

# Theory of Computation (CS6160) Syllabus

University of Virginia

Professor Gabriel Robins

**Course description** (as listed in the undergraduate catalog): Analyzes formal languages, the Chomsky hierarchy, formal computation and machine models, finite automata, pushdown automata, Turing machines, Church's thesis, reductions, decidability and undecidability, and NP-completeness.

**Special emphasis** will be placed on basic models, unifying ideas, problem solving, the “scientific method”, as well as elegance, insights, and generalizability in constructing mathematical proofs.

**Prerequisites:** Discrete mathematics (CS2102) or equivalent

**Web site:** the course Web site is <http://www.cs.virginia.edu/~robins/cs6160/>

**Textbook:** [Introduction to the Theory of Computation](#), by Michael Sipser, 2005, Second Edition

Supplemental reading: [How to Solve It](#), by George Polya, Princeton University Press

Selected papers at: [http://www.cs.virginia.edu/~robins/CS\\_readings.html](http://www.cs.virginia.edu/~robins/CS_readings.html)

**Office hours:** right after every class lecture, and other times by appointment (also Email Q&A and course blog); there is also a large group of TAs to help students, with office hours every single day (including weekends). There will also be a regular weekly problem-solving session with the TAs. The office hours schedule is posted on the course Web site, and we encourage students to meet with the TAs often.

**Class structure:** weekly readings, two exams (midterm and final), some homework problems taken from the posted problem sets (which include problems from the textbook and other sources). Extra credit will be given throughout the semester for solving challenging problems.

## Grading scheme:

- Attendance 10% (every student is expected to attend all lectures, except for emergencies)
  - Homeworks 20% (solutions to selected problems will be due several times during the semester)
  - Readings 20% (various readings will be due each week, as explained below)
  - Midterm 25% (most midterm questions will be minor variations from problem sets)
  - Final 25% (most final exam questions will be minor variations from problem sets)
  - Extra credit 10% (EC given for solving additional problems, and for more readings)
- Total: 110% +

**Study groups:** You are encouraged to work on the problem sets and on the homeworks in study groups (of size no more than six people). These study groups are intended to foster collaborations, encourage brainstorming, create excitement, and make the learning process more fun. Each study group should meet regularly (say twice per week throughout the semester). Everyone in the study group should contribute fairly to the overall group effort. Study groups are not meant for people to just copy solutions verbatim from each other, which is disallowed; it's OK to share ideas and explanations with each other, and then write your own solutions in your own words, but copying-and-pasting from other people's work & text is prohibited. Please form your study groups early in the semester (by the second week) and meet regularly.

**Weekly readings:** The weekly readings in this class consist of a minimum total of 36 items from the [recommended readings list](http://www.cs.virginia.edu/~robins/CS_readings.html) at [http://www.cs.virginia.edu/~robins/CS\\_readings.html](http://www.cs.virginia.edu/~robins/CS_readings.html) consisting of various papers, videos, animated demos, Web sites, and books. The required ones are highlighted in **red font** there, while the rest are "electives". The readings item types should constitute a diverse mix, with a minimum of at least 15 videos, at least 15 papers / Web sites, and at least 6 books. Any items above 36 will count towards extra-credit. The minimum writeup requirements for these readings are a 2 paragraph description for each paper / video / Web site, and 2 page description for books (longer writeups are of course welcomed also). Each writeup should summarize what you learned and what you found interesting and/or surprising.

**At least two submissions are due each week** (by 11:59pm on Monday, beginning the week after the first class), with **no late submissions accepted**, and more than two submissions per week are of course very welcomed and highly recommended. However, **no more than two submissions per day are allowed** (if more than two submissions per day occur, only the first two will be credited). **This policy will be strictly enforced**, and is designed to help you avoid "cramming" at the end of the semester, and also to help you retain more of the knowledge by pacing it more evenly over time. "Cramming" and procrastination are also highly correlated with cheating, so failure to consistently submit these weekly readings on time will attract higher scrutiny to you with respect to cheating detection. Please use the course readings submissions Web form for all submissions.

