Computer Science

Subject: Computer Science

Computer Science 1

Great Ideas in Computer Science (119953)

Henry Leitner

2019 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: General Education	Empirical and Mathematical Reasoning
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 20

Discrete Mathematics for Computer Science (128073)

Rebecca Nesson

2019 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: Final Assessment Category	Three-hour Exam
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Core Curriculum	Quantitative Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS: General Education	Empirical and Mathematical Reasoning

All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 50

Introduction to Computer Science (152514)

David J. Malan

2018 Fall (4 Credits) **Schedule:** F 0900 AM - 1145 AM

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

Introduction to the intellectual enterprises of computer science and the art of programming. This course teaches you how to think algorithmically and solve problems efficiently. Topics include abstraction, algorithms, data structures, encapsulation, resource management, security, software engineering, and web development. Languages include C, Python, SQL, and JavaScript plus CSS and HTML. Problem sets inspired by real-world domains of biology, cryptography, finance, forensics, and gaming. Designed for concentrators and non-concentrators alike, with or without prior programming experience. 68% of CS50 students have never taken CS before.

Class Notes: **Students may simultaneously enroll in CS50 and another course that meets at the same time, watching CS50's lectures anytime online and attending the other course in person. To do so, students should enroll in the other course via my.harvard.edu and then email enrollment@fas.harvard.edu to have CS50 manually added to their crimson carts as well. The Ad Board has already granted this exception for CS50; no other steps are required. CS50 is ordinarily graded SAT/UNS, though students taking CS50 to fulfill old Gen Ed requirements or whose concentration requires letter grades should change their grading status to letter-graded by the term's fifth Monday. First years may take both CS50 and a freshman seminar SAT/UNS. All students are expected to attend an orientation meeting either on Tue 9/11, 4:30pm–5:45pm, in Northwest Science B103 or on Wed 9/12, 6pm–7:15pm, in Science Center D; students with conflicts may watch online. Required sections to be arranged. See cs50.harvard.edu for FAQs.**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 51

Abstraction and Design in Computation (112960)

Stuart Shieber

2019 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: **The first meetings of the course will be January 29 and 31 at 10:30 in Menschel Hall, downstairs in the Harvard Art Museums building (Fogg), 32 Quincy Street.**

Students should have programming ability and computer science knowledge at the level of CS50; mathematical sophistication at the advanced high school level. FAS students in doubt about their preparation for the course may find the self-evaluation "preparation check" of interest. It is available in PDF form on Canvas, along with the answer key, under Files > Reference.

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 61

Systems Programming and Machine Organization (123623)

Eddie Kohler

2018 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: Course Level	Primarily for Undergraduate Students
FAS: Final Assessment Category	Three-hour Exam
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 90NAR

Applied Ethical and Governance Challenges in AI (203579)

Jonathan Zittrain

Joichi Ito

2019 Spring (4 Credits) **Schedule:** T 0500 PM - 0700 PM

Instructor Permissions: Instructor **Enrollment Cap:** 22

This course will pursue a cross-disciplinary investigation of the development and deployment of the opaque complex adaptive systems that are increasingly in public and private use. We will explore the proliferation of algorithmic decisionmaking, autonomous systems, and machine learning and explanation; the search for balance between regulation and innovation; and the effects of AI on the dissemination of information, along with questions related to individual rights, discrimination, and architectures of control.

Course Notes: **This course is jointly listed with HLS and HKS, and does not count for concentration credit in Computer Science. Enrollment by application. The link to the course application can be found at https://goo.gl/forms/ijFh75qlcFtiyaiZ2. Applications will be due by November 11.**

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 90NBR

Internet & Society: The Technologies and Politics of Control (203578)

Jonathan Zittrain

Jordi Weinstock

2019 Spring (4 Credits) **Schedule:** M 0500 PM - 0700 PM

Instructor Permissions: Instructor **Enrollment Cap:** 22

This course offers a rigorous introduction to the field of cyberlaw. We will investigate the evolving nature of online architecture and activities, and the ways in which law has been, and will be, leveraged to influence them.

Course themes include the complex interaction between Internet governance organizations and sovereign states, the search for balance between the ease of disseminating information online and the interest of copyright holders, privacy advocates, and others in controlling that dissemination, and the roles of intermediaries and platforms in shaping what people can and cannot do online. The course will entail an intense array of learning and teaching methods. Students will be expected to participate in a variety of activities. May include Berkman Center fellows and affiliates.

