CSCI 3104 Algorithms Syllabus (Summer 2021)

Contents

1 Logistics

1.1 Instructional Staff

Instructor: Michael Levet (He/Him/His); michael (dot) levet (at) colorado (dot) edu.

Graduate Teaching Assistants: Ethan Hobbs, Vimal Kakaraparthi, Sagi Shaier

Undergraduate Course Assistants: Helen Kim, Seok Jun Song

1.2 Key Dates

Last Day to Drop Before Grade of 'W' Is Recorded: June 10, 2021.
Last Day to Drop Before Grade of 'WF' Is Recorded: July 15, 2021.
Breaks: Monday July 5.

1.3 Course Website

All announcements will be posted to the course website: `https://michaellevet.github.io/Summer21/`. Students are responsible for checking the course website daily.

1.4 Lecture and Recitation

Lectures:

- Section 400: MTW 9:25-10:45 AM, ECES 112.
- Section 401: MTW 9:25-10:45 AM, Zoom (see the course website for the link).
- Section 410: MTW 11:20 AM - 12:40 PM, ECES 114.
- Section 411: MTW 11:20 AM - 12:40 PM, Zoom (see the course website for the link).

Recitations (all on Zoom; see the course website for the link):

- Section 403 (Vimal Kakaraparthi): Thursday 9:25-10:45 AM.
- Section 405 (Vimal Kakaraparthi): Friday 9:25-10:45 AM.
- Section 413 (Sagi Shaier): Thursday: 11:20 AM - 12:40 PM.
- Section 415 (Ethan Hobbs): Friday 11:20 AM - 12:40 PM.

1.5 Office Hours

All office hours will be held over Zoom. See the course website for the Zoom links.

- Michael Levet: TBD and by Appointment
- Ethan Hobbs
- Vimal Kakaraparthi
- Sagi Shaier

2 Course Description

2.1 Prerequisites

The prerequisites include Calculus I-II, Data Structures, and some Discrete Math course. This course relies **heavily** on **all** of the prerequisites. It is **dangerous** to take this course without a solid handle on the prerequisites. On the other hand, students from outside of Computer Science who are comfortable writing mathematical proofs are likely to be well prepared and are very welcome. Please discuss ASAP with the instructor if you have concerns about your background.

- Calculus I-II (Grade of C- or Better)
- CSCI 2270 or CSCI 2275 Data Structures (Grade of C- or Better)
- Discrete Math (Grade of C- or Better in one of the following: CSCI 2824, Math 2001, APPM 3170, or ECEN 2703).

2.2 Workload

CSCI 3104 is a 4-credit course. During the Fall or Spring semesters, well-prepared students should expect to spend on average 9-12 hours/week outside of class. Be aware that this summer course covers the same content (and at the same depth) at an accelerated rate. Well-prepared students should expect to spend 18-24 hours/week outside of class. Students who have significant gaps in their backgrounds may find that they need to carve out additional time to review the prerequisite material.

2.3 Course Content

CSCI 3104 Algorithms is an undergraduate course in theoretical computer science. The primary goals include surveying fundamental algorithm design techniques, analyzing algortihm runtime complexities, and identifying computational problems that are unlikely to have efficient algorithmic solutions. We will begin the semester with a survey of including greedy algorithms, including shortest path problems, computing minimum-weight spanning trees, and network flows. Afterwards, we will discuss the technicalities of analyzing an algorithm's efficiency, including asymptotic notation (e.g., Big-O), and techniques to ascertain and compare the asymptotic runtimes (e.g., Calculus techniques, Recurrences). Once we have a sense of how to analyze algorithms, we will proceed to discuss both the divide & conquer and dynamic programming paradigms. We will also examine our algorithm design techniques closely, discussing both instances where they apply and where they fail to yield the desired results.

