HARVARD
John A. Paulson
School of Engineering
and Applied Sciences

THE UNOFFICIAL GUIDE TO

COMPUTER SCIENCE @ HARVARD

VERSION 16

CS.HARVARD.EDU

DESIGNED BY CS50

Haven't taken CS50 yet?
Visit **cs50.harvard.edu** *for FAQs.*

What is CS?

We like to say that CS teaches you how to think more methodically and how to solve problems more effectively. As such, its lessons are applicable well beyond the boundaries of CS itself.

But CS is also, more generally, the study of information. How do you represent it? With what methods (aka algorithms) can you process it?

Perhaps the most liberal answer, though, is that CS "has no exclusive domain of its own, and that its importance comes from the problems to which it is applied." And therein lies the excitement. CS empowers you with tools and ideas that can be applied to practically any domain of interest to you, both in college and beyond.

What is CS not?

Contrary to popular belief, CS is not really about programming, even though you do learn how to program. Programming languages are tools that Computer Scientists use or create in order to solve problems of interest to them.

How can I get a secondary in CS?

Take any four courses numbered 50 or higher. See page 9 for popular study cards. See **Computer Science** under **Secondary Fields** in the *Handbook for Students*.

How do I concentrate in CS?

Take at least two of CS50, CS51, and CS61; take CS121 and another "theory" course; take four technical electives; and take Math 21a and Math 21b. Plus take any of Math 1a, Math 1b, and CS20 as needed. See page 8 for popular study cards. See **Computer Science** under **Fields of Concentration** in the *Handbook for Students*.

Can I change my concentration to CS?

Yes, so long as you still have time to satisfy the requirements. Even David J. Malan '99, who now teaches CS50, didn't take his first CS course until his sophomore year, when he switched from Government to CS.

Does CS require a thesis?

No, not for non-Honors or Honors, but for High Honors and Highest Honors, it's expected. See **Computer Science** under **Fields of Concentration** in the *Handbook for Students*.

Is a thesis just a big program?

No, a thesis is a research paper. You might end up writing programs in order to evaluate your ideas, but those programs are ordinarily means to an end, not an end in themselves. Visit **cs.harvard.edu/thesis** for examples.

Popular Study Cards for Concentrators

Plenty of other combinations are possible. Graduate-level (200-level) courses are also allowed!

For late converts to CS
- Math 1a: Introduction to Calculus
- Math 1b: Calculus, Series, and Differential Equations
- AM21b: Mathematical Methods in the Sciences
- CS20: Discrete Mathematics for Computer Science
- CS50: Introduction to Computer Science I
- CS61: Systems Programming and Machine Organization
- CS109a: Introduction to Data Science
- CS109b: Advanced Topics in Data Science
- CS121: Introduction to the Theory of Computation
- CS124: Data Structures and Algorithms
- CS126: Fairness, Privacy, and Validity in Data Science
- CS141: Computing Hardware
- CS179: Design of Usable Interactive Systems

For those without prior college-level math, interested in human-computer interaction
- Math 1a: Introduction to Calculus
- Math 1b: Calculus, Series, and Differential Equations
- AM21a: Mathematical Methods in the Sciences
- AM21b: Mathematical Methods in the Sciences
- CS20: Discrete Mathematics for Computer Science
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS61: Systems Programming and Machine Organization
- CS96: System Design Projects
- CS105: Privacy and Technology
- CS108: Intelligent Systems: Design and Ethical Challenges
- CS121: Introduction to the Theory of Computation
- CS124: Data Structures and Algorithms
- CS126: Fairness, Privacy, and Validity in Data Analysis
- CS171: Visualization
- CS179: Design of Usable Interactive Systems
- CS182: Artificial Intelligence