Course Notes: **This course will be taught jointly by Professor Jonathan Zittrain and Mr. Jordi Weinstock. This course is jointly listed with HLS and HKS, and does not count for concentration credit in Computer Science. The link to the course application can be found at https://goo.gl/forms/1Wc92mnMUDTN9CXI2. Applications will be due by November 11.**

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 90NCR

Law for Algorithms: A Research and Discussion Forum (210870)

Cynthia Dwork

2018 Fall (4 Credits) **Schedule:** R 0300 PM - 0500 PM

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

Human-designed algorithms -- from the digital to the genetic -- reach ever more deeply into our lives, creating alternate and sometimes enhanced manifestations of social and biological processes that yield powerful levers for good and ill amidst a sea of unforeseen consequences. This cross-cutting, interdisciplinary, course connects concepts of proof, verifiability, privacy, security, and trust in computer science with legal concepts of autonomy, consent, governance, and liability in law, and examines interests at the evolving intersection of DNA technology and the law.

Course Notes: **The course consists of weekly meetings to be attended simultaneously by faculty, students and scholars based at Harvard, Berkeley, Columbia and Boston University, with an optional research project. Sessions will be held every Thursday 3-5pm EST. Additional Faculty: Martha Minow (HLS), Ran Canetti (BU), Daniela Caruso (BU), Stacey Dogan (BU), Shafi Goldwasser (UC Berkeley), and Patricia Williams (Columbia).**

Class Notes: **Starting on September 13 the class will meet in Maxwell Dworkin G125.**

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 91R

Supervised Reading and Research (113257)

Stephen Chong

Boaz Barak

2019 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

2018 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: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 100

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

David J. Malan

2018 Fall (4 Credits) **Schedule:** TR 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. COMPSCI 100 will meet at 1 Story Street #306 (not Maxwell Dworkin G125).**

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

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 105

Privacy and Technology (125407)

James Waldo

2018 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: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Core Curriculum	Social Analysis
FAS: General Education	Aesthetic and Interpretive Understanding
FAS: General Education	Culture and Belief

Computer Science 109A

Data Science 1: Introduction to Data Science (109899)

Pavlos Protopapas

Kevin A. Rader

2018 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)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
Full Year Course	Divisible Course

Computer Science 109B

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

Pavlos Protopapas

Mark Glickman

2019 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)
Full Year Course	Divisible Course
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 121

Introduction to Theoretical Computer Science (119064)

Boaz Barak

2018 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.**

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)
FAS: Final Assessment Category	Three-hour Exam
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 124

Data Structures and Algorithms (115384)

Jelani Nelson

2019 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)
FAS: Final Assessment Category	Three-hour Exam
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Computer Science 134

Networks (160409)

Yaron Singer

Michael Mitzenmacher

2018 Fall (4 Credits) **Schedule:** MW 1200 PM - 0115 PM

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

Networks—of social relationships, economic interdependencies, and digital interactions—are critical in shaping our lives. This course introduces models and algorithms that help us understand networks. Fundamental concepts from applied mathematics, microeconomics, and computer science will be presented through the lens of network science, in order to equip students to usefully analyze the "big data" generated by online networks. Applications discussed include the viral spread of ideas, maximizing influence, and the contagion of economic downturns. Concepts and tools covered include game theory, graph theory, data mining, and machine learning.

Recommended Prep: **Linear Algebra, Calculus, probability (either their courses or their equivalents): AM 21a, AM 21b, Statistics 110.**

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 136

Economics and Computation (128164)

David Parkes

2018 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)
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 141

Computing Hardware (113856)

David Brooks

Vijay Janapa Reddi

2019 Spring (4 Credits) **Schedule:** TR 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: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 143

Computer Networks (118418)

H. Kung

2018 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. Second, cyber security 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, network security, 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 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 144R

Networks Design Projects (112630)

H. Kung

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

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

Deep neural networks (DNNs) are becoming a popular tool in data-driven applications. One of the next frontiers is distributed DNNs over computer networks for improved scaling (e.g., for scaling training as in federated learning) and parallel DNNs over processor arrays for low-latency inference in real-time applications. To this end, there is a need to understand issues such as communication, computation, and accuracy trade-offs. This research-oriented course will address this relatively new, yet rapidly advancing, topic. We will survey the main approaches, with a unique focus on the interplay between deep learning models, parallel and distributed computing architectures, and the hardware structures of end devices. The class will be organized into the following eight modules:

