

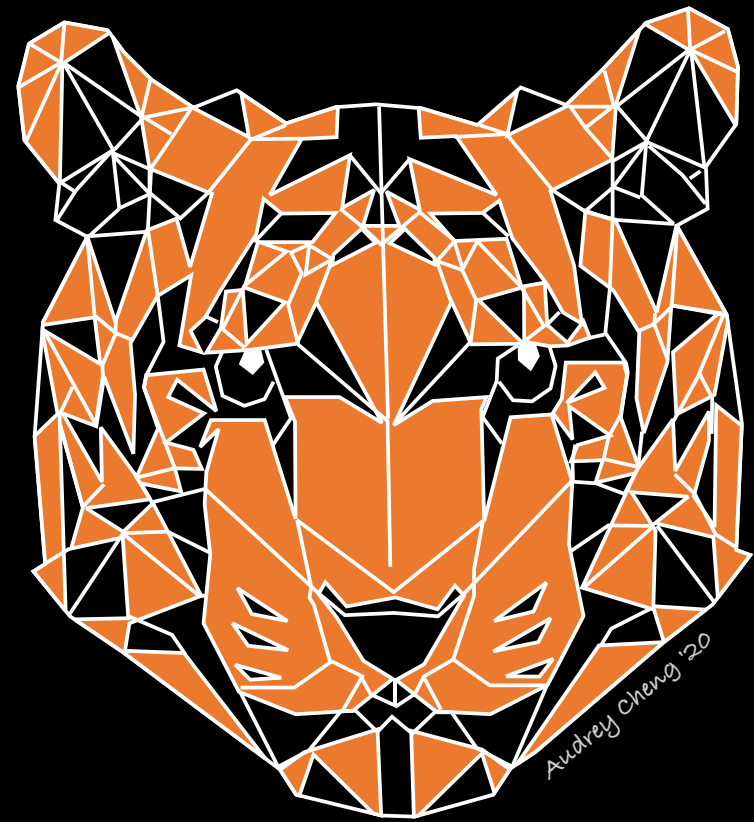
COS 226, FALL 2023

ALGORITHMS
and
DATA STRUCTURES

MARCEL DALL'AGNOL · PEDRO PAREDES · KEVIN WAYNE



FINE PRINT



I will be recording lectures and make them available in Canvas.

*Because of privacy, compliance, and legal considerations,
you may not record or redistribute recordings of this class.*



<https://algs4.cs.princeton.edu>

INTRO TO COS 226

- ▶ *motivation*
- ▶ *course structure*
- ▶ *assessments*
- ▶ *resources*



<https://algs4.cs.princeton.edu>


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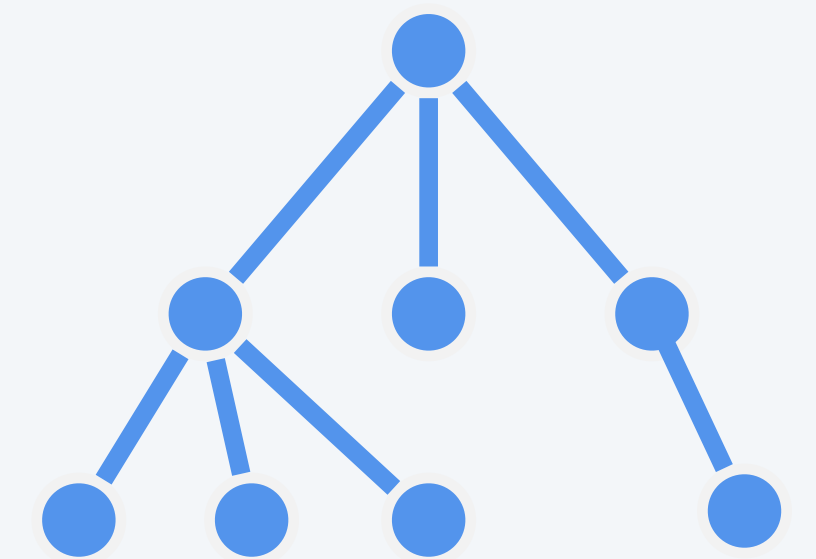
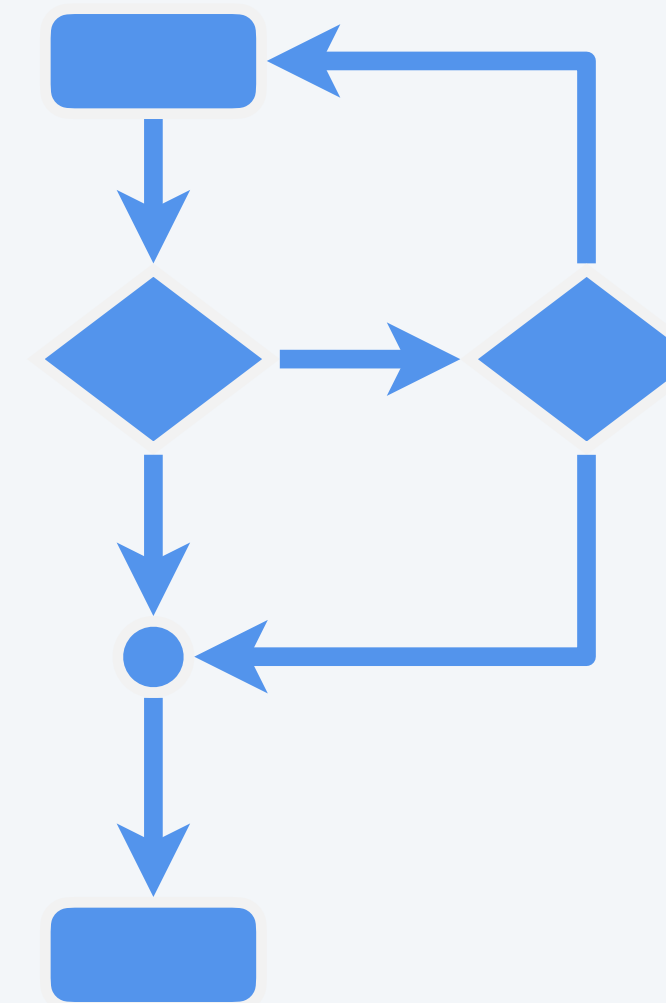
COS 226 course overview

What is COS 226?

- Intermediate-level survey course.
- Programming and problem solving, with applications.
- **Algorithm:** step-by-step procedure for solving a problem.
- **Data structure:** method for organizing data in a computer.

topic	algorithms and data structures 
data types	stack, queue, union-find
sorting	insertion sort, quicksort, mergesort, priority queue
searching	BST, red-black tree, hash table, k-d tree
graphs	BFS, DFS, Prim, Kruskal, Dijkstra
advanced	randomness, multiplicative weights, intractability

← *new this semester*



Why study algorithms and data structures?

Their impact is broad and far-reaching.