At the end of the semester, we will discuss Computational Complexity, which seeks to classify problems into complexity classes based on how efficiently they can be solved. The goal then is to compare these complexity classes, as opposed to individual problems. We will restrict attention to the complexity classes P (the set of decision problems that have efficient solutions) and NP (the set of decision problems where correct solutions can be verified efficiently). While it is known that $\mathsf{P} \subseteq \mathsf{NP}$, determining whether $\mathsf{P} = \mathsf{NP}$ remains the central open problem in Computer Science and one of the six biggest open problems in Math. Resolving the P vs. NP problem will have far-reaching, real-world implications, including on the security of online transactions (cryptography), curing cancer (protein folding), scheduling, routing, and a host of other combinatorial optimization problems of practical interest. Our goal will be to understand the statement of the P vs. NP problem, including contextualizing the role that our algorithmic techniques play. Our discussions on the structure of these complexity classes will be quite shallow.

We will briefly discuss Hash Tables at the end of the course.

Ultimately, this course is mathematical in nature. The obvious connections are with Discrete Math (Math 3110, Math 3170, Math 4440) and Theoretical Computer Science (CSCI 3434, CSCI 3090, CSCI 4114). However, our algorithmic techniques also serve as key tools in application areas, including Artificial Intelligence (CSCI 3202), Machine Learning (CSCI 3832, CSCI 4622), Bioinformatics (CSCI 4314), Network Science (CSCI 3352), Economics (CSCI 7000 Algorithmic Game Theory, Econ 4050), Operations Research (CSCI 5654), and Circuit Design (ECEN 2350). In order to understand how to adapt and apply our techniques (in this course, subsequent courses, job interviews, or your careers), it is necessary to understand how and why these techniques work. For

this reason, formal proofs and the underlying ideas will be examined in great detail. Therefore, a key objective in this course is to develop your mathematical maturity; that is, your ability to understand mathematical statements and formulate rigorous mathematical proofs. This will ultimately be the best indicator for success (outside of hard work). We will rigorously prove mathematical statements in class and discuss proof strategy throughout this course. Every student will be expected to formulate proofs on homework and assessments.

Remark 1. CSCI 3104 is effectively an abstract math course. This is **not** a software engineering/coding course. We also stress that while the material we cover has a myriad of applications, the focus will be on developing and understanding the techniques rather than on the applications themselves. Our goal will be to prepare students to apply the techniques we develop beyond this course.

2.4 Learning Objectives

Algorithms is one of the key maturity courses for undergraduates in Computer Science programs (the others being Systems and Principles of Programming Languages). The obvious course objective is gaining proficiency with the material outlined above. Beyond that, the development of rigorous mathematical thought, mathematical maturity, and sharpness of proof writing will be emphasized. The underlying goal is for you to improve your ability to read and write mathematics, as well as appreciate the design and usage of axioms in a theoretical discipline. A third goal is to provide a solid preparation for subsequent courses that utilize rigorous algorithmic techniques. To this end, we have the following learning objectives.

- Students will work through key algorithms by hand, including Breadth-First Search, Dijkstra's Algorithm, Prim's Algorithm, Kruskal's Algorithm, the Ford-Fulkerson procedure, Quicksort and variations thereof.
- Students will prove theorems by induction.
- Students will prove theorems about greedy algorithms or problems amenable to greedy algorithms using exchange arguments.
- Students will construct functions to model algorithm runtimes, as well as determine closed-form asymptotic solutions for said functions.
- Students will design algorithms using the greedy, divide & conquer, and dynamic programming techniques.
- Students will ascertain when algorithm design techniques fail to apply, clearly justifying their reasoning.

2.5 Course Text

We will provide course lecture notes, which will serve as the official course text. If you would like supplemental reading, there are several good options, including the texts by Cormen, Leiserson, Rivest, and Stein [CLRS09]; Kleinberg and Tardos [KT05]; and Dasgupta, Papadimitriou, and Vaziarni [DPV06]. These texts may be freely available through the CU Boulder Library website.

Remark 2. Many of the algorithms we study have minor variations, which may impact the final answer or intermediary steps. The official version of the algorithms will be those presented in the lecture notes (and not in supplemental texts). You are responsible for using the version of the algorithm presented in the lecture notes.