For those with stronger math backgrounds, interested in hard-core systems
- AM21a: Mathematical Methods in the Sciences
- AM21b: Mathematical Methods in the Sciences
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS61: Systems Programming and Machine Organization
- CS96: System Design Projects
- CS125: Algorithms and Complexity
- CS127: Introduction to Cryptography
- CS143: Computer Networks
- CS144r: Network Design Projects
- CS148: Design of VLSI Circuits and Systems
- CS153: Compilers
- CS161: Operating Systems
- CS165: Data Systems

For budding theorists writing theses
- Math 25a: Honors Linear Algebra and Real Analysis I
- Math 25b: Honors Linear Algebra and Real Analysis II
- AM106: Applied Algebra
- AM107: Graph Theory and Combinatorics
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS91r: Supervised Reading and Research
- CS121: Introduction to the Theory of Computation
- CS124: Data Structures and Algorithms
- CS134: Networks
- CS141: Computing Hardware
- CS152: Programming Languages
- CS175: Computer Graphics
- CS191: Classics of Computer Science

For those interested in machine intelligence
- AM21a: Mathematical Methods in the Sciences
- AM21b: Mathematical Methods in the Sciences
- CS20: Discrete Mathematics for Computer Science
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS61: Systems Programming and Machine Organization
- CS121: Introduction to the Theory of Computation
- CS124: Data Structures and Algorithms
- CS136: Economics and Computation
- CS141: Computing Hardware
- CS146: Computer Architecture
- CS181: Machine Learning
- CS187: Computational Linguistics
- CS189: Autonomous Multi-Robot Systems

Popular Study Cards for Secondaries

Plenty of other combinations are possible. Graduate-level (200-level) courses are also allowed!

For "those less comfortable"
- CS50: Introduction to Computer Science I
- CS105: Privacy and Technology
- CS108: Intelligent Systems: Design and Ethical Challenges
- CS179: Design of Usable Interactive Systems

For "those more comfortable"
- CS51: Introduction to Computer Science II
- CS61: Systems Programming and Machine Organization
- CS125: Algorithms and Complexity
- CS161: Operating Systems

For those interested in data
- CS50: Introduction to Computer Science I
- CS109a: Introduction to Data Science
- CS109b: Advanced Topics in Data Science
- CS126: Fairness, Privacy, and Validity in Data Analysis

For those interested in economics
- CS51: Introduction to Computer Science II
- CS121: Introduction to the Theory of Computation
- CS134: Networks
- CS136: Economics and Computation

For those interested in efficiency
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS121: Introduction to the Theory of Computation
- CS124: Data Structures and Algorithms

For those interested in graphics
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS171: Visualization
- CS175: Computer Graphics

For those interested in hardware
- CS61: Systems Programming and Machine Organization
- CS141: Computing Hardware
- CS146: Computer Architecture
- CS148: Design of VLSI Circuits and Systems

For those interested in life sciences
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS124: Data Structures and Algorithms
- CS171: Visualization

For those interested in business
- CS50: Introduction to Computer Science I
- CS105: Privacy and Technology
- CS127: Cryptography
- CS165: Data Systems

For those interested in math
- CS51: Introduction to Computer Science II
- CS121: Introduction to the Theory of Computation
- CS124: Data Structures and Algorithms
- CS191: Classics of Computer Science

For those interested in networks
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS143: Computer Networks
- CS144r: Networks Design Projects

For those interested in programming languages
- CS51: Introduction to Computer Science II
- CS61: Systems Programming and Machine Organization
- CS152: Programming Languages
- CS153: Compilers

For those interested in robotics
- CS51: Introduction to Computer Science II
- CS121: Introduction to Formal Systems and Computation
- CS181: Machine Learning
- CS189: Autonomous Multi-Robot Systems

For those interested in speech recognition
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS182: Artificial Intelligence
- CS187: Computational Linguistics

For those interested in software development
- CS50: Introduction to Computer Science I
- CS51: Introduction to Computer Science II
- CS96: System Design Projects
- CS124: Data Structures and Algorithms

How do I graduate with Honors in CS?