Algorithm That Tells the Boss Who Might Quit

Wal-Mart, Credit Suisse Crunch Data to See Which Workers Are Likely to Leave or Stay



This Algorithm Knows You Better Than Your Facebook Friends Do

PERSONALITY TESTS
4:09 PM | JAN 12 | By CHRISTIE ASCHWANDEN

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CIO JOURNAL

Algorithms Will Drive Future Health Gains, Dean of Stanford Medical School Predicts

innovation is at the algorithmic

Prisons turn to computer algorithms for deciding who to parole

By Jacob Kastrenakes on October 14, 2013 10:06 am



Can maths find you love? eHarmony love algorithm

Could maths find you love? The dating site eHarmony, who claim to have

ALGORITHMS TAKE CONTROL OF WALL STREET

New Google algorithm elevates facts; critics worry 'dissidents' will be quashed

29 comments

Computer Scientists Are Building Algorithms to Tackle COVID-19

Algorithms that can detect infections, differentiate COVID-19 from the common flu, and more

Dave Gershgorin Mar 13 · 3 min read



Bitcoin and the Digital-Currency Revolution

For all bitcoin's growing pains, it represents the future of money and global finance.

The Algorithm Economy Heads To Amazon

@DannyCrichton

THE WALL STREET JOURNAL | TECH

At UPS, the Algorithm Is the Driver

Turn right, turn left, turn right: inside Orion, the 10-year effort to squeeze every penny from

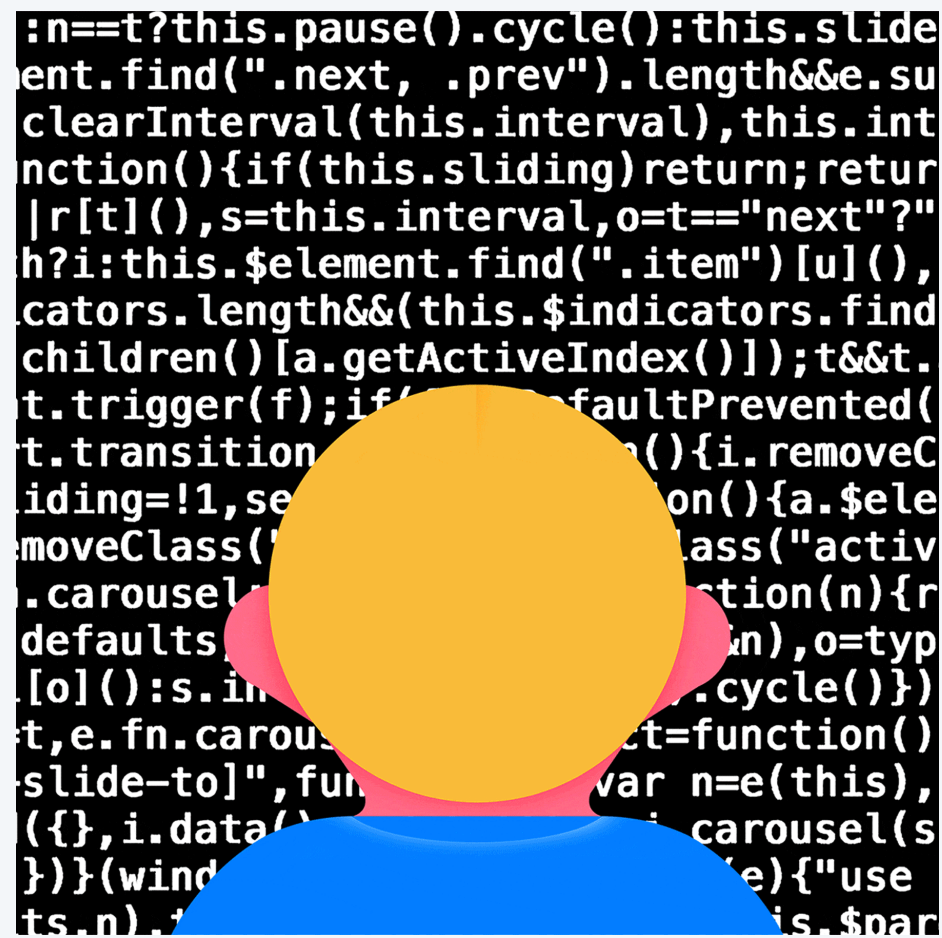
By STEVEN ROSENBUSH and LAURA STEVENS
Feb. 16, 2015 8:28 p.m. ET

87 COMMENTS

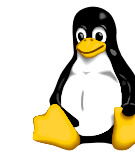


Why study algorithms and data structures?

To become a proficient programmer.