Remark 3. We also highly recommend MIT's Open Courseware notes [MIT11] and Jeff Errickson's notes [Err] as supplemental resources. These are incredibly high-quality resources. In particular, Jeff Errickson has devoted considerable efforts to creating materials that are both accessible and useful for Algorithms students.

In contrast, there are a number of popular online resources that are actually harmful to use. Amongst the most popular of these is Geeks for Geeks. Many of their articles make subtle, but crucial errors (e.g., forgetting key base cases, incorrect arguments, etc.). These errors are not always apparent to students. Folks who use Geeks for Geeks and similar low-quality resources often find that their grades suffer heavily.

3 Course Structure and Grading

3.1 Grading Scheme

This course will use **Standards-Based Grading**. The content is organized into key learning outcomes (standards), with the goal of demonstrating proficiency by the end of the course. Final letter grades will correspond to the number of standards for which proficiency was demonstrated by the end of the course.

The key idea behind Standards-Based Grading is that student grades at the end of the semester should correspond to their demonstrated learning by the end of the semester. In particular, only attempts that demonstrate proficiency are factored into one's grade. Attempts where students do not demonstrate proficiency are not factored into final grades and so do not pull down one's average. Students will also have multiple opportunities to demonstrate proficiency. In this sense, the grading system is iterative.

Students will have (at least) four attempts to demonstrate proficiency on a given standard, including on homework, a weekly quiz, a requizzing opportunity in the midst of the course, and a requizzing opportunity at the end of the course. In order to earn credit for given single standard, one must demonstrate proficiency twice. Below is our list of standards.

Remark 4. In the event that there is not enough time to give four attempts on the standards at the end of the course, students will only need to demonstrate proficiency once to earn credit for the impacted standards. Students will have at least two attempts at each of these standards. Any such decision as to enact this policy will be made closer to the end of the semester and will be communicated in a timely manner.

3.2 Standards

1. Proof by Induction.
2. Greedy Algorithms: Graph Traversals (BFS/DFS). (*)
3. Greedy Algorithms: Dijkstra's Algorithm. (*)
4. Greedy Algorithms: Examples where Greedy Algorithms Fail. (*)
5. Greedy Algorithms: Exchange Arguments.
6. Greedy Algorithms: Safe and Useless Edges. (*)
7. Greedy Algorithms: Kruskal's Algorithm. (*)
8. Greedy Algorithms: Prim's Algorithm. (*)
9. Greedy Algorithms: Network Flows: Terminology. (*)
10. Greedy Algorithms: Network Flows: Ford-Fulkerson. (*)
11. Greedy Algorithms: Network Flows: Reductions and Applications.
12. Asymptotics: Calculus I Techniques (Polynomials, Polylogarithmic Functions, L'Hopital's Rule) (*)
13. Asymptotics: Calculus II Techniques (Exponentials, Factorials, Quasipolynomials, Ratio and Root Test) (*)
14. Analyzing Code I: Independent Nested Loops (*)
15. Analyzing Code II: Dependent Nested Loops (*)
16. Analyzing Code III: Writing Down Recurrences (*)
17. Analyzing Recurrences I: Unrolling (*)
18. Analyzing Recurrences II: Tree Method
19. Divide and Conquer: Principles and Algorithm Design

20. Divide and Conquer: Quicksort, Modifications, and Analysis (*)
21. Divide and Conquer: Applications of Quicksort (*)
22. Dynamic Programming: Identify the precise subproblems. (*)
23. Dynamic Programming: Write Down Recurrences
24. Dynamic Programming: Using Recurrence or Existing Structure to Solve One-Dimensional Examples. (*)
25. Dynamic Programming: Using Recurrence or Existing Structure to Solve Two-Dimensional Examples. (*)
26. Dynamic Programming: Design DP Algorithms.
27. Computational Complexity: Formulating Decision Problems (*)
28. Computational Complexity: Showing Problems belong to P. (*)
29. Computational Complexity: Showing Problems belong to NP. (*)
30. Computational Complexity: Structure and Consequences of P vs. NP.
31. Hashing and Collision (*)
32. Engagement.