Take six technical electives instead of four and have a concentration GPA in the top half of your class. See **Computer Science** under **Fields of Concentration** in the *Handbook for Students*.

How do I graduate with High Honors in CS?

High Honors are decided by faculty vote. You must ordinarily write an "excellent thesis" to be considered. See **Computer Science** under **Fields of Concentration** in the *Handbook for Students*.

How do I graduate with Highest Honors in CS?

Highest Honors are decided by faculty vote. You must ordinarily write an "outstanding thesis" to be considered. See **Computer Science** under **Fields of Concentration** in the *Handbook for Students*.

Do any CS courses count for Gen Ed?

Yes! To satisfy Empirical & Mathematical Reasoning, take CS1, CS20, CS50, or CS171. (Note that CS1 does not count toward a concentration or secondary in CS.) To satisfy Culture & Belief, take CS105.

Should I study CS even if I don't want to be a programmer?

Yes! CS concentrators head off in all sorts of directions after graduation. See **Figure 1** for titles that alumni since 1984 now hold. See **Figure 2** for fields in which alumni since 1984 can now be found.

Should I activate Advanced Standing and get a fourth-year master's degree in CS?

Maybe! If you are eligible for Advanced Standing and think you could handle eight (mostly) 200-level CS courses, it's a great opportunity. Your bachelor's degree doesn't even need to be in CS, so long as you can still satisfy the prerequisites for the 200-level courses. See **Other Academic Opportunities** in the *Handbook for Students*.

Can I do a joint concentration between CS and another field?

Yes, but you probably shouldn't. Joint concentrations are really for students who want to write a thesis on some research problem in the intersection of two fields. If you simply want to study both fields, it's generally best to get a secondary or simply take courses in CS or the other field.

Is CS part of Mind, Brain, and Behavior?

Yes! See **Computer Science** under **Fields of Concentration** in the *Handbook for Students*.

Does a grade of SAT in CS50 count toward concentration or secondary credit?

If you intend to concentrate in or do a secondary in CS, you should take CS50 for a letter grade. But should you decide to concentrate in or do a secondary in CS only after taking CS50, a SAT in CS50 would count for concentration or secondary credit.

Figure 1: Titles that alumni since 1984 now hold.

Figure 2: Fields in which alumni since 1984 can now be found.

Photograph by Joseph Ong

Should I concentrate or minor in CS even if I don't want to work in tech?

Yes! CS empowers you to solve problems in all sorts of domains. Here's where alumni since 1984 can be found:

ACME Labs • **AECON** • AT&T • **AXA Equitable** • Abercrombie and Fitch • **Addison-Wesley Publishing Co** • Administration for Children & Families • **Adobe Systems** • Adult Cardiovascular Consultants, P.A. • **Advanced Research Projects Agency - Energy U.S. Department of Energy** • Agilex Technologies, Inc. • **Air Force Research Laboratory** • Airbnb.com • **Alberto Campari Knoepffler, Architect** • Amazon.com • **American Express** • Amgen Inc. • **Ancestry.com** • Angelynn Grant Design • **Angle Assoc** • AppNexus, Inc • **Apple Inc.** • Apple, Inc. • **Arbor Scientia** • Argosy Partners • **Associates International, Inc.** • Atco Plastics Inc • **Athens University of Economics** • Autodesk, Inc. • **BBN** • BBW Technologies • **BC Partners** • BMO Capital Markets • **Babcock & Wilcox Alliance Research Center** • Bain Capital Sankaty Advisors • **Banaras**

