPU, clusters, accelerators, and virtualization; End---to---end example 2: mapping convolutional neural networks onto parallel computing units in the forms of CPU, GPU, ASIC, FPGA and clusters; Great inner loops and parallelization for feature extraction, data clustering and dimension reduction: PCA, random projection, clustering (K---means, GMM---EM), sparse coding (K---SVD), compressive sensing, FFT, etc.; Software abstractions and programming models: MapReduce (PageRank, etc.), GraphX/Apache Spark, OpenCL and TensorFlow; Advanced topics: autotuning and neuromorphic spike---based computing. Students will learn the subject through lectures/quizzes, programming assignments, labs, research paper presentations, and a final project. Students will have latitude in choosing a final project they are passionate about. They will formulate their projects early in the course, so there will be sufficient time for discussion and iterations with the teaching staff, as well as for system design and implementation. Industry partners will support the course by giving guest lectures and providing resources. The course will use server clusters at Harvard as well as external resources in the cloud. In addition, labs will have access to state---of---the---art IoT devices and 3D cameras for data acquisition. Students will use open source tools and libraries and apply them to data analysis, modeling, and visualization problems.

Recommended Prep: **(1) programming experience (Python, MatLab or C/C++ should be fine); (2) basic knowledge in systems and machine organization; (3) familiarity in data structures and algorithms; and (4) maturity in mathematics (e.g., undergraduate linear algebra and statistics). For students with strong interest in the subject matter and related research topics, one of these four requirements may be waived. Labs and extra support will provide preparation in the first weeks of the semester to help students quickly obtain the background necessary to excel in the course.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Computer Science 243

Advanced Computer Networks (212686)

Minlan Yu

2019 Fall (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This is a graduate-level course on computer networks. It provides a comprehensive overview of advanced topics in network protocols and networked systems. The course will cover both classic papers on computer networks and recent research results. It will examine a wide range of topics including routing, congestion control, network architectures, network management, data center networks, software-defined networking, and programmable networks, with an emphasis on core networking concepts and principles and their usage in practice. The course will include lectures, in-class presentations, paper discussions, and a research project.

More information can be found at http://minlanyu.seas.harvard.edu/teach/cs243-fall19/.

Recommended Prep: **System programming at the level of CS 61, CS 143, CS145. Prior knowledge of basic networking concepts is useful.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 246

Advanced Computer Architecture (127937)

David Brooks

2019 Fall (4 Credits) **Schedule:** F 0900 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

The contents and course requirements are similar to those of Computer Science 146, with the exception that students enrolled in Computer Science 246 are expected to undertake a substantial course project.

Recommended Prep: **Computer Science 141.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Computer Science 247R

Advanced Topics in Computer Architecture (128149)

David Brooks

2020 Spring (4 Credits) **Schedule:** TR 0900 AM - 1015 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Seminar course exploring recent research in computer architecture. Topics vary from year to year and will include subjects such as multi-core architectures, energy-efficient computing, reliable computing, and the interactions of these issues with system software. Students read and present research papers, undertake a research project.

Recommended Prep: **Computer Science 146 or 246 or permission of the instructor.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 248

Advanced Design of VLSI Circuits and Systems (121984)

Gu-Yeon Wei

2020 Spring (4 Credits) **Schedule:** WF 0300 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** 16

The contents and course requirements are similar to those of Computer Science 148, with the exception that students enrolled in Computer Science 248 are expected to do a substantial design project and paper discussions on advanced topics.

Course Notes: **Offered in alternate years.**

Recommended Prep: **Computer Science 141 or permission of instructor.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 249R

Special Topics in Edge Computing: Autonomous Machines (212687)

Vijay Janapa Reddi

2019 Fall (4 Credits) **Schedule:** MW 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

The course covers a range of emerging research topics in edge computing. The Fall 2019 course focuses on computing systems for autonomous machines (drones, cars, etc.). We survey fundamental and cutting-edge research across algorithms, systems, and hardware, and learn how to optimize the cyber-physical system-stack for performance, power efficiency, reliability, and safety. This research-oriented course is ideal for students interested in interdisciplinary and cross-layer research.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 252R

Advanced Topics in Programming Languages (114807)

Nada Amin

2019 Fall (4 Credits) **Schedule:** MW 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This year only: We'll focus on making communication with computers more accessible: easier, faster, and safer. The course co-locates two advanced graduate seminars in HCI and PL. From HCI, students will learn new design and evaluation methods focused on utility and usability. From PL, students will learn new PL techniques relevant to building user-centric systems.

