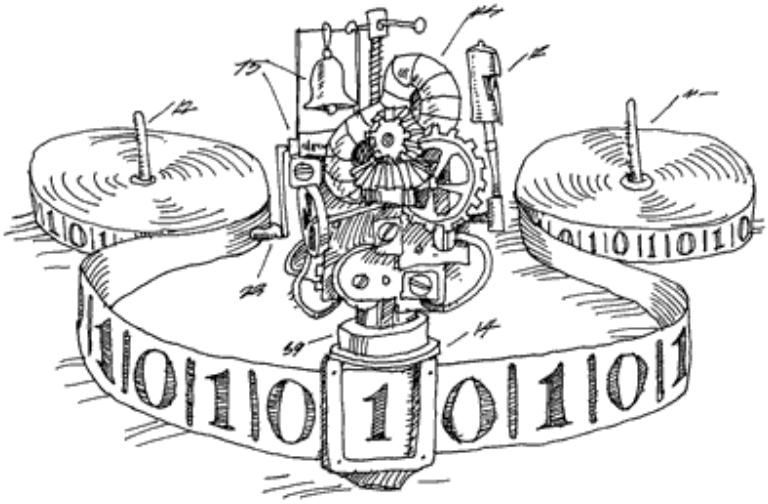
SPRING 2020 **CS235**

Welcome to **CS235**, an introduction to **the theory of computation**



ABOUT CS235

This course offers an introduction to the theory of computation. Topics include languages, regular expressions, finite automata, grammars, pushdown automata, and Turing machines. The first part of the course covers the Chomsky hierarchy of languages and their associated computational models. The second part of the course focuses on decidability issues and unsolvable problems. The final part of the course investigates complexity theory.

MEET THE **PROFESSOR**

Brian Tjaden

Office location: Virtual

Office hours: Mondays 9:55-11:10am,
Thursdays 9:55-11:10am

CS235 SPRING 2020 **SCHEDULE**

Please check this page frequently, as it is subject to change.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
JAN 27	**JAN 28**	**JAN 29**	**JAN 30**	**JAN 31**
Finite State Machines (lectures/1_FiniteStateMachines.pdf) Assignment 1 out (assignments/Assignment1.pdf)			Language Recognizers (lectures/2_LanguageRecognizers.pdf)	
FEB 3	**FEB 4**	**FEB 5**	**FEB 6**	**FEB 7**
Nondeterminism (lectures/3_Nondeterminism.pdf) Assignment 2 out (assignments/Assignment2.pdf) Assignment 1 due (assignments/Assignment1.pdf)			The Equivalence of NFAs and DFAs (lectures/4_EquivalenceNFAsDFAs.pdf)	
FEB 10	**FEB 11**	**FEB 12**	**FEB 13**	**FEB 14**
Closure Under Regular Operations			Regular Expressions (lectures/6_RegularExpressions.pdf)	

(lectures/5_ClosureUnderRegularOperations.pdf)

Assignment 3 out (assignments/Assignment3.pdf)

Assignment 2 due (assignments/Assignment2.pdf)

FEB 17	FEB 18	FEB 19	FEB 20	FEB 21
Presidents' Day	Regular Expressions <==> Regular Languages (lectures/7_RegularLanguages.pdf)		Nonregular Languages (lectures/8_NonregularLanguages.pdf) Assignment 3 due (assignments/Assignment3.pdf)	

FEB 24	FEB 25	FEB 26	FEB 27	FEB 28
Midterm Examination 1			Context-Free Languages (lectures/9_ContextFreeLanguages.pdf) Assignment 4 out (assignments/Assignment4.pdf)	

MAR 2	MAR 3	MAR 4	MAR 5	MAR 6
Pushdown Automata (lectures/10_PushdownAutomata.pdf)			Context Free <==> Pushdown Recognition (lectures/11_ContextFreeAndPushdown.pdf) Assignment 5 out (assignments/Assignment5.pdf) Assignment 4 due (assignments/Assignment4.pdf)	