3.3 Grading

Submissions will be graded for correctness and clearly articulated reasoning. It is not enough to arrive at the correct answer. Supporting work and reasoning must also be included and **easy to follow**. That is, both your work (including attention to intermediary details) and the clarity in which it is presented will be graded.

Each problem will receive a score of $0, 1, 2, 3$, or 4 as follows.

- 4 (**Near Perfect**): The solution was near-perfect and clearly explained. This is almost a textbook caliber solution.
- 3 (**Demonstrated Proficiency**): The solution demonstrated proficiency, with perhaps minor (but not content-related) errors. While there may be room to improve the exposition, the solution was relatively easy to follow.
- 2 (**Demonstrated Progress, but Fell Short of Proficiency**): The solution demonstrated some measure of understanding, but had significant errors or was extremely difficult to understand.
- 1 (**Significant Errors or Misconceptions**): The solution demonstrated glaring misunderstandings, had significant or fatal errors.
- 0 (**No meaningful attempt**).

Note that scores of 3 are considered **full credit**, though scores of 3 and 4 count equally. We stress that solutions do not need to be perfect in order to demonstrate proficiency (this is more favorable than partial credit). Scores of $0, 1$, and 2 count equally (in that they do not contribute towards proficiency), but denote feedback as to how close one was to demonstrating proficiency. A score of 2 means that you likely have some handle on the content, but need to iron out some misconceptions or pay closer attention to details. A score of 1 is alarming, and you should attempt to fix any misunderstandings immediately. Please stop by office hours so we can help you!

Final cutoffs will be awarded according to the following scale. **There will be no curve. Extra credit does not exist.**

A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
30-32	29	28	27	26	25	24	23	22	21	20	0-19

Grades in the **A** range indicate strong preparedness for subsequent courses in Theoretical Computer Science and Math. Grades in the **B** range indicate a strong understanding of the mechanics and a moderate understanding of the theoretical underpinnings. Grades in the **C** range indicate comfort with the mechanics, such as how to execute the algorithms or solve procedural problems. Note that there are 23 such mechanical standards marked with a (*) in Section 3.2, plus the Engagement standard.

Remark 5. Algorithms (and Theory/Math courses in general) require more time to gain traction than applied/coding-based courses. Poor early performance is not indicative of one's ability to succeed (or even earn an A) in this course. Furthermore, student growth (both on an individual level and in the aggregate) in Standards-Based Grading tends to be concave-up. That is, students tend to learn the material and earn credit for standards at a faster rate as the semester progresses. As a rough gauge, students who have, after the first midcourse requizzing period, earned credit for at least 3 standards twice and demonstrated proficiency for another 3-4 standards at least once are likely to be on track to pass the course.

3.4 Homework

Homework will be assigned regularly, with clearly posted deadlines. You are responsible for being aware of both the **dates** and **times** for these deadlines. Late homework will not be accepted, unless prior arrangements are made or in emergency situations. No late submissions will be accepted once solutions have been released. Please discuss with the instructor as soon as possible if you have a situation that may warrant an extension. Please submit your homework via Canvas.

- There will be a regular written homework. The written homework must be **typed** using LaTeX. Diagrams (e.g., graphs, trees) may be hand-drawn and embedded in the LaTeXdocument as an image and **oriented so that we do not have to rotate our screens to grade your work.** Please note that **handwritten solutions or those prepared without LaTeXwill not be graded.** Similarly, **if we have to rotate our screens to grade your work, then your wil will not be graded.**

- Both your **name** and **student ID** must be included in the appropriate fields. You **must** include these on your assignment; otherwise, Gradescope may not be able to match your assignment to your submission. In this case, your submission will not be graded.

- The first question on every homework will be an honor pledge. Failure to indicate that you have upheld the honor code will result in your assignment not being graded.