Hindu University • Bank of America • **Bay Imaging Consultants** • Bechtel Limited • **Bell Laboratories** • Bellcore • **BlackBerry** • Blue Mountain Capital Management • **Boeing Satellite Systems** • Bogazici University • **Boston Common** • Boston Public Schools • **Bradley Woods & Co. Ltd.** • Brickhouse Freight • **Bridgewater Associates** • Bridgewood Design • **Brooktrout Technology** • Bungie, LLC • **C A McNary and Associates** • C S Draper Laboratory • **CBCS** • CISCO Systems Foundation • **CTB/McGraw-Hill** • Cambridge Innovation Center • **Canadian Consulate General** • Cancer Services of New Mexico • **Cane & Boniface, PC** • Canon Inc. • **Capital One** • Center Mfg Co • **Charles Schwab** • Chelmsford Public Schools • **Chevron Corporation** • Chrysler/JTE • **Cisco Systems** • Citibank • **Citigroup** • Citigroup Inc. • **City Gas Pte Ltd** • Code.org • **Cohera Medical, Inc.** • College of Engineering • **Comcast** • CommonMind LLC • **Cornell University** • Craig Taylor Equipment • **Creare Inc** • Ctr. for Sustainability and Global Environment University of Wisconsin-Madison • **D. E. Shaw & Co.** • DAVA Oncology • **Dalberg Global Development Advisors** • Damtp Center for Mathmatical Sciences • **Davidson**

Can I do research in CS?

Yes! Many CS courses offer opportunities for research, particularly 200-level courses. And you can take CS91r to work one-on-one with faculty. Students and faculty do research in all sorts of areas, including, but not limited to:

- Architecture
- Artificial Intelligence
- Computational and Data Science
- Computational Neuroscience
- Graphics, Vision, and Interaction
- Information and Society
- Programming Languages
- Systems, Networks, and Databases
- Theory of Computation

Will everyone in CS know more than me?

No! Contrary to popular belief, not every Computer Scientist has been programming since childhood! In fact, 66% of the students who took CS50 in Fall 2016 had never taken a CS course before. Only 22% had taken one, and only 12% had taken two or more, per **Figure 3**.
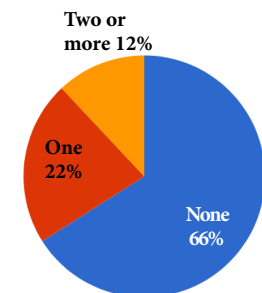

Figure 3: CS50 is most students' very first course in CS. 66% of the students who took CS50 in Fall 2016 had never taken a CS course before, 22% had taken one, and 12% had taken two or more.

Laboratories • KKR 1996 GP LLC • **Kahn International** • Kaiser Permanente • **Karr Tuttle Campbell** • Khan Academy • **King Abdullah University of Science and Technology** • Kirkland & Ellis LLP • **Kohlberg Kravis Roberts & Co.** • Kotzias-Stamatopoulos • **Langdale E3 Pte Ltd** • Larkspur Marketing • **Lava Bear Films** • Law Office of David A. Kahne • **Learning Objects** • Levi Strauss & Co. • **Lewis Brisbois Bisgaard & Smith** • Lexington Software Consulting • **LinkedIn** • Lockheed-Martin • **Lumosity** • MTA New York City Transit • **Macquarie Capital** • Magma Design Automation • **Marin Software** • Mass Bay Transportation Authority • **Massachusetts Dept. of Enviro. Quality Engineering -- SERO** • Materials Development Corp • **Mattel, Inc** • McKinsey & Co. • **McKinsey & Company** • MedTouch • **Medicine in Need** • Merrill Lynch • **Micro Office Solutions** • Micromega Corp • **Microsoft Corp.** • Microsoft Corporation • **Minnesota Council of GIfted&Talented** • Minnesota Pollution Control Agency • **Mitsubishi Corporation** • Morgan Stanley • **Motorola Mobility/Google** • Mozilla Corporation • **Multimodal Technologies, Inc** • Museum of Science • **MySpace** • N.Y. University Stern School of Business • **NASA Goddard Space Flight Center** • NASA Jet Propulsion Laboratory • **NASA/Goddard Space Flight Center** • National Institute of Standards & Technology • **National Institutes of Health** • National Jewish Medical & Research Center • **Netflix** • Network Appliance • **New York City Department of Education** • Northeastern University • **Northrop Grumman** • Northwest Center for Public Health Practice • **OkCupid.com** • Old Dominion University • **Oracle Corporation** • Oregon Independent College Foundation • **Osborn Architects** • Oxy Systems, Inc. • **Pacific Northwest National Lab** • Palo Alto Research Center • **Parfums Christian Dior** • Patch & Associates • **Pearson Education** • Pearson Knowledge Technologies • **Pegasystems** • PerkStreet Financial • **Pixar Animation Studios** • PlayFab, Inc. • **Pleco Software** • Policy Development & Review Department International Monetary Fund • **Popcap** • Prefab Software Inc • **PricewaterhouseCoopers** • Princeton Health Care System • **Princeton University Department of Chemistry** • Procter and Gamble • **Prophet** • Pushtribe • **Quantitative Support Services** • Quantopian • **RRE Ventures LLC** • Radiological Associates of Sacramento • **Rain Wine** • Raytheon • **Raytheon Co** • Regas • **Renaissance Interests, LP** • Richard A Fay & Company • **Robbins Russell Englert Orseck & Untereiner, LLP** • Robert Howard Law Office • **Royal Thai Airforce**