Motivations for parallel and distributed deep learning; Parallelism available in deep neural networks; Review of background concepts in deep learning, computer networks, computer architectures, and FPGA/ASIC hardware accelerators; Deep dive case studies in parallel and distributed training and inference (e.g., distributed federated learning and quantized low-latency and energy-efficient inference); Full-stack design optimization for inference in which deep learning models, computing architectures, and hardware circuits are simultaneously optimized; Collaborative deep learning inference between the cloud, edge, and client machines; Privacy and security protocols, and the novel use of blockchains in support of parallel and distributed deep learning; and Emerging technologies in deep learning such as automated neural architecture search and neuromorphic computing. Students working in 2- or 3-person teams will do a substantial project in these and other related areas.

Course Notes: **Preference given to upper-class undergraduates or graduate students in computer science or in business.**

Recommended Prep: **Basic courses in networking (e.g., CS 143) and AI (e.g., CS 181 or 182), programming experience (e.g., CS 51), some research experience, and a strong interest in the subject matter. Lab sessions will be provided to give extra support.**

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 145

Cloud Networking and Computing (208314)

Minlan Yu

2019 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.

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	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 152

Programming Languages (119629)

Stephen Chong

2019 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: Final Assessment Category	Three-hour Exam
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 153

Compilers (131493)

Stephen Chong

2018 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 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 161

Operating Systems (113847)

Eddie Kohler

James Mickens

2019 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)
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 165

Data Systems (119249)

Stratos Idreos

2018 Fall (4 Credits) **Schedule:** MW 0900 AM - 1015 AM

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)
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 171

Visualization (124364)

Hanspeter Pfister

2018 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: Core Curriculum	Quantitative Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Course Level	For Undergraduate and Graduate Students

Computer Science 175

Computer Graphics (113410)

Steven Gortler

2018 Fall (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 21b or Mathematics 21b.**

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 179

Design of Useful and Usable Interactive Systems (123971)

Krzysztof Gajos

Elena Glassman

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

Instructor Permissions: Instructor **Enrollment Cap:** 60

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.

Recommended Prep: **CS 50 or web programming experience.**

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

Computer Science 181

Machine Learning (148156)

Finale Doshi-Velez

2019 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
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 182

Artificial Intelligence (110661)

Goran Radanovic

Haifeng Xu

2018 Fall (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

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

Artificial Intelligence (AI) is an exciting field that has enabled a wide range of cutting-edge technology, from driverless cars to grandmaster-beating Go programs. The goal of this course is to introduce the ideas and techniques underlying the design of intelligent computer systems. Topics covered in this course are broadly be divided into 1) planning and search algorithms, 2) probabilistic reasoning and representations, and 3) machine learning (although, as you will see, it is impossible to separate these ideas so neatly). Within each area, the course will also present practical AI algorithms being used in the wild and, in some cases, explore the relationship to state-of-the-art techniques. The class will include lectures connecting the models and algorithms we discuss to applications in robotics, computer vision, and speech processing.

Recommended Prep: **CS 51; Stat 110 (may be taken concurrently).**

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 189

Autonomous Robot Systems (127551)

Radhika Nagpal

2019 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)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Computer Science 191

Classics of Computer Science (204964)

Harry Lewis

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

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

Papers every computer scientist should have read, from all areas of the field and dating from its origins to the present.

Recommended Prep: **Intended for juniors and seniors in CS who have taken at least one 100 level course in Computer Science. Open to students from other concentrations who have the same background.**

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 205

Computing Foundations for Computational Science (128104)

Ignacio Martin Llorente

2019 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

2018 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 208

Applied Privacy for Data Science (211395)

James Honaker

Salil Vadhan

2019 Spring (4 Credits) **Schedule:** MF 1030 AM - 1145 AM

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

The risks to privacy when making human subjects data available for research and how to protect against these risks using the formal framework of differential privacy. Methods for attacking statistical data releases, the mathematics of and software implementations of differential privacy, deployed solutions in industry and government. Assignments will include implementation and experimentation on data science tasks.