- You are welcome to discuss the problems with your classmates, as well as reference outside resources. **Anything you submit must be in your own words and reflect your understanding of the material. You should be able to explain your solutions to the instructor, such as in an interview grading session.** If there are any questions about this, it is your responsibility to contact the instructor (and not the TAs) reasonably ahead of the submission deadline. **Looking up solutions or copying from other sources (including your classmates) is an honor code violation.** You must **cite** any resource (other than the course text, instructor, TAs, or CAs) that you use. This includes any classmates with whom you collaborate. Failure to cite your sources will be treated as an **honor code violation.** See Section 3.9.

- Posting to online forums for help (e.g., Chegg, Reddit, StackExchange, etc.) is an **honor code violation.** See Section 3.9.

- Individual assignments may have additional instructions beyond the syllabus. Students are responsible for adhering to those instructions.

Each homework will cover one or more standards. Problems will be organized by standard. Each question will receive a score and feedback. The scores on each question for a given standard will be aggregated into an Overall Standard Score, which will be your grade on that standard. In general, students who demonstrate proficiency on an overwhelming preponderance on the individual questions are likely to earn a score of 3 or 4 for their Overall Standard score. For more challenging standards, an occasional 2 on an individual question

may not *necessarily* disqualify one from proficiency on the Overall Proficiency Score. Any scores of 0 or 1 on individual questions will disqualify one from scoring higher than a 2 on the Overall Proficiency Score.

We note that the Overall Proficiency Score is neither the raw average nor the total number of points accrued. We illustrate this with the following example.

Example 6. Suppose that on HW2, there are three questions (Q1, Q2, and Q3) associated with Standard 3. Q1 asks students to execute Dijkstra's algorithm on an example graph, while Q2 and Q3 ask students to apply Dijkstra's algorithm to new situations. We note that Q3 is more challenging than Q2.

- Student A earned a 2 on Q1 due to a couple of careless mistakes, and 3's on both Q2 and Q3. They were awarded a 3 for their Standard 3 Overall Proficiency Score on HW2.
- Student B earned a 3 on Q1, a 3 on Q2, and a 2 on Q3 due to several fundemantal misunderstandings about Dijkstra's algorithm. For this reason, Student B was awarded a 2 for their Standard 3 Overall Proficiency Score on HW2.

3.5 Quizzes

There will be regular quizzes covering the given standards. The due dates will be announced in advance.

- **Written Quizzes:** Each written quiz will have between 1-3 questions and will be timed for 45 minutes. The intent is that students will have 30 minutes (scaled for students with extra time acommodations) to take the quiz and 15 minutes to submit to Canvas. In practice, students are welcome to allocate the 45 minutes as they see fit. As we have allocated 15 minutes to prepare the quizzes for submission, late quizzes will **not** be accepted. If your internet goes out, you may take a picture (such as with Cam Scanner) and send a **legible** picture (in JPEG, PNG, or PDF formats) within the 45 minute window to one of the instructor (and not the TAs). **We are unable to accept HEIC files.**

  We will provide a LaTeXtemplate for the quiz. You may either type your work using the LaTeXtemplate, or you may handwrite your work and embed it as an image in the LaTeXtemplate. If you choose to handwrite your work, the image must be **legible** and **oriented so that we do not have to rotate our screens to grade your work.** If your work is illegible or we have to rotate our screens, your work will not be graded.

- If you choose to upload images for answers, please post them with the appropriate question. For instance, please post the Question 1 answer immediately under Question 1, and then the Question 2 answer immediately under Question 2. **Please do not post both answers at the bottom of the document, as our graders will not check there and are likely to miss them.**

Quizzes are open-book and open-note, but are individual efforts. Consulting anyone who is not a member of the instructional staff about a quiz, which includes your classmates, tutors, and posting online (e.g., Chegg, Reddit, Discord, StackExchange, etc.) constitutes an **honor code violation.** Similarly, all answers must be in your own words and reflect your understanding of the material. Copying from any resource is strictly prohibited. See Section 3.9.

You are welcome to email the instructor (but not the TAs or CAs) with clarification questions, with the understanding that doing so counts against your allotted time and that we may not respond to you in time.