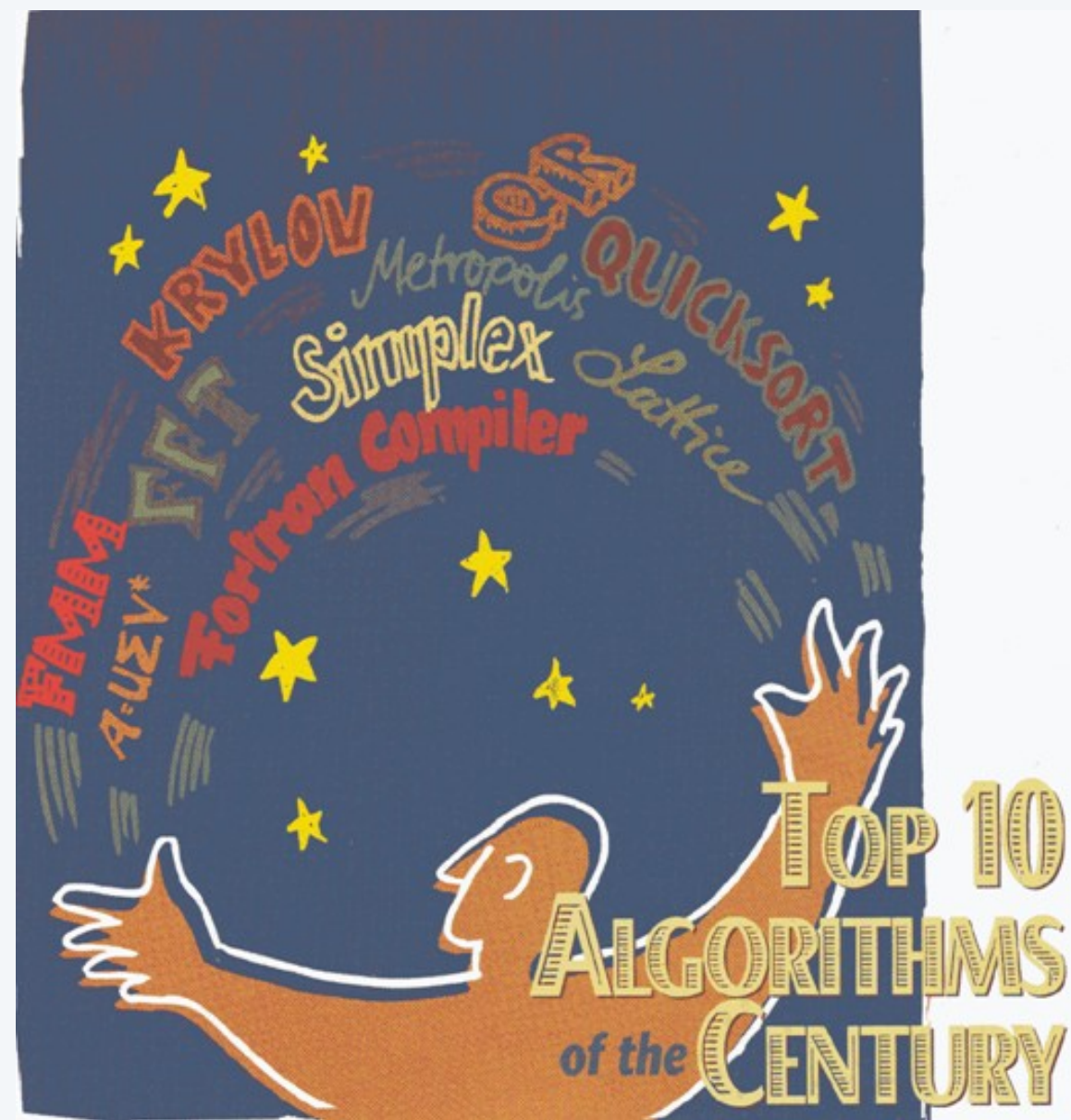


*“ I will, in fact, claim that the difference between a bad programmer and a good one is whether [they] consider [their] code or [their] data structures more important. Bad programmers worry about the code. Good programmers worry about **data structures** and their relationships.”* — Linus Torvalds (architect of Linux and git)



Why study algorithms and data structures?

For intellectual stimulation.



“For me, great algorithms are the poetry of computation. Just like verse, they can be terse, allusive, dense, and even mysterious. But once unlocked, they cast a brilliant new light on some aspect of computing.” — Francis Sullivan

Why study algorithms and data structures?

For fun and profit.



Why study algorithms and data structures?

- Their impact is broad and far-reaching.
- To become a proficient programmer.
- For intellectual stimulation.
- For fun and profit.

Why study anything else?





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INTRO TO COS 226

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- ▶ *resources*

Lectures

Live lectures. Introduce new material.

What	When	Where	Who	Office Hours
L01	TTh 11-12:20pm	Friend 101	Kevin Wayne	<i>see web</i>

Questions. Raise your hand and ask a question. ← *carpe diem!*

Electronic devices. Permitted *only* to support lecture. ← *viewing slides, taking notes, iClickers, ...*



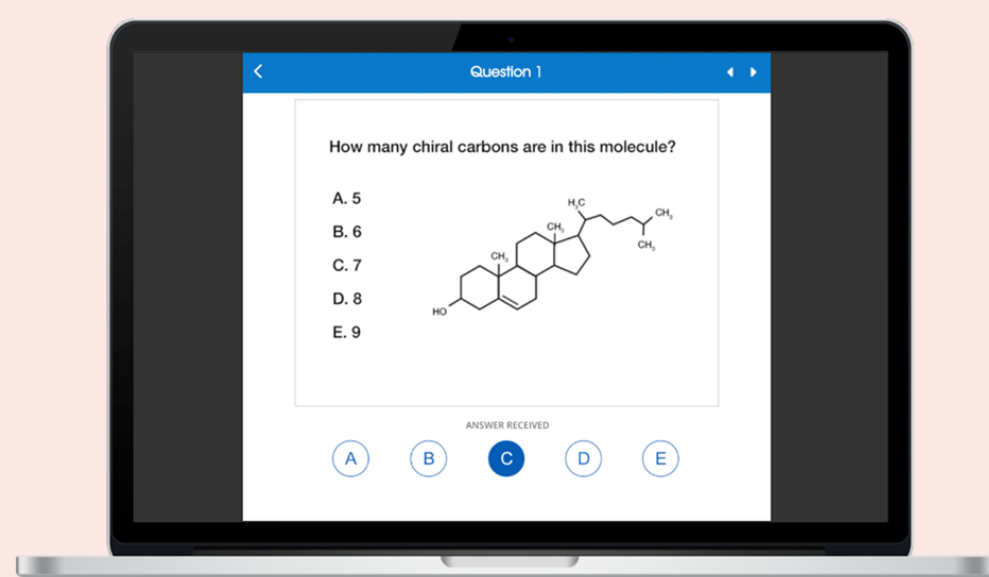
iClicker (required). To earn participation credit:

- Create iClicker Cloud account using Princeton email. ← *free for Princeton students*
- Answer multiple choice questions during lecture.

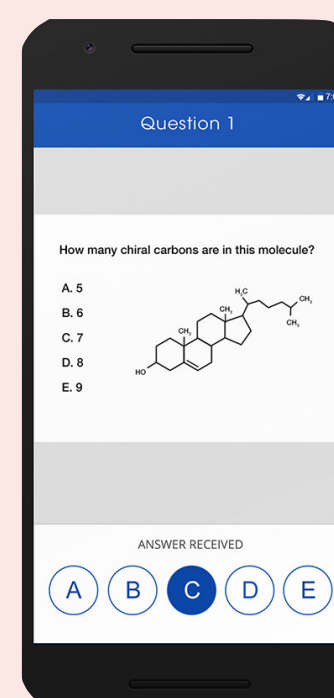


<https://www.iclicker.com>

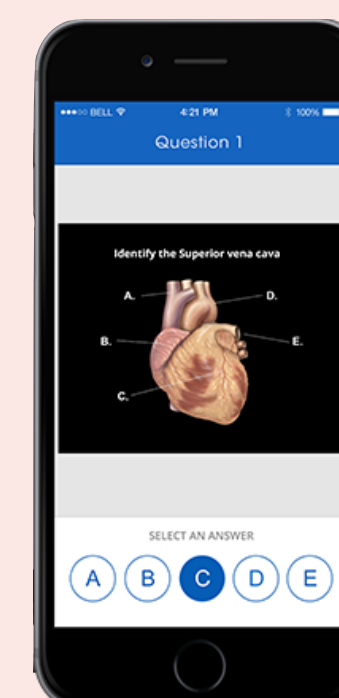
Which iClicker device are you using?



A. Web



B. iPhone



C. Android

Precepts

Active learning. Problem-solving, discussion, assignment prep, ...



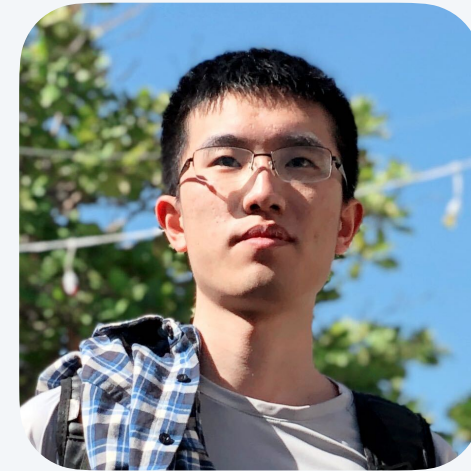
Prof. Pedro Paredes



Prof. Marcel Dall'Agnoll



Nataliia K.