Recommended Prep: **Basic probability, algorithms, and programming at the level of CS109/AC209. STAT110 and CS124 should also be sufficient preparation.**

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 222

Algorithms at the Ends of the Wire (111994)

Michael Mitzenmacher

2018 Fall (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

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

Covers topics related to algorithms for big data, especially related to networks. Themes include compression, cryptography, coding, and information retrieval related to the World Wide Web. Requires a major final project.

Recommended Prep: **Computer Science 124.**

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 229BR

Topics in Theoretical Computer Science: Biology and Complexity (207862)

Leslie Valiant

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

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

Many processes in biology consist of step by step processes, whether in evolution, neural activity, development, or protein circuits. In many of these processes the actual steps taken by biological systems are not currently understood. Further, even the outcomes that are being realized by these processes are not well understood. In general current understanding of most aspects of biology is not complete or specific enough to provide theories in which predictions can be made by analysis or computer simulation. Computer science is the study of step by step processes and of specifications of the outcomes that such processes can realize. For many computational outcome specifications it is known or believed that no mechanism with feasible resources can realize them. Computer science therefore offers a top-down approach to understanding what could possibly be computed in biology, and how. In this course we shall pursue this computational complexity approach, whose origins go back to Turing and von Neumann. Emphasis will be on evolution and neuroscience, but other topics such as development will be also discussed. Research papers that address some aspect of the complexity question, whether by mathematical analysis, computer simulations or experimental findings will be discussed.

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

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 229CR

High Dimensional Probability (211336)

Kyle Luh

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

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

This course is a mathematically rigorous introduction to high-dimensional probability and its applications. The material will revolve around concentration inequalities, random matrices and random graphs. Interspersed in the theory will be various applications to machine learning, statistics and information theory.

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

Recommended Prep: **STAT 110 (Probability), MATH 21b (Linear Algebra) 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: Information Theory in CS (120237)

Madhu Sudan

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

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

Information Theory originated in a seminal work of Shannon that attempted to formalize and quantify communication. This theory was mostly ignored by theoretical computer science till the 1990s when tools and concepts from Information Theory started to play a central role in powerful results in the field. Notable examples include the Parallel Repetition Theorem of Raz (1994), the development of the Information Complexity measure as a means of understanding Communication Complexity (2001). Today Information Theoretic measures and tools influence many aspects of CS theory including analysis of streaming algorithms, differential privacy and game theory. This course will introduce the basic concepts in information theory and then sample topics of interest to CS theory where information theoretic tools play a central role. See http://madhu.seas.harvard.edu/courses/Spring2019 for more information.

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

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 229R

Topics in Theoretical Computer Science: Interactions between Physics and Computation (120237)

Boaz Barak

Tselil Schramm

2018 Fall (4 Credits) **Schedule:** F 0130 PM - 0245 PM

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

In this graduate seminar we will explore some of the connections between theoretical computer science and physics. Some topics include: connections between statistical physics and computational complexity, quantum information theory, quantum Hamiltonian complexity, black holes, bulk/boundary correspondence, "quantum superiority experiments", the "conformal bootstrap". and more.

All of these are topics that I personally find fascinating, but know very little about. I hope we can learn about them together. Each one of those can probably be the topic of a full semester-long course (and even that, assuming significant physics background). I hope this seminar will be like a "tasting menu" where we pick some of the juiciest and most interesting questions and results from all these areas, and attempt to understand and present them using the minimal amount of physics.

See the website https://www.boazbarak.org/fall18seminar/ for more information about this seminar.

Course Notes: **While the seminar is officially listed as taking place from 1:30 till 2:45, it will actually take place from 1:30-4:30 as it is merged with the theory reading group.**

Recommended Prep: **This seminar is mostly geared towards graduate in theoretical computer science, but advanced undergraduates might also enjoy it. I recommend undergraduate take this seminar if they have already taken a graduate course in theoretical computer science (i.e., CS22x course) but feel free to email me to discuss whether this course will be a good fit for you.**

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 236R

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

Yiling Chen

2019 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 Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Computer Science 244R

Networks Design Projects (112631)

H. Kung

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

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

The contents and course requirements are similar to those of Computer Science 144r, with the exception that students enrolled in Computer Science 244r are expected to do substantial system implementation and perform graduate-level work.

