Welcome to CMSC 452: Elementary Theory of Computation
Today:
Admin,
Intro to Theory of Computation
Admin
Course Webpage:
Necessary Administrative

Course Webpage:

Course Zoom Site:
https://umd.zoom.us/my/gasarch
Necessary administrative stuff

- Course Website: Will post slides, recordings, notes, and HW there. Will NOT be using canvas or elms.
- Gradescope: you will **submit HW** there.
- Gradescope: we will **grade HW** there.
- Regrade requests due within a week of the HW being graded.
- Piazza is great for asking questions.

IF you are auditing this class for whatever reason- perhaps you are having a hard time getting permission to take it, or perhaps you like the material but don’t want to take it, let me know and I will put you on the class email list and invite you to join the Piazza.
Office Hours and Contact Information

Prof Gasarch
▸ gasarch@cs.umd.edu, (301) 503-3157
▸ OH Tu & Thur 12:30-2:00
https://umd.zoom.us/my/gasarch

TA Saadiq Shaik
▸ saadiqks@gmail.com
▸ OH Mon 10-12 https://umd.zoom.us/j/6670074227

TA Yaelle Goldschlag
▸ yaelle.goldschlag@gmail.com
▸ OH Wed 12-1 https://umd.zoom.us/j/5803841177

TA Eric Shen
▸ eric.shen2000@gmail.com
▸ OH Wed 4-5 https://umd.zoom.us/j/6670074227
What You Need For This Class

▶ Discrete math, modular arithmetic, algorithms, misc math.
▶ Mathematical maturity.
▶ Ability to write short proofs. (This is not a course like MATH410 where the point is RIGOR.)
▶ There will be one short programming project. (This is not a course like Operating Systems where the project IS the course.)
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1. Read notes and slides before class. (Caution: Some of the slides are in progress. They will be labeled as such. You should not read those, they may contain fake news.)

2. Ask questions on Piazza and/or bring questions to class.

3. This course will be taped so can catch up or review. However, better to come to class because:
   3.1 You can ask questions.
   3.2 If you miss class and don't watch the video before the next class you could fall far behind.
   3.3 During COVID try to do normal things (Fall CMSC456 students told me that).
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HWs/exams

- HWs most weeks.

- Due Tuesday before class begins. But see next item.

- Dead Cat Policy: Can submit HW Thursday before class without penalty.

- WARNING: YOU have already been given an extension, HW solutions will be posted on Thursday, so NO extensions past that.

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What you say, what I hear:

You Say
I thought it was due at midnight!

I hear
Oh, so you submitted it MONDAY at midnight, then realized that the Dead-Cat Policy saved you. You are telling me that you appreciate the Dead-Cat Policy!

You Say
Oh, I forgot to hand it in on time but I can prove I did it on time because my computer time stamps my work.

I hear
Oh, so you forgot to hand it in MONDAY, then realized this, got it in on Wednesday before rec. You are telling me that you appreciate the Dead-Cat Policy!

I am not sure why you are telling me about time stamps, but, as the kids say, whatever.
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Required Text None.
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There will be notes, slides, and recordings of lecture online.
How to contact Prof or TAs

▶ Email: Please put “452” in subject line.

▶ Office hours

▶ Piazza

▶ We are around A LOT outside of office hours. It’s not as though we’re going anywhere!
Elementary Theory of Computation
Our Key Question

Given a problem, classify how hard it is.
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Given a problem, **classify** how hard it is.

This question permeates all branches of mathematics and computer science.
The Classification Problem in 600BC-1840AD

1. How hard is it to express $\sqrt{2}$ as a fraction? Impossible! (Proven by Pythagorean school ∼ 600 BC.)

2. How hard is it to solve a quintic equation by expressing its roots by a formula? Impossible! (Proven ind. by Galois and Abel in the 1800’s.)

3. How hard is it to trisect an angle with a ruler and compass? Impossible! (Proven by Wantzel in 1837.)

4. There was an awareness of computational problems taking an amount of time, but it was not rigorous. Example: Gauss invented the Fast Fourier Transform but never told anyone since he did not think it was that important.
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1. Given a real, we want to know how hard it is in terms of the lowest degree polynomial over \( \mathbb{Z} \) that it is a root of.

   Example: \( \frac{2}{3} \) is not the root of any quadratic over \( \mathbb{Z} \).

   (Folklore. This requires a proof which is in the notes, it is optional. It requires linear algebra but is not that hard.)

2. There exists reals that do not solve any polynomial over \( \mathbb{Z} \).

   (Liouville 1844, Hermite 1873, Cantor 1874, von Linderman-\( \pi \).)

3. There is no set of axioms from which one can derive all the truths of arithmetic.

   (Godel's Incompleteness Theorem, 1933.)
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The Age of Computers.
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4. $\{a^n b^n c^n : n \in \mathbb{N}\}$ is not context-free.
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4. We will prove some sets are not regular.
Part II: Context Free and Context Sensitive Grammars
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1. Grammars generate sets of strings.

2. Two kinds we study: Context Free Grammars (CFG) and Context Sensitive Grammars (CSG).

3. We will study grammars briefly, emphasizing:
   3.1 Sets CFGs can generate that are not regular.
   3.2 Sets CSGs can generate that CFGs cannot generate.
   3.3 Problems that can be done with a large DFA or NFA, but only need a small CFG.
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1. \( P \) is the set of sets that can be decided in Polynomial Time. We think of these as problems as being easy.

Because Nathan, Anthony, and Guido have not worked on it yet.

3. We will show SAT is \( NP \)-complete, and using that, many other problems are \( NP \)-complete.

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3. We will show **SAT** is **NP-complete**, and using that, many other problems are **NP-complete**.

4. **P, NP** have many closure properties. We will prove this.
Decidable sets and undecidable sets.
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5. We will define problems that are HARDER THAN HALT.
BILL, STOP RECORDING LECTURE!!!!

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