Dongsheng Yang



Sabhya Chhabria



Wei Luo



Malinda Huang



Shelley Xia

Turing precept P08. F 11-12:20pm.

- Intended for students seeking a more advanced treatment of material.
- Covers topics beyond scope of the course.
- Transfer in/out in TigerHub.



Prof. Bob Tarjan
(Turing award '86)



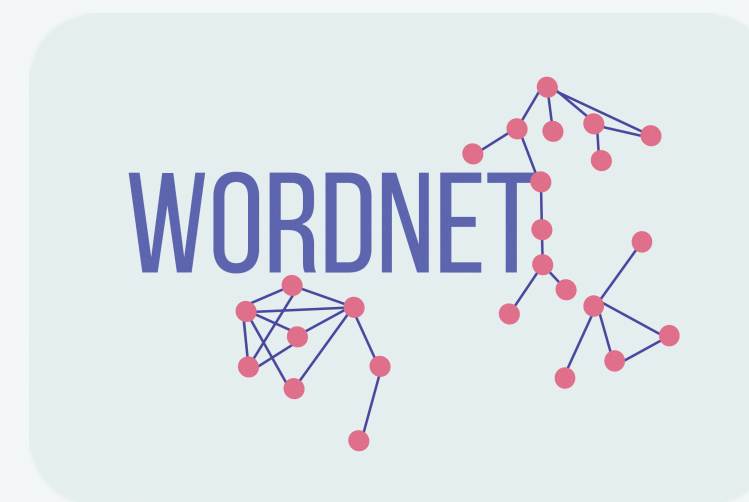
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INTRO TO COS 226

- ▶ *motivation*
- ▶ *course structure*
- ▶ ***assessments***
- ▶ *resources*
- ▶ *union-find*

Programming assignments

Implement an efficient **algorithm** or **data structure**:



Solve an interesting **application** using a “textbook” algorithm:



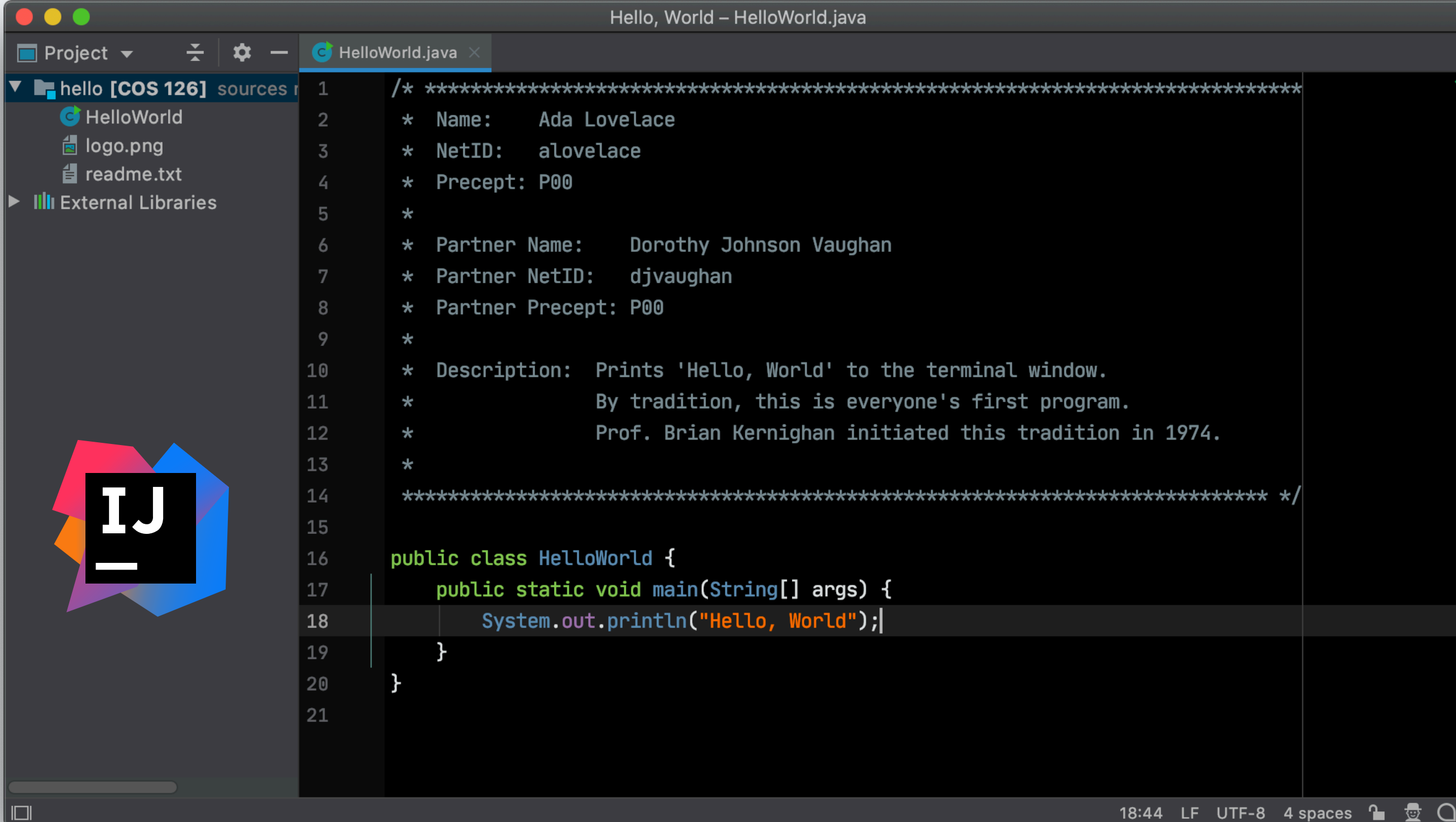
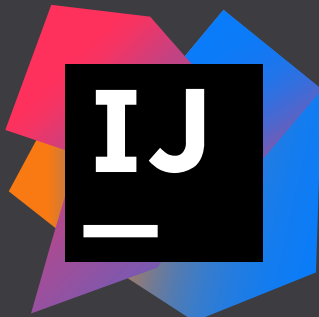
Pair programming encouraged on designated assignments.