We will also carve out time twice during the course for midcourse requizzing. The purpose is to give you time to review and reflect upon the material covered, as well as to demonstrate proficiency. If you have demonstrated proficiency twice on a given standard, then there is no obligation to take a scheduled requiz. Each midcourse requizzing period will tentatively cover 12-15 standards, depending on where we are in the course. These standards will be organized into individual (likely 6-8) quizzes, which can be taken at your convenience over a 36 hour period. We will also have a requizzing period over all the content standards organized into individual (likely 12-16) quizzes at the end of the semester, over a 2-3 day period. The precise dates of these requizzing opportunities will be determined later. The first midcourse requizzing period will be scheduled in such a way so that students will have feedback reasonably before the drop deadline.

3.6 Requiz Tokens

As part of our Standards-Based Grading system, students will be able to make additional attempts (beyond the homework, quizzes, and requizzing periods) towards standards of their choice, subject to a few guidelines. Please read through this thread carefully before submitting a reassessment request.

Students have three retake tokens. Each token is redeemable for an attempt at a single standard. Multiple tokens can be used for the same standard (e.g., one could use two or all three of tokens to attempt Standard 1 multiple times). Please note that tokens are redeemable for reassessment attempts, and not grades. That is, reassessing does not guarantee you a score of proficiency. Your work will still be graded for correctness. Tokens are non-refundable. Once your requiz request is approved, your token has been consumed, regardless of whether you take the quiz.You may not use retakes to attempt standards we have not covered.

In order to be eligible for retakes, students must write corrections and reflections for the relevant standard. The point is for students to iron out any misconceptions before attempting a retake. You may correct any HW, Quiz, or Exam problem on which you received below a 4. If you received below a 3 on any problem, you must correct one of those problems. It suffices to correct one problem.

- Submissions must be made through the following form: `https://forms.gle/ooe13gnHH6qgWKco8`.
- You may submit corrections and reflections for relevant homework, quiz, and exam problems, provided you got below a 4 on the problem. Please clearly state the HW/Quiz/Exam and Problem upon which you are correcting/reflecting (e.g., PS6, Problem 1a). You may use a requiz for your corrections and reflections.
- Please rework the **entire** problem, in addition to reflecting on your work. For reflections, please discuss points such as clear misunderstandings and technical gaps, as well as clearly explaining the techniques or concepts needed to correctly solve the problem. Alternatively, you could opt to write up a tutorial for how to solve the problem, while clearly explaining the key concepts and techniques. That is, address both the "how" and the "why." Writing a tutorial is a great way to correct/reflect if one fails to submit a problem set or quiz.
- If you failed to submit an assignment, you may still use that for your "corrections" and reflections by correctly working out the relevant problems and submitting reflections as described in the last bullet point.
- The corrections and reflections process may be iterative. If your submission has clear misconceptions or failed to thoroughly correct/reflect upon your solution, we will let you know about the issues and ask you to revise your reflection and resubmit through the Google form. Note that your token is considered redeemed once your corrections and reflections are accepted. This is intended to be a collaborative approach, to help ensure you better learn the content and succeed on future assessment opportunities.
- Reflections that make no attempt to meet these standards will be summarily rejected and asked to revise/resubmit. Repeat offenders who consistently ignore our feedback over multiple iterations may lose one of their retake tokens without being permitted to reassess the standard in question. This is at the discretion of the instructional staff. This is not a first or even second offense penalty.
- Examples of reflections that don't meet the standards include, but are certainly not limited to:
  - "I missed the due date."
  - "I forgot to study."
  - "I didn't know the derivative of 4^n."
  - Reflections and corrections that exhibit minimal effort, such as when no effort is made to correct or reflect.
  - Complaining or disputing your original grade.
  - Making demands of the instructional staff.

We expect to open the Requizzing Form shortly after Requizzing Period 1 (tenatively July 8) and to close the form shortly after the Requizzing Period 2 grades are returned (tentatively July 28 at 8 PM). We will

not accept new or revised Requiz Requests once the form has been closed. **Please allow for a two week processing time.** As we near the end of the semester, we will work to expide the processing time. Any student who submits a requiz request before the form closes will have their request reviewed to allow sufficient time for any requizzing to be done before the final requizzing period.