MAR 9	MAR 10	MAR 11	MAR 12	MAR 13
Turing Machines (lectures/13_TuringMachines.pdf)			Building a Better Mousetrap (lectures/14_BuildingBetterMousetrap.pdf) Assignment 6 out (assignments/Assignment6.pdf)	

Assignment 5 due (assignments/Assignment5.pdf)

MAR 16	MAR 17	MAR 18	MAR 19	MAR 20
Spring Break	Spring Break	Spring Break	Spring Break	Spring Break

MAR 23	MAR 24	MAR 25	MAR 26	MAR 27
Spring Break	Spring Break	Spring Break	Spring Break	Spring Break

MAR 30	MAR 31	APR 1	APR 2	APR 3
What is an Algorithm? (lectures/15_WhatIsAnAlgorithm.pdf)			What Machines Can Do (lectures/16_WhatMachinesCanDo) Assignment 7 out (assignments/Assignment7.pdf) Assignment 6 due (assignments/Assignment6.pdf)	

APR 6	APR 7	APR 8	APR 9	APR 10
What Machines Cannot Do (lectures/17_WhatMachinesCannotDo)			Undecidable Problems About Languages (lectures/18_UndecidableProblemsAboutLanguage Assignment 7 due (assignments/Assignment7.pdf)	

APR 13	APR 14	APR 15	APR 16	APR 17
Mapping Reducibility (lectures/19_MappingReducibility)			~~**Midterm Examination 2**~~	

APR 20	APR 21	APR 22	APR 23	APR 24
Patriot's Day	Measuring Time Complexity (lectures/20_MeasuringTimeComplexity) Assignment 8 out (assignments/Assignment8.pdf)		The Classes P and NP (lectures/21_ClassesPandNP)	

APR 27	APR 28	APR 29	APR 30	MAY 1

				NP Complete Problems (lectures/23_NPCompleteProblems)
The Hardest Problem in the World (lectures/22_HardestProblemInTheWorld) Assignment 9 out (assignments/Assignment9.pdf) Assignment 8 due (assignments/Assignment8.pdf)				
MAY 4	**MAY 5**	**MAY 6**	**MAY 7**	**MAY 8**
Where do we go from here? Assignment 9 due (assignments/Assignment9.pdf)			Reading Period	Reading Period
MAY 11	**MAY 12**	**MAY 13**	**MAY 14**	**MAY 15**
Final Exams	Final Exams	Final Exams	Final Exams	Final Exams

COURSE INFORMATION FOR CS235

Overview

Digital computers can do a great deal that is useful, but not everything that is useful. Computers can be taught to recognize lots of complicated languages, but not all languages. The goal of CS235 is to explore the power and limitations of the modern digital computer.

We will introduce several restricted models of computing machines: finite automata; pushdown automata; and Turing machines. Each model assumes an esstential role in computer science. For example, finite automata are used to design and implement digital logic circuits. Pushdown automata and the languages they recognize are central to the theory of programming languages. Program time and space complexity are analyzed using Turing machines. Taken together, these models form an elegant theory of languages and computation. We will focus on the language aspects of this theory through an exploration of the Chomsky hierarchy of languages: finite automata and regular languages; pushdown automata and context-free grammars; Turing machines and recursively enumerable languages.

After a brief introduction to the theory of computation, we begin by introducing the problem of representation of languages by finite specifications. Initially, we will study the simplest language recognition devices: *finite automata*. Next, we will investigate properties of languages accepted by these machines. Then we switch gears and study an alternative model of computation: *context-free grammars*. By adding a stack memory to our finite state machines, we prove the equivalence of these two notions of computation. We complete our hierarchy of languages and computation by studying *Turing machines* and exploring the limits of computer power. The course concludes by examining *complexity theory*.