#### **Milestones in Computability and Logic:**

- Axiomatic systems
- Principia Mathematica
- Gödel's Incompleteness Theorem
- The Turing / Church thesis
- Dovetailing / diagonalization
- The infinity hierarchy
- Independence of the axioms
- Hilbert's Tenth Problem
- Information Theory
- Self-reproduction
- Formal languages
- Complexity theory
- Completeness theory
- Quaternions and Surreal numbers

#### **Beyond the Chomsky hierarchy:**

- Review of the Chomsky hierarchy
- Two-way finite automata
- Generalized finite automata
- State set minimization
- Left/right linear grammars
- Infinite automata
- Nondeterminism and alternation
- Deterministic context-free languages
- Counter automata and languages
- Ambiguity in grammars and languages
- Grammar parsing
- Context-sensitive grammar
- The Turing test

#### **Advanced undecidability:**

- Context-free intersections
- Post correspondence problem
- Linear-bounded automata
- Turing reducibilities
- Computational universality
- Conway's Game of Life
- Busy beaver problem
- The recursion theorem
- Oracles and relativizations
- Non-recognizability
- Turing degrees
- Randomness, compressibility, and entropy

#### **Advanced complexity theory:**

- Time and space complexity classes
- Complexity hierarchies / separations
- Denseness and gap theorems
- Axiomatic complexity
- NP-completeness reloaded
- Problem reductions
- Graph colorability
- Set cover problem
- Knapsacks and subset sums
- Bounded approximation
- Savitch's Theorem
- PSPACE completeness
- NL completeness
- Approximation algorithms
- Zero-knowledge proofs
- Mental poker

**Cheating policy:** Cheating and/or plagiarism is strictly prohibited, including under the [UVa Honor Code](http://honor.virginia.edu/) (see <http://honor.virginia.edu/> for more details). Violators will be subject to serious penalties, including receiving a failing grade on an exam or even in the entire course, as well as possible referral to the UVa Honor Committee (which could lead to expulsion from the University).

Some examples of cheating / plagiarism include:

- Copying of solutions from other people or sources (including downloading from Web sites);
- Sharing of solutions with other people (including uploading to Web sites);
- Cutting-and-pasting from other people’s work and/or text;
- Posting to Web sites or to blogs questions from the course (problem sets, exams, homeworks, etc.)
- Copying article/book/video/movie reviews from anyone (including from Web sites);
- Having other people solve entire problems for you with little effort on your part;
- Providing other people with verbatim solutions to problems with little effort on their part;
- Providing solutions on an exam or assignment that you cannot explain in person;

The list above contains only some selected examples of bad behavior and is definitely not exhaustive. It isn’t feasible to enumerate all the possible ways to cheat, so **please don’t exploit “loop holes” in this policy**, and instead please respect its spirit and positive intent. If you’re in doubt as to whether any particular behavior violates the cheating policy or Honor Code, please ask any of the TAs or the Professor. We reserve the right to ask you in person any of your answers on any exam / homework / submission (and we will do this at our discretion). **If you can’t clearly explain in person one of your answers, we will consider this to be cheating.** Similarly, if we find one of your answers on the Web verbatim (or near-verbatim), we will consider this to be cheating also.

Remember that this is a course in "computer science theory" and “problem solving”, and not a course in "Google searching", nor a course in "copying-and-pasting", nor is it a course in "TED talks binge-watching" (and we will repeat this ethos in class many times throughout the semester). The readings and extra-credit opportunities in this course are not a substitute for learning about the theory of computation, but rather they are designed to ignite your intellectual curiosity, expose you a lot of interesting and cool ideas, help you become a better problem-solver, and elevate the grades of those who diligently study and learn.

Also, **“cramming” and procrastination are highly correlated with cheating**, so failure to submit the weekly readings on time will attract higher scrutiny to you with respect to cheating detection. Additional damage caused by cheaters include creating unnecessary stress and wasted time for your fellow students and course administrators, and it also demoralizes your professors and TAs over time and forces them to become more suspicious and act more strictly and sternly with students. For example, past cheating behavior has already forced us to dedicate a full one-third of this syllabus to address cheating-related issues. ☹

Important note: We do have access to automated cheating/plagiarism detection tools (e.g., software that automatically compares the text of submissions pairwise for textual similarity). These tools also employ automated Google searches that systematically compare phrases and sentences from a submission against general Web searches. We also perform manual comparisons across submissions to detect cheating/plagiarism. So please be aware that cheating/plagiarism is very easy to detect, and it is definitely not a risk worth taking.

We would like to encourage honest collaborations, brainstorming, and study groups, but we prefer to not play “gotcha” with well-meaning people, so **please don’t play “gotcha” with us**. We sincerely ask for your help in creating a more positive learning experience for everyone.