Programming environment

Recommended IDE. Custom IntelliJ 2023.2 environment.  *upgrade to Fall 2023 version*

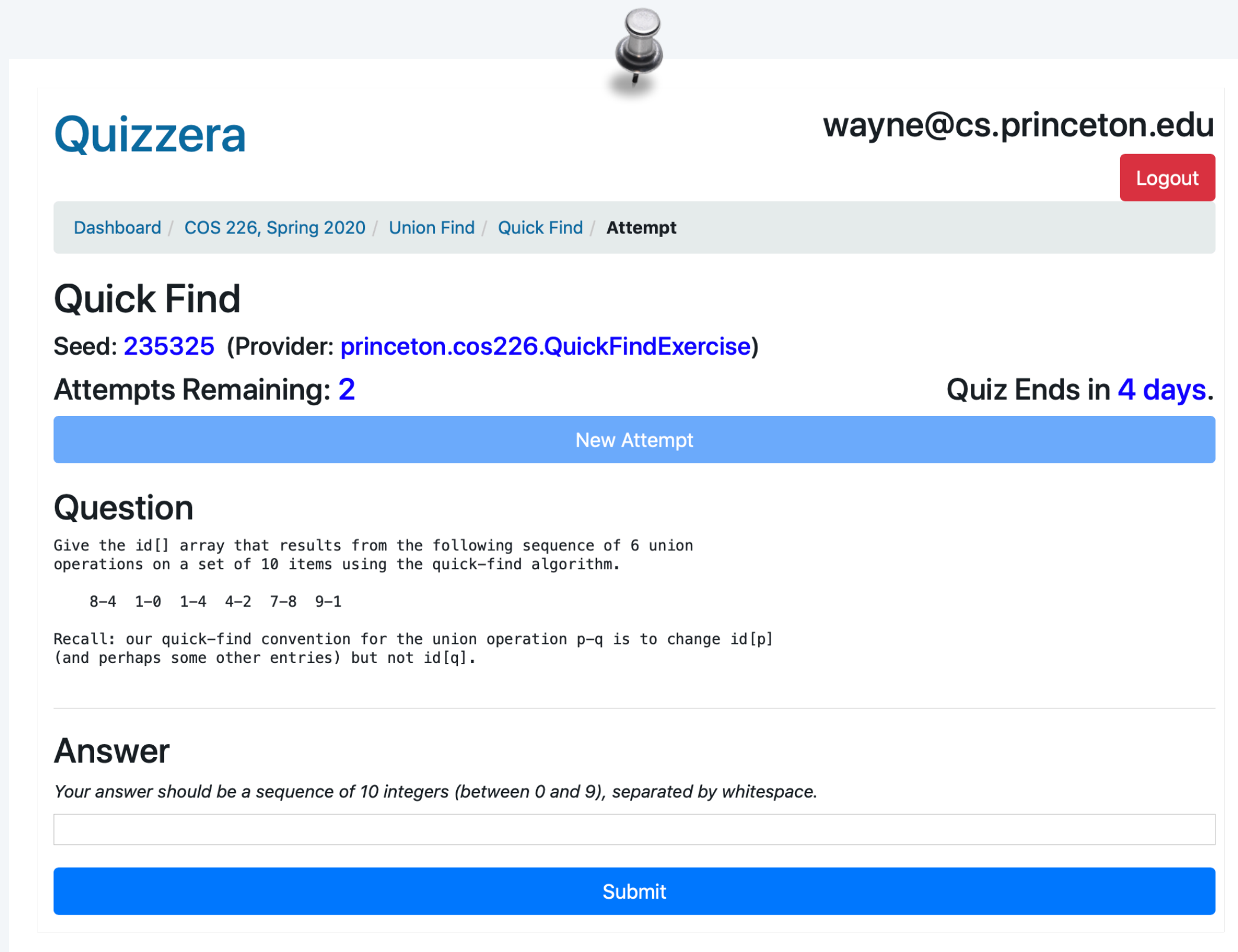
- Embedded Bash terminal.
- Autoformat, autoimport, autocomplete, ...
- Continuous code inspection; integrated Checkstyle and SpotBugs.
- ...



```
1  /* *****  
2  * Name:    Ada Lovelace  
3  * NetID:   alove lace  
4  * Precept: P00  
5  *  
6  * Partner Name:    Dorothy Johnson Vaughan  
7  * Partner NetID:   djvaughan  
8  * Partner Precept: P00  
9  *  
10 * Description: Prints 'Hello, World' to the terminal window.  
11 *                By tradition, this is everyone's first program.  
12 *                Prof. Brian Kernighan initiated this tradition in 1974.  
13 *  
14 ***** */  
15  
16 public class HelloWorld {  
17     public static void main(String[] args) {  
18         System.out.println("Hello, World");  
19     }  
20 }  
21
```

Quizzera platform.

- 2–3 short questions per lecture.
- Solve using pencil and paper.
- 3 attempts per question (your score = max of 3 attempts).



The screenshot shows the Quizzera interface for a user named wayne@cs.princeton.edu. The page title is "Quizzera" and the user is logged in. The breadcrumb trail is "Dashboard / COS 226, Spring 2020 / Union Find / Quick Find / Attempt". The quiz is titled "Quick Find" and has a seed of 235325. There are 2 attempts remaining and the quiz ends in 4 days. A "New Attempt" button is visible. The question asks for the id[] array after a sequence of 6 union operations on a set of 10 items. The operations are: 8-4, 1-0, 1-4, 4-2, 7-8, 9-1. A recall note states that the union operation p-q changes id[p] and perhaps some other entries, but not id[q]. The answer field is empty, and a "Submit" button is at the bottom.

Quizzera wayne@cs.princeton.edu [Logout](#)

[Dashboard](#) / [COS 226, Spring 2020](#) / [Union Find](#) / [Quick Find](#) / **Attempt**

Quick Find

Seed: 235325 (Provider: [princeton.cos226.QuickFindExercise](#))

Attempts Remaining: 2 Quiz Ends in 4 days.

[New Attempt](#)

Question

Give the `id[]` array that results from the following sequence of 6 union operations on a set of 10 items using the quick-find algorithm.

8-4 1-0 1-4 4-2 7-8 9-1

Recall: our quick-find convention for the union operation `p-q` is to change `id[p]` (and perhaps some other entries) but not `id[q]`.

Answer

Your answer should be a sequence of 10 integers (between 0 and 9), separated by whitespace.

[Submit](#)

Written exams.

- Questions drawn from lectures, precepts, and quizzes.
- Emphasizes **non-programming** material.

COS 226 MIDTERM, SPRING 2023

3

3. Data structures. (6 points)

- (a) Consider the following *parent-link* representation of a *weighted quick union* (link-by-size) data structure.

parent[]	4	5	4	5	?	5	2	5	8	5
	0	1	2	3	4	5	6	7	8	9

Which of the following values could be `parent[4]`?

Fill in all checkboxes that apply.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
0	1	2	3	4	5	6	7	8	9

Grading **A+**

Programming assignments. **45%**

- Due at 11:59pm on Mondays via TigerFile.
- Collaboration/lateness policies: see web.