Learning Goals

The aim of this course is to enable students to engage in a world shaped by computation, so that students can evaluate and distinguish problems that can and cannot be solved by computers, and students can understand and analyze the complexity of such problems.

Students who complete this course should be able to:

- Apply mathematical concepts, especially proof techniques, to problems in theoretical computer science.
- Identify languages at different levels of the Chomsky hierarchy.
- Design appropriate finite state machines to recognize different languages.
- Explain how mathematical models of computing relate to formal languages.
- Analyze the limits of different computational models such as finite automata and Turing machines.
- Explain the concept of undecidability and evaluate undecidable problems.
- Identify and prove that certain problems do not admit efficient solutions through reductions from well-known intractable problems.

Textbook

The textbook for the course is Introduction to the Theory of Computation, 3rd Edition (http://www.cengage.com/c/introduction-to-the-theory-of-computation-3e-sipser/9781133187790) by Michael Sipser, published by Cengage Learning.

Course Requirements (Before Spring Break)

- *Class meetings:* Class meets twice per week. If you miss a class for some reason, you are responsible for studying the notes on the course website (and corresponding reading from the text). If you have questions about the material, you should see the instructor during regular office horus.
- *Problem sets:* During the term, there will be regular homework assignments.

- *Midterm examinations:* There will be two midterm examinations. Both will be in-class. Please note these dates in your calendar, as they are not flexible.
- *Final examination:* There will be a comprehensive final examination at the end of the semester. The final exam is self-scheduled. All examinations are open book and open notes.

Course Requirements (After Spring Break)

- *Class meetings:* There will be two classes per week. PDFs of the slides for each class are available from the course website. Recorded videos of the instructor discussing the material for each class are also available from the course website. Each week, you should watch the videos for the week's classes at a time that is convenient for you.
- *Problem sets:* During the term, there will be regular homework assignments.
- *Midterm examinations:* The course involved one midterm exam taken before Spring Break.

Late Policy (Before Spring Break)

Assignments are due at the start of class on their due dates. It is beneficial to student learning for course work to be completed regularly throughout the semester. Since much of the material in the course builds off of previous content from earlier in the course, it is helpful to keep on schedule so that students have the necessary background to engage with the material as it is presented in class together with their classmates. Timely submission of assignments also helps us grade and return assignments prompty. For these reasons, excepting the lateness coupons described below, we cannot accept late assignment submissions. In extenuating circumstances (e.g., sickness, personal crisis, family problems, religious holidays), you may request an extension. We will often require that an extension request be made on your behalf by your dean.

In order to offer some amount of flexibility and exception to the above policy, we offer five lateness coupons to be used at the discretion of each student:

- Each student gets five lateness couons. Each coupons corresponds to a 24 hour extension. Coupons can be used at any time during the semester up to the last day of classes but may not be used to extend deadlines into reading period or final exam period (College legislation restricts work, other than final exams/papers/projects from being due after the last day of classes). Coupons may not be used for midterm or final examinations. Multiple coupons may be used for a single assignment or distributed across assignments as a student deems best.
- Coupons are not fractional in nature. If an asignment is one hour, or twelve hours, or 24 hours late, one entire coupon must be used.
- A coupon can be used only on assignments, not on exams.
- For partnered assignments, only one team member needs to use coupons for each 24 extension. Thus, if the partnered group wants to submit an assignment 3 days after the deadline, one team member can use 3 coupons while the other uses 0 coupons, or one team member can use 2 coupons while the other uses 1 coupon. It is up to the team members to work this out together in advance.
- While we use the term "coupon" there are not actually physical coupons. A student simply adds a note to their assignment indicating how many coupons they are using, i.e., how many days late they are submitting the assignment. In the case of partnered assignments, students should indicate which partner is using coupons. The instructor will keep track of coupons that have been used.

Late Policy (After Spring Break)

Assignments are due at the start of class on their due dates. It is beneficial to student learning for course work to be completed regularly throughout the semester. Since much of the material in the course builds off of previous content from earlier in the course, it is helpful to keep on schedule so that students have the necessary background to engage with the material as it is presented in class. Timely submission of assignments also helps us grade and return assignments prompty.