3.7 Engagement Standard

The main theme of recitation is solving problems in groups, especially homework and test questions. Explaining the material to others serves to reinforce the material for you. Conversely, it is beneficial to have multiple perspectives on the material. It is highly likely that you will benefit from the perspectives your classmates bring to the table. Working in groups is **required**. Students who are not engaged in the material may not receive credit for that day.

Each week in recitation, the TAs will take attendance and relay this to the instructor (this is done automatically via Zoom, which records both attendance and duration). There will also be a brief online exit-ticket asking students to reflect upon the content covered that day (such as to explain a concept in one's own words or to identify the muddiest point from that day). The exit-tickets will be graded for thoughtful responses, as opposed to correctness. They serve to help the instructor identify what students are (not) understanding, which enable for adjustments to be made in subsequent lectures and assignments.

Note that students **must** attend the recitations for which they are enrolled. Students may occasionally be permitted to attend different recitation sections, but they **must** obtain permission from the instructor (and not the TAs) ahead of time. Students who attend a different recitation section without receiving prior permission will not receive credit for that week.

Additionally, students are required to complete a syllabus quiz at the start of the semester. Students who complete the syllabus quiz (with a score of 10/12 or better) and miss **at most** two recitations will receive credit for the Engagement standard. Exceptions to the attendance policy will be made only in emergency situations, and only if this is discussed with the instructor in a timely manner. Please contact the instructor to discuss extenuating circumstances.

3.8 Regrade Requests

Students have three days (excluding weekends) from when a grade was returned to request a regrade. So if a grade is released on a Monday, students have through the end of the day on Thursday to raise concerns. If a grade is released on a Thursday, students have until Tuesday to raise concerns.

The only regrade requests that will be considered are those where a mistake was made in grading. In particular, all points earned (or lost) are final, unless due to a mistake made by the grader. In order for a grade dispute to be considered, students must submit a written request indicating the problem(s) in question, a clear explanation indicating where a mistake in grading. All regrade requests must be submitted using the following Google form. I reserve the right to regrade the entire problem set; grades may go up or down accordingly.

3.9 Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550. Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Much of what you will learn about mathematics and theoretical computer science will come from your discussions with your peers. You are welcome and encouraged to discuss the homework problems with each other and with me. It is expected that you work the problems by yourself first, so that you can contribute to the discussion. This policy will be changed, reluctantly, if I find it is being abused. **Your submissions must**

be written in your own words and reflect your understanding of the material. Note that you are responsible for citing any resource (including other people) that are not members of the course staff, the course lecture notes, or the lectures. Posting to online forums for help (e.g., Chegg, Reddit, StackExchange, etc.) is an **honor code violation.** If there are any questions regarding this policy, please ask the instructor.

Any honor code violation will result in the following minimum penalties:

(a) You will be disqualified from receiving credit for each standard on the assignment in question. Furthermore, your final grade will be lowered by -2 for each standard on the assignment. (So if there are three standards on an assignment, your final grade will be lowered by -6.)

(b) You will be reported to the Office of Academic Integrity, which may choose to impose additional penalties.

The usual penalty for honor code violations is receiving an F for the course. Multiple instances of cheating will certainly result in an F for the course. **Please do not cheat.** It is not worth it.

4 Course Policies

4.1 Office Hours: Norms and Expectations

Office hours will be held online (see Section 1.5 for the Zoom links). The purpose of office hours is to supplement lecture, recitation, and the associated readings. In order to get the most out of office hours, we recommend the following.