Quizzes. **10%**

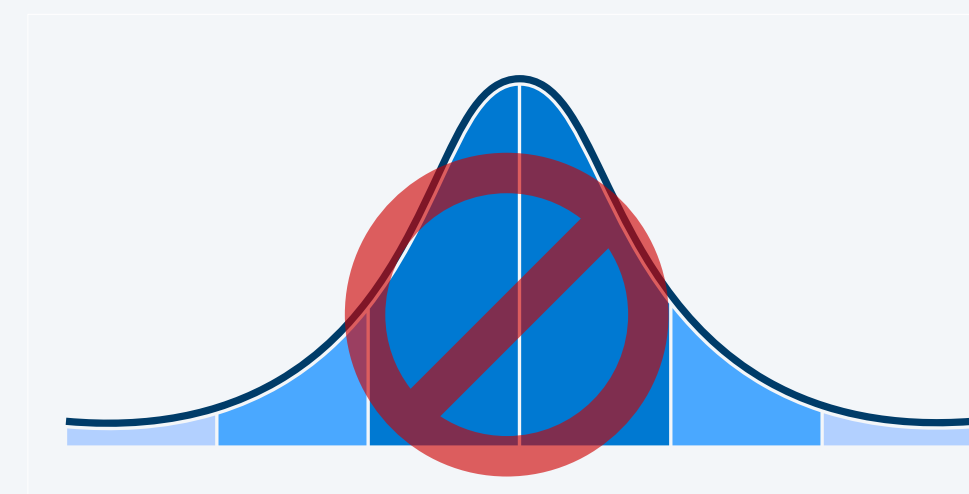
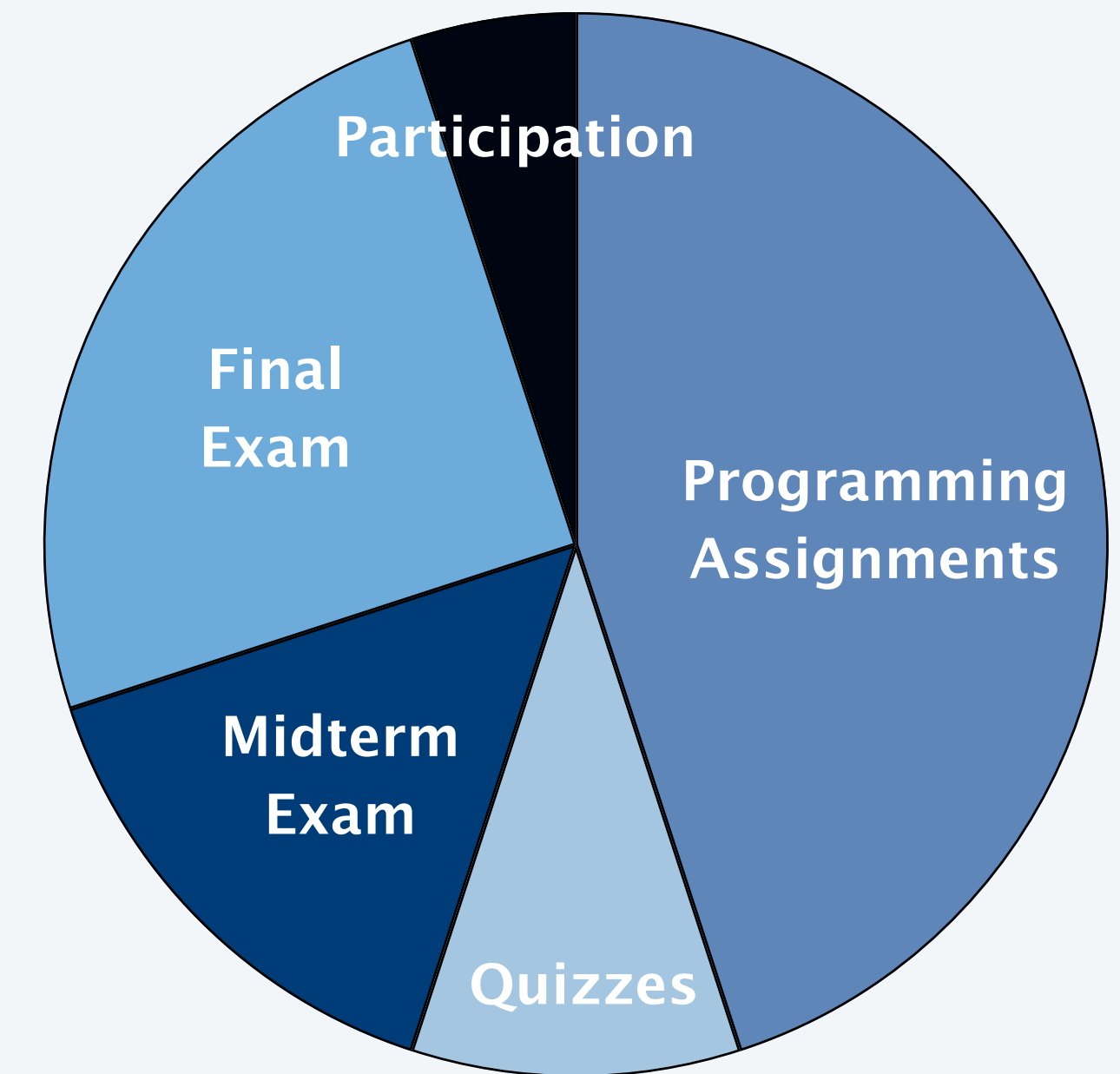
- Due at 11:59pm on Fridays via Quizzera.
- Collaboration/lateness policies: see web.

Exams. **15% + 25%**

- 80-minute midterm on Tuesday, October 10.
- 3-hour final, as scheduled by Registrar.

Active participation. **5%**

- iClicker participation in lecture.
- Collaborative participation in precept.



grade	score
A	93.0%
A-	90.0%
B+	87.0%
⋮	⋮



<https://algs4.cs.princeton.edu>

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Resources (textbook)