Students enrolled in 252r will select and present papers on PL topics including type systems, program synthesis, and metaprogramming. Students enrolled in 279 will select and present systems HCI papers about communicating intent between humans and computers, such as programming by demonstration and representing transformations on large piles of data. Activities will include a small number of lectures, discussion of relevant literature in each field, and a project, in which students from 252 and 279 will work together in groups to propose and carry out research at the intersection of PL and HCI.

Course Notes: **Designed for PhD students from all areas. Masters students and advanced undergraduates are welcome, particularly those who wish to do research (or write a thesis) in an area related to Human-Computer Interaction and/or Programming Languages.**

Recommended Prep: **Computer Science 152 or permission of the instructor.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 252R

Advanced Topics in Programming Languages (114807)

Stephen Chong

2020 Spring (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Seminar course exploring recent research in programming languages. Topics vary from year to year. Students read and present research papers, undertake a research project.

Recommended Prep: **Computer Science 152 or permission of the instructor.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 263

Systems Security (160579)

James Mickens

2019 Fall (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This course explores practical attacks on modern computer systems, explaining how those attacks can be mitigated using careful system design and the judicious application of cryptography. The course discusses topics like buffer overflows, web security, information flow control, and anonymous communication mechanisms such as Tor. The course includes several small projects which give students hands-on experience with various offensive and defensive techniques; the final, larger project is open-ended and driven by student interests.

Recommended Prep: **Computer Science 161 (Operating Systems)**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	Primarily for Graduate Students

Computer Science 265

Big Data Systems (113660)

Stratos Idreos

2020 Spring (4 Credits) **Schedule:** MW 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Big data is everywhere. A fundamental goal across numerous modern businesses and sciences is to be able to utilize as many machines as possible, to consume as much information as possible and as fast as possible. The big challenge is how to turn data into useful knowledge. This is a moving target as both the underlying hardware and our ability to collect data evolve. In this class, we discuss how to design data systems, data structures, and algorithms for key data-driven areas, including relational systems, distributed systems, graph systems, noSQL, newSQL, machine learning, and neural networks. We see how they all rely on the same set of very basic concepts and we learn how to synthesize efficient solutions for any problem across these areas using those basic concepts.

Recommended Prep: **CS 165 or permission of instructor.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Computer Science 271

Topics in Data Visualization (211349)

Johanna Beyer

2020 Spring (4 Credits) **Schedule:** MW 0430 PM - 0545 PM

Instructor Permissions: Instructor **Enrollment Cap:** 30

This course covers advanced topics in data visualization. Over the course of the semester, we will examine seminal works and recent state-of-the-art research in information visualization, scientific visualization and visual analytics. Students will work on a semester-long visualization project that will allow them to visualize their own data sets and write a short paper about their project. We will employ peer-feedback and formal design critiques to analyze each other's work.

Course Notes: **Enrollment limited to 30 students. Instructor permission needed.**

Recommended Prep: **CS 171, CS 179, CS 279, or some data visualization experience. Please contact course staff if you are unsure about the course pre-requisites.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 279R

Research Topics in Human-Computer Interaction (121985)

Elena Glassman

2019 Fall (4 Credits) **Schedule:** MW 1200 PM - 0115 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

This year only: We'll focus on making communication with computers more accessible: easier, faster, and safer. The course co-locates two advanced graduate seminars in HCI and PL. From HCI, students will learn new design and evaluation methods focused on utility and usability. From PL, students will learn new PL techniques relevant to building user-centric systems.

Students enrolled in 252r will select and present papers on PL topics including type systems, program synthesis, and metaprogramming. Students enrolled in 279 will select and present systems HCI papers about communicating intent between humans and computers, such as programming by demonstration and representing transformations on large piles of data. Activities will include a small number of lectures, discussion of relevant literature in each field, and a project, in which students from 252 and 279 will work together in groups to propose and carry out research at the intersection of PL and HCI.