Deep neural networks (DNNs) are becoming a popular tool in data-driven applications. One of the next frontiers is distributed DNNs over computer networks for improved scaling (e.g., for scaling training as in federated learning) and parallel DNNs over processor arrays for low-latency inference in real-time applications. To this end, there is a need to understand issues such as communication, computation, and accuracy trade-offs. This research-oriented course will address this relatively new, yet rapidly advancing, topic. We will survey the main approaches, with a unique focus on the interplay between deep learning models, parallel and distributed computing architectures, and the hardware structures of end devices. The class will be organized into the following eight modules:

Motivations for parallel and distributed deep learning; Parallelism available in deep neural networks; Review of background concepts in deep learning, computer networks, computer architectures, and FPGA/ASIC hardware accelerators; Deep dive case studies in parallel and distributed training and inference (e.g., distributed federated learning and quantized low-latency and energy-efficient inference); Full-stack design optimization for inference in which deep learning models, computing architectures, and hardware circuits are simultaneously optimized; Collaborative deep learning inference between the cloud, edge, and client machines; Privacy and security protocols, and the novel use of blockchains in support of parallel and distributed deep learning; and Emerging technologies in deep learning such as automated neural architecture search and neuromorphic computing. Students working in 2- or 3-person teams will do a substantial project in these and other related areas.

Course Notes: **Preference given to upper-class undergraduates or graduate students in computer science or in business who are proficient in computer programming or in business software.**

Recommended Prep: **Basic courses in networking (e.g., CS 143) and AI (e.g., CS 181 or 182), programming experience (e.g., CS 51), some research 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 Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 245

Cloud Networking and Computing (208351)

Minlan Yu

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

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

The contents and course requirements are similar to those of Computer Science 145, with the exception that students enrolled in Computer Science 245 are expected to do substantial system implementation and perform graduate-level work. 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.

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

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 247R

Advanced Topics in Computer Architecture (128149)

David Brooks

2018 Fall (4 Credits) **Schedule:** F 0900 AM - 1145 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)
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 252R

Advanced Topics in Programming Languages (114807)

Stephen Chong

2019 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 Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Computer Science 260R

Projects and Close Readings in Software Systems (110276)

Eddie Kohler

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

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

Modern software systems construction and analysis. Distributed systems; operating systems; networks; data centers; big data; emerging systems deployments. Close, careful reading of research papers and code, coupled with programming projects. Readability and programmability. Topic focus will change each offering. May be repeated for credit with instructor permission.

Recommended Prep: **Programming experience and instructor permission.**

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 263

Systems Security (160579)

James Mickens

2018 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: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 265

Big Data Systems (113660)

Stratos Idreos

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

2019 Spring (4 Credits) **Schedule:** MW 0130 PM - 0245 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)
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 279

Research Topics in Human-Computer Interaction (121985)

Krzysztof Gajos

2018 Fall (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

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

The course covers major areas of inquiry and core research methods in Human-Computer Interaction including experimental design, statistical data analysis, and qualitative methods. Activities will include discussion of primary literature, a small number of lectures, assignments (design, execution and analysis of both lab-based and on-line experiments), and a research project.

Course Notes: **Designed for first year 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.**

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)
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 281

Advanced Machine Learning (107677)

Alexander Rush

2018 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
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Computer Science 282R

Machine Learning: Advances in Uncertainty Quantification, Structured Prediction, Large-Scale Methods (156936)

David Parkes

David Belanger

Alexander D'Amour

Dougal Maclaurin

Roland Snoek

Alexander Wiltschko

2019 Spring (4 Credits) **Schedule:** F 0900 AM - 1045 AM

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

Recent advances in ML have enabled rapid progress in data-driven systems in a wide range of domains like image processing and NLP. However, to unlock additional areas of application, ML methods must provide good estimates of uncertainty, operate on structured representations of data, and work at large scale. We will explore a collection of cutting-edge advancements in these topics. Students will read multiple papers per week, present papers to the class, and complete a final project. Sometimes the machine learning literature is daunting because it changes so quickly. An overarching goal of the course will be to collectively identify broad frameworks and trends of the research community and to identify opportunities for high-impact research.