That said, given the exceptional context this semester, we think flexibility on our end is essential. Everyone has different circumstances as they engage with learning in a remote environemnt. Thus, there will be no late coupons. Instead, everyone is automatically granted a 48-hour extension on assignment due dates. No questions asked. You need not inform the instructor if you are taking such an extension. If you would benefit from more than a 48-hour extension, we ask that you inform the instructor in this situation. For these longer extensions, the instructor is inclined to be as supportive as possible, but it helps us to be well informed in these cases so that we can make sure each student is making appropriate progress in their learning, so that we can work together to determine the best learning approach for each student, and so that we can be as supportive as possible.

Collaboration Policy (Before Spring Break)

We believe that collaboration fosters a healthy and enjoyable educational environment. For this reason, we encourage you to talk with other students about the course material and to form study groups.

You are encouraged on any assignment to form a two-person "team" with a partner. The two team members must work closely together on the assignment and turn in a single assignment submission for the team. The grade received on such a submission will be given to both team members.

Team efforts on assignments are subject to the following ground rules:

- The work must be a true collaboration in which each member of the team will carry their own weight. It is *not* acceptable for two team members to split the problems of the assignment between them and work on them independently. Instead, the two team members must actively work together on all parts of the assignment.
- You can only work with a given partner on a single assignment during the semester. So if you want to continue to collaborate, you must choose a different partner for every assignment. Rotating through partners is a good way to build community in the class and is helpful for avoiding situations where one individual feels pressured to continue working with another.
- You are *required* to work with a partner on at least three assignments during the semester. You are *encouraged* to work with a partner on all assignments but you are not required to do so beyond three of the assignments. Based on past experience, working with a partner can significantly decrease the amount of time you spend on an assignment, because you are more likely to avoid silly errors and blind alleys. You are also more likely to have a deeper understanding of a problem if you talk it through with someone else.

Unless otherwise instructed, teams are allowed to discuss problem sets with other teams and exchange ideas about how to solve them. However, there is a thin line between collaboration and plagiarizing the work of others. Therefore, I require that each (one-person or two-person) team must compose its own solutions to each assignment. In particular,

> **You must compose your own solution to each assignment**. You may discuss strategies for approaching the problems with your classmates and may receive general advice from them, but **you are required to write up all of your own solutions**. Furthermore, **you should never look at another student's solutions.**

For example, it is OK to borrow ideas from the textbook, from materials discussed in class, and from other sources as long as you give proper credit. However it is **unacceptable and constitutes a violation of the Honor Code** (1) to write a solution together (with someone not part of your team) and turn in two copies of the same solution, (2) to copy a solution written by your classmates, (3) to read another student's or team's solution or (4) to view assignments, exams and solutions from previous terms of CS235.

In keeping with the standards of the scientific community, **you must give credit where credit is due**. If you make use of an idea that was developed by (or jointly with) others, please reference them appropriately in your work. It is **unacceptable** for students to work together but not to acknowledge each other in their write-ups.

Collaboration Policy (After Spring Break)

We believe that collaboration fosters a healthy and enjoyable educational environment. For this reason, we encourage you to talk with other students about the course material and to form *virtual* study groups.

You are encouraged on any assignment to form a two-person "team" with a partner. The two team members must work closely together on the assignment and turn in a single assignment submission for the team. The grade received on such a submission will be given to both team members.

We encourage you to use the following shared Google document to indicate your interest in partnering up for one of the assignments (https://docs.google.com/document/d/1Zr6YzO-CVZNVYjFZEdQybNfpm89nEJE1CPKYnNEAEMQ/edit?usp=sharing) (note, the document is only accessible once you have signed in to your Wellesley account).