Course Notes: **Designed for PhD students from all areas. Masters students and advanced undergraduates are welcome, particularly those who wish to do research (or write a thesis) in an area related to Human-Computer Interaction and/or Programming Languages.**

Recommended Prep: **None for PhD students; for undergrads CS 179 or CS 171 is strongly recommended and permission of the instructor is required. Basic programming skills will be needed to implement and conduct experiments.**

Additional Course Attributes:

Attribute	Value(s)
GSD: MDS/MDE Rec. Elec.	MDE recommended elective

All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 280R

Curricular Design for Computer Science: Computational Linguistics and Natural-language Processing (109283)

Stuart Shieber

2019 Fall (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** 15

This graduate seminar focuses on the design of a curriculum and pedagogical infrastructure for a new computer science course. This term, the target course will be an undergraduate course in computational linguistics, the study of human language using the tools and techniques of computer science, and the technological applications thereof. The class will investigate appropriate subject matter for the target course, canvas existing and novel pedagogical methods for teaching the subject, and construct a curriculum and course materials and infrastructure for a new course on the subject, to be taught in the fall of 2020.

Course Notes: **Enrollment limited to 15 students, selected on the basis of a preregistration survey.**

Recommended Prep: **CS51, CS121, some statistics background.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Computer Science 281

Advanced Machine Learning (107677)

Jean-Baptiste Tristan

Michael Wick

2019 Fall (4 Credits) **Schedule:** MW 0130 PM - 0245 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Advanced statistical machine learning and probabilistic data analysis. Covers discrete and continuous probabilistic modeling and computational inference. Topics include: Bayesian modeling, probabilistic graphical models, latent variables and unsupervised learning, deep learning, time series models, variational inference, and sampling. Requires a final project.

Recommended Prep: **Students should be comfortable with linear algebra and probability theory, basic machine learning (at the level of CS 181), and large-scale Python data analysis.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 282BR

Topics in Machine Learning: Interpretability and Explainability (213653)

Hima Lakkaraju

2019 Fall (4 Credits) **Schedule:** F 1200 PM - 0230 PM

Instructor Permissions: Instructor **Enrollment Cap:** 25

As machine learning models are increasingly being employed to aid decision makers in high-stakes settings such as healthcare and criminal justice, it is important to ensure that the decision makers (end users) correctly understand and consequent trust the functionality of these models. This graduate level course aims to familiarize students with the recent advances in the emerging field of explainable ML. In this course, we will review seminal position papers of the field, understand the notion of model interpretability from the perspective of decision makers (end users), discuss in detail different classes of interpretable models (e.g., case (prototype) based approaches, sparse linear models, rule-based techniques, saliency maps, generalized additive models, and counterfactual explanations), and explore the connections between model interpretability and causality, debugging, and fairness. The course will also emphasize on various applications which can immensely benefit from model interpretability including medical imaging and judicial decision making.

Recommended Prep: **Knowledge of machine learning, convex optimization, probability and statistics, basic computer science and programming skills.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
GSD: MDS/MDE Rec. Elec.	MDE recommended elective

Computer Science 282R

Topics in Machine Learning: Batch Reinforcement Learning (156936)

Finale Doshi-Velez

2019 Fall (4 Credits) **Schedule:** MW 0900 AM - 1015 AM

Instructor Permissions: Instructor **Enrollment Cap:** 20

This course will take a deep dive into batch reinforcement learning, with a focus on healthcare applications. Sequential decision making is at the core of many healthcare problems: a clinician observes a patient, determines a treatment, and based on the response and the patient's previous history, determines what to try next. Reinforcement learning is a formal framework for thinking about such problems. Batch reinforcement learning aims to extract as much as possible from previously-observed trajectories: given a large batch of previous clinician-patient interactions, what inferences can we make about good courses of action? What inferences are not possible?

We will first review the fundamentals through lectures, readings, and coding assignments; they will also engage in a semester-long project applying and extending these ideas to problems related to healthcare (including the opportunity to work with clinical decision-making in intensive care units).

Recommended Prep: **Students are expected to be fluent in basic linear algebra (matrix manipulation), basic statistics (e.g. rules of expectations, importance**

sampling), algorithms (e.g. dynamic programming), and software engineering/numerical computing (e.g. programming in Python and numpy, working with data with 100,000+ rows).