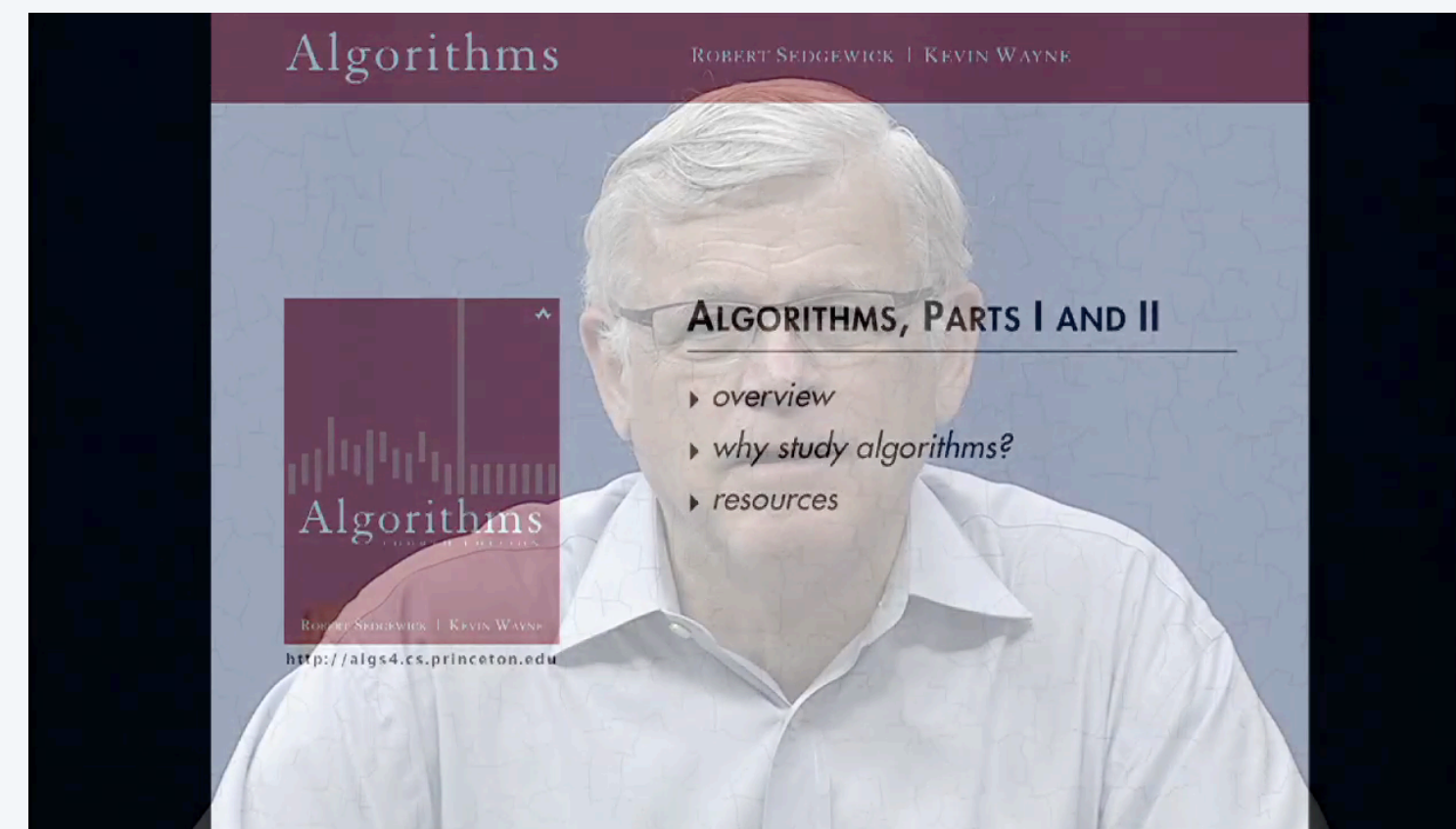


Readings (required). *Algorithms 4th edition* by R. Sedgwick and K. Wayne, ← *Labyrinth Books, Amazon, ...*
Addison–Wesley Professional, 2011, ISBN 0–321–57351–X.

Studio–produced videos (optional). By R. Sedgwick and K. Wayne.



4th edition (2011)



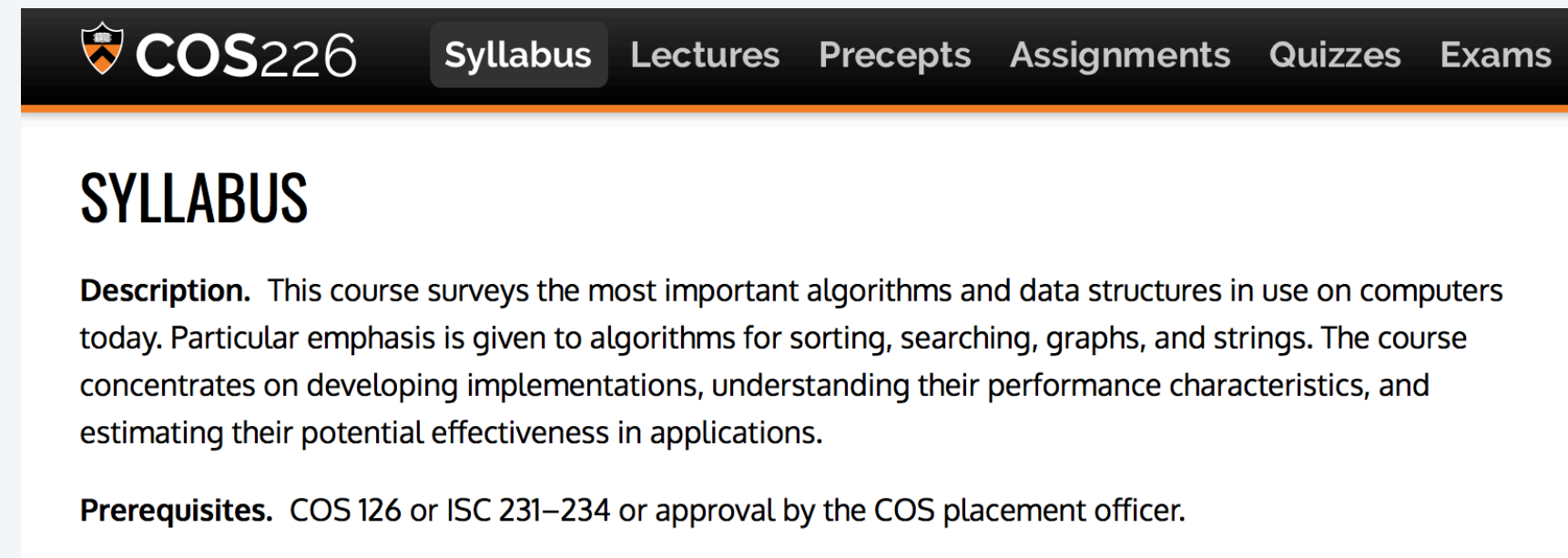
<https://www.cubits.ai>

Course content.

- Course info.
- Lecture slides.
- Precept lessons.
- Programming assignments.
- Quizzes.
- Exam archive.

Booksite.

- Brief summary of content.
- Download code from book.
- APIs and Javadoc.



The screenshot shows the top navigation bar of the COS226 website with links for Syllabus, Lectures, Precepts, Assignments, Quizzes, and Exams. Below the navigation bar is the 'SYLLABUS' section, which includes a description of the course and its prerequisites.