Team efforts on assignments are subject to the following ground rules:

- The work must be a true collaboration in which each member of the team will carry their own weight. It is *not* acceptable for two team members to split the problems of the assignment between them and work on them independently. Instead, the two team members must actively work together on all parts of the assignment.
- ~~You can only work with a given partner on a single assignment during the semester. So if you want to continue to collaborate, you must choose a different partner for every assignment.~~ Rotating through partners is a good way to build community in the class and is helpful for avoiding situations where one individual feels pressured to continue working with another.
- ~~You are *required* to work with a partner on at least three assignments during the semester.~~ You are *encouraged* to work with a partner on all assignments but you are not required to do so ~~beyond three of the assignments~~. Based on past experience, working with a partner can significantly decrease the amount of time you spend on an assignment, because you are more likely to avoid silly errors and blind alleys. You are also more likely to have a deeper understanding of a problem if you talk it through with someone else.

Unless otherwise instructed, teams are allowed to discuss problem sets with other teams and exchange ideas about how to solve them. However, there is a thin line between collaboration and plagiarizing the work of others. Therefore, I require that each (one-person or two-person) team must compose its own solutions to each assignment. In particular,

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Grading Policy

For assignments, normally a subset of assigned problems will be graded. After assignments are submitted, sample solutions will be provided for all assigned problems.

Your *final* grade will be based on a weighted average of the following components:

- ✔ Homework Assignments: 70%
- ✔ Midterm Examination 1: 30%

The grading for this course is mandatory credit/non.

Google Group

There is a CS235 Google Group named `CS-235-01-SP20`. This group has several purposes. We will use it to make class announcements, such as corrections to assignments and clarifications of material discussed in class. We encourage you to post questions or comments that are of interest to students in the course. The instructor will read messages posted to the group on a regular basis and post answers to questions found there. If you know the answer to a classmate's question, feel free to post a reply yourself. The course group is also a good place to find people to join a study group. **You should plan on reading group messages on a regular basis.**

Anonymous Feedback Form

Here is a form for providing anonymous feedback (https://forms.gle/dZwkq1uqcnqp47Kw5) to the instructor. You must be logged in to a Wellesley account to use the form, however neither your email address nor any other identifying information will be recorded.

Disabilities and Accommodations

If you have a disability or condition, either long-term or temporary, and need reasonable academic adjustments in this course, please contact Accessibility and Disability Resources (ADR) to get a letter outlining your accommodation needs, and submit that letter to me. You should request accommodations as early as possible in the semester, or before the semester begins, since some situations can require significant time for review and accommodation design. If you need immediate accommodations, please arrange to meet with me as soon as possible. If you are unsure but suspect you may have an undocumented need for accommodations, you are encouraged to contact ADR. They can provide assistance including screening and referral for assessments.

Accessibility and Disability Resources can be reached at accessibility@wellesley.edu, at 781-283-2434, by scheduling an appointment online at their website www.Wellesley.edu/adr , or by visiting their offices on the 3rd floor of Clapp Library, rooms 316 and 315.

Faculty Responsibilities on Disclosures of Discrimination, Harassment, and Sexual Misconduct

Pursuant to Wellesley College policy, all employees, including faculty, are considered *responsible employees*. That means that any disclosure of discrimination, harassment, or sexual misconduct to a faculty member will need to be shared with the College's Director of Non-Discrimination Initiatives / Title IX and ADA / Section 504 Coordinator, Kate Upatham (781-283-2451; titleix@wellesley.edu). Students who do not wish to have these issues disclosed to the College should speak with *confidential resources* who are the only offices at the College

that do not have this same reporting obligation. On campus, confidential resources include *Health Services* (781-283-2810 available 24/7), the *Stone Center Counseling Services* (781-283-2839 available 24/7) and the *Office of Religious and Spiritual Life* (781-283-2685). You should assume that any person employed on campus outside of these three confidential offices has an obligation to share information with Wellesley College through the Office of Non-Discrimination Initiatives.