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 283

Computer Vision (113944)

Todd Zickler

2019 Fall (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Vision as an ill-posed inverse problem: image formation, two-dimensional signal processing; feature analysis; image segmentation; color, texture, and shading; multiple-view geometry; object and scene recognition; and applications.

Course Notes: **Offered jointly with the Design School as SCI-06275.**

Additional Course Attributes:

Attribute	Value(s)
GSD: MDS/MDE Rec. Elec.	MDE recommended elective
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Computer Science 289

Biologically-inspired Multi-agent Systems (120238)

Radhika Nagpal

2019 Fall (4 Credits) **Schedule:** WF 1030 AM - 1145 AM

Instructor Permissions: Instructor **Enrollment Cap:** 20

Surveys biologically-inspired approaches to designing distributed systems. Focus is on biological models, algorithms, and programming paradigms for self-organization. Topics vary year to year, and usually include: (1) swarm intelligence: social insects and animal groups, with applications to networking and robotics, (2) cellular computing: including cellular automata/amorphous computing, and applications like self-assembling robots and programmable materials, (3) evolutionary computation and its application to optimization and design.

Course Notes: **Geared toward graduate students of all levels as well as advanced undergraduates. Preference given to graduate students or upper-level concentrators.**

Recommended Prep: **Students should have a familiarity/experience with computer systems (e.g. software, networking) and algorithms/analysis through classes and/or internship experiences. Background in biology not required.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 299R

Special Topics in Computer Science (114035)

David Brooks

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: None **Enrollment Cap:** n/a

Supervision of experimental or theoretical research on acceptable computer science problems and supervision of reading on topics not covered by regular courses of instruction.

Course Notes: **Open to graduate students and AB/SM candidates only. Students must arrange such work with a member of the School of Engineering and Applied Sciences. This course is graded and is ordinarily taken with the approval of the Committee on Higher Degrees. Applicants must file a project sheet before study cards are filed. Project sheets may be obtained from the Academic Office, Pierce Hall 110.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 299R

Special Topics in Computer Science (114035)

Leslie Valiant

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: None **Enrollment Cap:** n/a

Supervision of experimental or theoretical research on acceptable computer science problems and supervision of reading on topics not covered by regular courses of instruction.

Course Notes: **Open to graduate students and AB/SM candidates only. Students must arrange such work with a member of the School of Engineering and Applied Sciences. This course is graded and is ordinarily taken with the approval of the Committee on Higher Degrees. Applicants must file a project sheet before study cards are filed. Project sheets may be obtained from the Academic Office, Pierce Hall 110 or at https://www.seas.harvard.edu/office-academic-programs/graduate-policies-procedures-and-forms/graduate-student-forms.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students

All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 306

Readable, Extensible, High-Performance Software Systems (109278)

Eddie Kohler

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 306

Readable, Extensible, High-Performance Software Systems (109278)

Eddie Kohler

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 308

Biologically-Inspired Multi-Agent Systems, Distributed Systems, and Computational Biology (119252)

Radhika Nagpal

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 308

Biologically-Inspired Multi-Agent Systems, Distributed Systems, and Computational Biology (119252)

Radhika Nagpal

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 310

Computational Mechanism Design, Electronic Marketplaces, and Multi-Agent Systems (116301)

David Parkes

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 310

Computational Mechanism Design, Electronic Marketplaces, and Multi-Agent Systems (116301)

David Parkes

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 312

Collaborative Systems, AI Planning, and Natural Language Processing (143299)

Barbara Grosz

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 312

Collaborative Systems, AI Planning, and Natural Language Processing (143299)

Barbara Grosz

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 314

Visual Computing (124155)

Hanspeter Pfister

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 314

Visual Computing (124155)

Hanspeter Pfister

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 316

Social Computing: Computation and Economics (125388)

Yiling Chen

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 316

Social Computing: Computation and Economics (125388)

Yiling Chen

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 320

Data Systems Design (156744)

Stratos Idreos

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 320

Data Systems Design (156744)

Stratos Idreos

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 324

Human-Computer Communication through Natural, Graphical, and Artificial Languages (111666)

Stuart Shieber

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 324

Human-Computer Communication through Natural, Graphical, and Artificial Languages (111666)