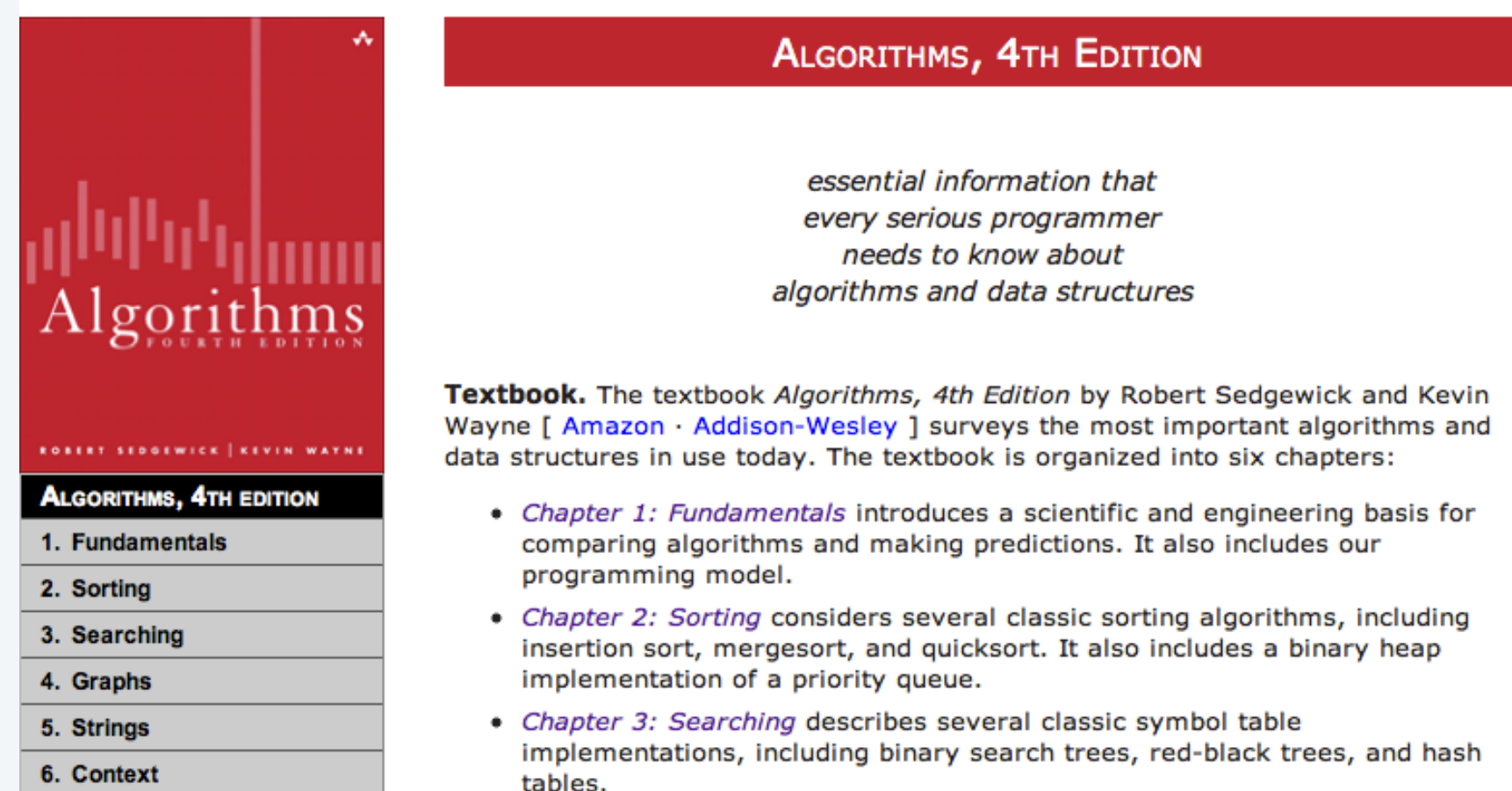
COS226 Syllabus Lectures Precepts Assignments Quizzes Exams

SYLLABUS

Description. This course surveys the most important algorithms and data structures in use on computers today. Particular emphasis is given to algorithms for sorting, searching, graphs, and strings. The course concentrates on developing implementations, understanding their performance characteristics, and estimating their potential effectiveness in applications.

Prerequisites. COS 126 or ISC 231–234 or approval by the COS placement officer.

<https://www.princeton.edu/~cos226>



The screenshot shows the book's website for 'Algorithms, 4th Edition'. It features the book cover on the left and a summary of the book's content on the right.

ALGORITHMS, 4TH EDITION

essential information that every serious programmer needs to know about algorithms and data structures

Textbook. The textbook *Algorithms, 4th Edition* by Robert Sedgwick and Kevin Wayne [[Amazon](#) · [Addison-Wesley](#)] surveys the most important algorithms and data structures in use today. The textbook is organized into six chapters:

- **Chapter 1: Fundamentals** introduces a scientific and engineering basis for comparing algorithms and making predictions. It also includes our programming model.
- **Chapter 2: Sorting** considers several classic sorting algorithms, including insertion sort, mergesort, and quicksort. It also includes a binary heap implementation of a priority queue.
- **Chapter 3: Searching** describes several classic symbol table implementations, including binary search trees, red-black trees, and hash tables.

<https://algs4.cs.princeton.edu>

Online discussion forum.

- Low latency, low bandwidth.
- Designate post as private only when necessary.
- See Ed FAQ for guidelines.



<https://us.edstem.org/courses/41414>

Office hours.

- High bandwidth, high latency.
- See web for schedule.



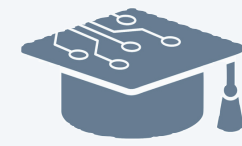
<https://www.princeton.edu/~cos226>










Intro COS lab.

- Undergrad lab TAs.
- For help with debugging.
- See web for schedule.



<https://introlab.cs.princeton.edu>



Platform	What
 Ed	<i>discussion forum, precept lessons</i>
 IntelliJ	<i>Java IDE</i>
 Quizzer	<i>quizzes</i>
 TigerFile	<i>assignment submissions</i>
 codePost	<i>assignment feedback</i>
 Gradescope	<i>exam feedback</i>
 Canvas	<i>grades, lecture recordings</i>
 iClicker	<i>in-class polls</i>
 CUbits	<i>studio-produced videos</i>

← *also use for communication with course staff*

A typical week (including this one!)



Sun	Mon	Tue	Wed	Thu	Fri	Sat
	30	5 Lecture 1 (Union-Find)	6	7 Lecture 2 (Analysis)	8 Precept 1 Quiz 0, 1, 2	9
10	11 Assignment 1 (Percolation)	12	13	14	15	16

you are here!

*again on
Thursday*

*support lecture material;
assignment prep*

*content based on
week's material*

*content based on
corresponding lectures*

Administrative Q+A

Not registered? Register today.

Change precept? Use TigerHub.

All non-conflicting precepts closed? Contact our course admin, Sue Giranda.



Sue Giranda

Haven't taken COS 126? See COS placement officer.

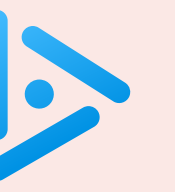
Placed out of COS 126? Review Sections 1.1-1.2 of Algorithms 4/e.

Additional administrative questions. Ask now, after class, or any time in Ed Discussion.



Credits

image	source	license
<i>THX Eclipse Deep Note</i>	<u>THX Ltd.</u>	
<i>Wireframe Tiger</i>	Audrey Cheng '20	by author
<i>Programmer</i>	<u>Wall Street Journal</u>	
<i>Student Raising Hand</i>	<u>classroomclipart.com</u>	<u>educational use</u>
<i>A is for Algorithms</i>	<u>comtechpass.com</u>	
<i>Assignment Logos</i>	Kathleen Ma '18	by author
<i>Normal Distribution</i>	<u>Adobe Stock</u>	<u>education license</u>
<i>Pair Programming</i>	<u>Adobe Stock</u>	<u>education license</u>
<i>Office Hours</i>	<u>clipground.com</u>	<u>CC BY 4.0</u>
<i>COS Lab TAs</i>	<u>Pulkit Singh '20</u>	by author
<i>Question Marks</i>	<u>pikpng.com</u>	<u>non-commercial use</u>
<i>Elbow Bump</i>	<u>The Noun Project</u>	<u>CC BY 3.0</u>
<i>Countdown Timer</i>	<u>YouTube</u>	



Have you met the person sitting next to you?

- A. Yes.
- B. No.