Academy • Russell Investments • **SLC Consultants Inc** • SLH Inc • **SNiP** • Safe Horizon • **Samuel Wong, MD** • Saudi Aramco • **Schlumberger** • ScholarPRO • **Sears Holdings, Inc.** • Seatwave • **Security Mail** • Shell Oil Company • **Siam Commercial Bank** • Siemens PLM • **Silicon Graphics Computer Systems** • Siu On Realty Company Ltd • **SolidWorks** • Sony Computer Entertainment America • **Southern California Permanente Medical Group Neonatal Intensive Care Unit** • Spiegel Liao & Kagay LLP • **SquareR Partners** • St. Edward's University • **Star Thrower Educational Multimedia** • Starbucks Coffee Company • **State Street Associates** • Stem Cell Source, LLC • **Stonebridge Associates LLC** • Strake Jesuit College Preparatory School • **Stratis, LLC** • Sughrue Mion PLLC • **Sullivan County Community College** • Sun Micro Systems Inc • **Sun Microsystems** • Sun Microsystems Laboratories • **SunGard Higher Education** • Susman Godfrey LLP • **Sutherland Associates** • Swarthmore College • **Synaxis Corp** • System Services • **Tarr Technology Consulting** • TechPar Group LLC • **Teradici Corporation** • Tesla Motors • **Tetrad Digital Integrity** • Texas Instruments • **Teza Technologies** • The 1636 Group • **The Boeing Company** • The Boston Company Asset Management • **The Bridgespan Group** • The Container Store • **The Invus Group LLC** • The Oregon Clinic • **The Research Board** • The River Farm • **The Walt Disney Company** • The World Bank • **Thoreau Society Shop at Walden Pond** • Ticketmaster Inc • **Tilera Corporation** • Tisch School of the Arts New York University • **Town of Andover** • U S Postal Service • **U.S. Department of Homeland Security** • U.S. Federal Government • **US Department of Housing and Urban Development** • US Secret Service • **UW Department of Biomedical and Health Informatics** • Undercover Culture Music • **Unibios Holdings** • Union Park Capital • **United Learning Paddington Academy** • United States Air Force • **United States Navy** • Univ Cal • **University of California Berkeley** • University of California at Davis • **University of California, San Francisco School of Medicine** • University of Chicago Booth School of Business • **University of Illinois at Urbana-Champaign Dept. of Chemical and Biomolecular Engineering** • University of Stuttgart • **University of Washington** • University of Waterloo • **VMware, Inc** • VMware, Inc. • **Vanasse Hangen Brustlin Inc** • Varbra S.A. • **Venmo** • Viacom • **Vital Arts Inc** • Vogue Plastic Surgery • **Vulcan Inc.** • Wells Fargo Home Mortgage • **William Blair & Company** • Windward Mark Interactive • **Woods Hole Group** • Yahoo, Inc. • **Yelp** • Zipcar, Inc.