Class Notes: **The class will meet in Maxwell Dworkin G115 for the first class, Friday, Feb. 1. Course will meet at Google after the first meeting. The course is taught by a group of researchers on the Google Brain team. Starting with the Feb 8 class, students should head to Google Kendall Square Office at 355 Main Street in Cambridge (Kendall Square t-station). Students should arrive 15 minutes early (8:45am) for the second class Friday, Feb. 8, check in with security downstairs and then head to reception on the 5th floor, where Carolyn Cismondi will greet them and lead them to the "Esplanade East" training room. The course will be capped at 20 students.**

Recommended Prep: **Students should be comfortable with the basics of modern probabilistic machine learning, such as deep learning, variational inference, and Markov Chain Monte Carlo.**

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 282R

Topics in Machine Learning: Deep Bayesian Models (156936)

Finale Doshi-Velez

2018 Fall (4 Credits) **Schedule:** MW 0900 AM - 1015 AM

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

Many domains involve placing uncertainties over functions: If we took two precipitation readings two miles apart, what are the possible precipitations in between? If we have a function mapping drug dosage to blood pressure change for a variety of patients, what is our uncertainty for a new patient? Deep Bayesian models are a flexible class of priors over deterministic and stochastic functions, but truly understanding that model class, and performing inference in it, has many open questions. In this course, we will begin with Gaussian processes, a much simpler prior over functions, and then explore deep Bayesian models via

readings, coding assignments, and a final project. Along the way, we'll learn what works when, and where the research questions are.

Course Notes: **The course will be capped at 25 students.**

Recommended Prep: **While no experience with deep Bayesian models is expected, students will be expected to be comfortable with basic ideas of Bayesian inference, including Markov Chain Monte Carlo and variational inference. Take a peek at Rasmussen and William's Chapter 2.2 and see if you're in love.**

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 287R

Machine Learning for Natural Language (112867)

Alexander Rush

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

Instructor Permissions: Instructor **Enrollment Cap:** 35

Machine learning for natural language processing with a focus on deep learning and generative models. Topics include language modelling, information extraction, multi-model applications, text generation, machine translation, and deep generative models. Course is taught as a reading seminar with student presentations. Requires comfort with reading ML research papers and completion of a major final project.

Course Notes: **Enrollment limited to 35 students.**

Recommended Prep: **Machine learning at the level of CS 281 is recommended, as is significant programming background.**

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 289

Biologically-inspired Multi-agent Systems (120238)

Radhika Nagpal

2018 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)
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 299R

Special Topics in Computer Science (114035)

Salil Vadhan

2019 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.**

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 299R

Special Topics in Computer Science (114035)

Salil Vadhan

2018 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
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Computer Science 306

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

Eddie Kohler

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 306

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

Eddie Kohler

2018 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 308

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

Radhika Nagpal

2019 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	Not Available for Cross Registration

Computer Science 308

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

Radhika Nagpal

2018 Fall (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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 310

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

David Parkes

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 310

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

David Parkes

2018 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	Not Available for Cross Registration

Computer Science 312

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

Barbara Grosz

2019 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	Not Available for Cross Registration

Computer Science 312

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

Barbara Grosz

2018 Fall (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 314

Visual Computing (124155)

Hanspeter Pfister

2019 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 314

Visual Computing (124155)

Hanspeter Pfister

2018 Fall (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 316

Social Computing: Computation and Economics (125388)

Yiling Chen

2019 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	Not Available for Cross Registration

Computer Science 316

Social Computing: Computation and Economics (125388)

Yiling Chen

2018 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	Not Available for Cross Registration
FAS: Course Level	Graduate Course

Computer Science 320

Data Systems Design (156744)

Stratos Idreos

2019 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 320

Data Systems Design (156744)

Stratos Idreos

2018 Fall (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 324

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

Stuart Shieber

2019 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	Not Available for Cross Registration

Computer Science 324

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

Stuart Shieber

2018 Fall (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 326

Intelligent Interactive Systems and Human-Computer (126331)

Krzysztof Gajos

2019 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 326

Intelligent Interactive Systems and Human-Computer (126331)

Krzysztof Gajos

2018 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	Not Available for Cross Registration
FAS: Course Level	Graduate Course

Computer Science 327

Tools for Reliable Meaningful Efficient Communication (160962)

Madhu Sudan

2019 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	Not Available for Cross Registration
FAS: Course Level	Graduate Course

Computer Science 327

Tools for Reliable Meaningful Efficient Communication (160962)

Madhu Sudan

2018 Fall (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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 328

Mathematical Logic, Theory of Computation (133437)

Harry Lewis

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 328

Mathematical Logic, Theory of Computation (133437)

Harry Lewis

2018 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 335

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

Boaz Barak

2018 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	Science & Engineering & Applied Science