Stuart Shieber

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 325

Communicating with Machines About Data (212951)

Elena Glassman

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Not Available for Cross Registration
FAS Divisional Distribution	None

Computer Science 325

Communicating with Machines About Data (212951)

Elena Glassman

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Not Available for Cross Registration
FAS Divisional Distribution	None

Computer Science 326

Intelligent Interactive Systems and Human-Computer (126331)

Krzysztof Gajos

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 326

Intelligent Interactive Systems and Human-Computer (126331)

Krzysztof Gajos

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 327

Tools for Reliable Meaningful Efficient Communication (160962)

Madhu Sudan

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 327

Tools for Reliable Meaningful Efficient Communication (160962)

Madhu Sudan

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 328

Mathematical Logic, Theory of Computation (133437)

Harry Lewis

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 328

Mathematical Logic, Theory of Computation (133437)

Harry Lewis

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 335

Complexity, Algorithms, Cryptography, and Convex Programming (206566)

Boaz Barak

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 335

Complexity, Algorithms, Cryptography, and Convex Programming (206566)

Boaz Barak

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course

Computer Science 344

Computer Architecture: Modeling and Design (116858)

David Brooks

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 344

Computer Architecture: Modeling and Design (116858)

David Brooks

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 345

Datacenter networking (117839)

Minlan Yu

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 346

High-Performance Computer Systems (117841)

Michael Smith

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 346

High-Performance Computer Systems (117841)

Michael Smith

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 348

Computer Vision (120091)

Todd Zickler

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 348

Computer Vision (120091)

Todd Zickler

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 356

Computational Complexity, Parallel Computation, Computational Learning, Neural Computation (113027)

Leslie Valiant

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 356

Computational Complexity, Parallel Computation, Computational Learning, Neural Computation (113027)

Leslie Valiant

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 358

Computational Complexity, Cryptography, and Pseudorandomness (115136)

Salil Vadhan

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 358

Computational Complexity, Cryptography, and Pseudorandomness (115136)

Salil Vadhan

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 360

On-line Algorithms and Randomized Algorithms (109883)

Michael Mitzenmacher

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 360

On-line Algorithms and Randomized Algorithms (109883)

Michael Mitzenmacher

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 362

Software Systems: Security, Performance, and Robustness (160959)

James Mickens

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 362

Software Systems: Security, Performance, and Robustness (160959)

James Mickens

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 364

Programming Languages and Security (126329)

Stephen Chong

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 364

Programming Languages and Security (126329)

Stephen Chong

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 372

Topics in Theory for Society (204561)

Cynthia Dwork

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course

Computer Science 372

Topics in Theory for Society (204561)

Cynthia Dwork

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 376

Computer Graphics (121071)

Steven Gortler

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 376

Computer Graphics (121071)

Steven Gortler

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 378

Sketching Algorithms for Massive Data (110261)

Jelani Nelson

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 378

Sketching Algorithms for Massive Data (110261)

Jelani Nelson

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 380

Algorithms for Social Data (110263)

Yaron Singer

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 380

Algorithms for Social Data (110263)

Yaron Singer

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 382

Natural Language Understanding and Generation (160961)

Alexander Rush

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 382

Natural Language Understanding and Generation (160961)

Alexander Rush

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Computer Science 384

Advanced Control, Estimation, and Analysis of Robots and Dynamical Systems (160963)

Scott Kuindersma

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 384

Advanced Control, Estimation, and Analysis of Robots and Dynamical Systems (160963)

Scott Kuindersma

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 385

Artificial Intelligence for Social Good (213680)

Milind Tambe

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Not Available for Cross Registration
FAS Divisional Distribution	None

Computer Science 385

Artificial Intelligence for Social Good (213680)

Milind Tambe

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Not Available for Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 386

Machine Learning (160970)

Finale Doshi-Velez

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Computer Science 386

Machine Learning (160970)

Finale Doshi-Velez

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 387

Statistical Reinforcement Learning (214477)

Susan Murphy

2020 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Not Available for Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Computer Science 387

Statistical Reinforcement Learning (214477)

Susan Murphy

2019 Fall (4 Credits) **Schedule:** TBD

Instructor Permissions: Instructor **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Not Available for Cross Registration
FAS Divisional Distribution	None