Kempner Capital Management • Davis Polk & Wardwell • **Dell, Inc.** • Demdex • **Department of Defense** • Department of Environmental Health • **Diagnostic Incs** • Dimagi, Inc. • **Downtown Associates** • EMC Corporation • **ETAK Inc.** • EUtrek Ltd • **Earthwatch Inc** • Edward H Comfort CPA • **Ellington Management Group** • Elysium Digital • **Em Software, Inc.** • EnerNOC • **Epoch Investment Partners** • Erler Film A S • **Ernst & Young** • Evidence.com • **Expense Reduction Analysts** • ExxonMobil • **Facebook** • Family Dermatology • **Federal Communications Commission** • Federal Trade Commission • **First Databank** • Flybridge Capital Partners • **Food and Drug Administration** • Ford Motor Company • **Fore Research and Management** • Fortress Investment Group • **Frankel & Associates, Incorporated** • Franklin Templeton Investments • **Fujitsu Limited** • GFZ German Research Centre for Geosciences Helmholtz Centre Potsdam • **General Electric Commercial Finance Capital Solutions- EFS** • General Electric Global Research Center • **Gifts.com**

• GitHub, Inc. • **Goldman, Sachs & Co.** • Good Shepherd Medical Center • **Google, Inc.** • Greater Greater Washington • **Hanover Insurance Company** • Hartman, Blackstock & Moore • **Harvard Club in Beijing** • Harvard College Office of Admissions & Financial Aid • **Harvard-Smithsonian CFA** • Hasbro, Inc. • **Healthpoint Group** • Hermes Fund Managers Limited • **Hewlett-Packard Co** • Highland Capital • **Hong Kong Univ. of Science & Tech. Dept. of Electronic & Computer Engineering** • Hughes Aircraft Co • **Hulu** • Hunton & Williams • **IBM** • IBM Center for Advanced Learning • **IBM Research** • IBM Research Division • **ING** • Icahn School of Medicine at Mount Sinai • **Illustrator** • Imara (Wynford Drive) Limited • **Industrial Light & Magic** • Inflection, LLC • **Ing. Angelo Giuseppe** • Institute for Quantum Computing University of Waterloo • **Integrant Consulting** • Intel Corporation • **InterMed Advisors, Inc.** • Interactive Game Products • **JP Morgan Chase** • Jackson Memorial Hospital • **Jawbone** • Johns Hopkins University • **K & S**

Photograph by Joseph Ong

Life after 50

You can head off in all sorts of directions after CS50, but here are some popular routes. See **Computer Science** in the *Courses of Instruction* for prerequisites.

FALL

SPRING

CS148 — Design of VLSI Circuits and Systems

CS146 — Computer Architecture

CS134 — Networks

CS108 — Intelligent Systems: Design and Ethical Challenges

CS105 — Privacy and Technology

CS109a — Introduction to Data Science

CS109b — Advanced Topics in Data Science

CS126 — Fairness, Privacy, and Validity in Data Analysis

CS124 — Data Structures and Algorithms

CS141 — Computing Hardware

CS171 — Visualization

CS179 — Design of Usable Interactive Systems

CS50

CS20 — Discrete Mathematics for Computer Science

CS143 — Computer Networks

CS144r — Networks Design Projects

CS191 — Classics of Computer Science

CS121 — Introduction to the Theory of Computation

CS187 — Computational Linguistics

CS125 — Algorithms and Complexity

CS96 — System Design Projects

CS61 — System Programming & Machine Organization

CS165 — Data Systems

CS127 — Cryptography

CS181 — Machine Learning

CS182 — Artificial Intelligence

CS51 — Introduction to Computer Science II

CS153 — Compilers

CS161 — Operating Systems

CS136 — Economics and Computation

CS189 — Autonomous Multi-Robot Systems

CS152 — Programming Languages

CS175 — Computer Graphics