Computer Science 335

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

Boaz Barak

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Computer Science 344

Computer Architecture: Modeling and Design (116858)

David Brooks

2019 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	Not Available for Cross Registration
FAS: Course Level	Graduate Course

Computer Science 344

Computer Architecture: Modeling and Design (116858)

David Brooks

2018 Fall (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 346

High-Performance Computer Systems (117841)

Michael Smith

2019 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	Not Available for Cross Registration

Computer Science 346

High-Performance Computer Systems (117841)

Michael Smith

2018 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	Not Available for Cross Registration

Computer Science 348

Computer Vision (120091)

Todd Zickler

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 348

Computer Vision (120091)

Todd Zickler

2018 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	Not Available for Cross Registration

Computer Science 356

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

Leslie Valiant

2019 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 356

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

Leslie Valiant

2018 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	Not Available for Cross Registration
FAS: Course Level	Graduate Course

Computer Science 358

Computational Complexity, Cryptography, and Pseudorandomness (115136)

Salil Vadhan

2019 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 358

Computational Complexity, Cryptography, and Pseudorandomness (115136)

Salil Vadhan

2018 Fall (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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 360

On-line Algorithms and Randomized Algorithms (109883)

Michael Mitzenmacher

2019 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 360

On-line Algorithms and Randomized Algorithms (109883)

Michael Mitzenmacher

2018 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	Not Available for Cross Registration
FAS: Course Level	Graduate Course

Computer Science 362

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

James Mickens

2019 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 362

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

James Mickens

2018 Fall (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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 364

Programming Languages and Security (126329)

Stephen Chong

2019 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 364

Programming Languages and Security (126329)

Stephen Chong

2018 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	Not Available for Cross Registration

Computer Science 372

Topics in Theory for Society (204561)

Cynthia Dwork

2019 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	Science & Engineering & Applied Science

Computer Science 372

Topics in Theory for Society (204561)

Cynthia Dwork

2018 Fall (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	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course

Computer Science 376

Computer Graphics (121071)

Steven Gortler

2019 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 376

Computer Graphics (121071)

Steven Gortler

2018 Fall (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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 378

Sketching Algorithms for Massive Data (110261)

Jelani Nelson

2019 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 378

Sketching Algorithms for Massive Data (110261)

Jelani Nelson

2018 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 380

Algorithms for Social Data (110263)

Yaron Singer

2019 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	Not Available for Cross Registration

Computer Science 380

Algorithms for Social Data (110263)

Yaron Singer

2018 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	Not Available for Cross Registration

Computer Science 382

Natural Language Understanding and Generation (160961)

Alexander Rush

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 382

Natural Language Understanding and Generation (160961)

Alexander Rush

2018 Fall (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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 384

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

Scott Kuindersma

2019 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 384

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

Scott Kuindersma

2018 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	Not Available for Cross Registration

Computer Science 386

Machine Learning (160970)

Finale Doshi-Velez

2019 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: Course Level	Graduate Course
FAS Divisional Distribution	None

Computer Science 386

Machine Learning (160970)

Finale Doshi-Velez

2018 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	Not Available for Cross Registration

Subject: Engineering Sciences

Engineering Sciences 301

SEAS Teaching Practicum (125374)

John Girash

2018 Fall (4 Credits) **Schedule:** T 0300 PM - 0545 PM

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

Practicum emphasizing an active but reflective approach to teaching applied sciences and engineering; designed for graduate students in any SEAS area, not specifically Engineering Sciences. Topics: presentation and communication; in-class teaching and interaction; developing, grading and giving feedback on assignments; course head / TF relations and expectations; cognition and learning. Seminar style with an emphasis on observation, practice, feedback, and reflection. While the primary context of the course is classroom-style teaching, those interested in developing instructional communication skills in other contexts within science and engineering -- labs/studios, presentations, etc. -- are quite welcome, and course tasks can be adjusted for such.

Course Notes: **Unlike most 300-level courses at SEAS, this is a class with a regular meeting time and some assignments, largely involving lesson prep and brief background reading. The class will alternate between "teaching weeks" (likely taking until 5:45) and "reflection weeks" (aiming to end at 5pm). Counts towards the Derek Bok Center's Teaching Certificate. Graduate students from all science and engineering fields within Harvard are welcome. Postdocs and motivated undergraduates may audit, doing the same work as enrolled graduate students. Formerly COMPSCI 365.**

Additional Course Attributes:

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