- Watch the lectures and read through the lecture notes. In particular, work through the provided examples. These materials are there to help you!
- Spend some time working the problems first. Try to identify specific approaches you have made, as well as identify where you are stuck. If you are spending more than 30 minutes on a single problem without making much progress, then we strongly encourage you to seek help in office hours!
- If you wish to discuss specific work, please have it typed up so that you can share your screen on Zoom. It is very hard for us to help you if your work is on paper and you are holding it up to the camera.
- Our goal is to provide hints about homework problems, as well as help students obtain momentum to keep working. In particular, we aim to help students arrive at the solutions on their own. It is completely normal to need time to digest a hint, and then come back to office hours with more questions! Learning Math is an iterative process- we encourage students to iterate!
- Please note that the course staff will not provide entire solutions in office hours, nor will they grade work ahead of the due date. If a member of the course staff states that they are unable to offer more hints without giving away a solution, please respect this. Students are welcome to bring any concerns about this to the course instructor.

Office Hours vs. Email: The course instructor is generally happy to discuss course logistics via email (e.g., grades, excused absences, scheduling appointments, etc.). However, email is usually not a conducive medium for tutoring. If you email the instructor with a question about the homework (and you are certainly welcome to do so), the instructor reserves the right to ask you to come to office hours with your question. Note that this does associate some risk with procrastination, in that you may not get your question answered until after the assignment due date (or after the quiz/exam). Similarly, if you email the instructor late at night, we may not see your email until after the assignment is due. Please plan accordingly. **As the TAs and CAs have limited appointments, please avoid soliciting homework help from them via email. Please avoid contacting the CAs about the course outside of their office hours.**

4.2 Solutions

Solutions for Homework and the regular Quizzes will be posted, generally within 2-3 days of the due dates. We do not anticipate posting solutions for the quizzes assigned through the Requizzing Periods. Solutions will **not** be posted for the recitation activities.

4.3 Late Work

Late work will **not** be accepted, unless prior arrangements have been made or in case of emergency situations. In particular, no late work will be accepted once solutions have been posted. In the event of an emergency situation which prohibits you from turning in work before solutions are posted, the instructor may choose to offer additional requiz tokens (see Section 3.6) instead of accepting late work. Late work cannot be accepted after solutions are posted (hence, the intentional 2-3 day delay on posting solutions).

Note that missing the homework or quiz deadlines by a couple minutes is not a valid reason for late work to be accepted. Homework due dates and times will be clearly posted, and students will have 15 minutes to submit their quizzes (on top of 30 minutes to take their quizzes). Please plan accordingly.

4.4 Late Enrollments

Students who enroll in the course after the first day of class are subject to the same deadlines as the rest of the class.

4.5 Attendance

Attendance is not required for the lecture sections. However, it is expected that students are watching the lecture videos within 24 hours of when they are posted. Recitations will be designed based on the assumption that students have watched all of the lectures. Students who are enrolled for the in-person lecture sections may attend in-person or online. Students may attend any online lecture section. However, students enrolled for an in-person lecture section may only attend in-person for they section in which they are enrolled. Due to COVID restrictions, students enrolled for online sections **may not** attend in-person.

Students may only attend recitations for which they are enrolled. Students may **not** attend a different recitation without the instructor's consent. Occasionally, in emergency situations, students may be permitted to attend a different recitation section. However, they **must** discuss this in advance with the instructor.

Students who regularly attend recitation and are actively engaged will be eligible for the Engagement standard (see Section 3.7).

4.6 Modifications to the Syllabus

The instructor reserves the right to modify any of the policies in the syllabus at any time, particularly as dictated by the interests of learning and fairness. Students will not be graded any harsher than as outlined in Section 3.3.

4.7 Student Feedback

Student feedback regarding this course is welcome at any time. Those who wish to leave feedback anonymously are welcome to do so using this Google form. Students are also welcome to reach out to the instructor via email or in office hours to discuss their concerns.

5 Required Syllabus Statements

5.1 Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- maintain 6-foot distancing when possible,
- wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders (in particular, your mask must cover both your **mouth** and **nose**),
- clean local work area,

- practice hand hygiene,
- follow public health orders, and
- if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the "Accommodation for Disabilities" statement on this syllabus.

All students who are new to campus must complete the COVID-19 Student Health and Expectations Course. Before coming to campus each day, all students are required to complete the Buff Pass. In this class, you may be reminded of the responsibility to complete the Buff Pass and given time during class to complete it.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, please email the instructor as soon as you are able. Accommodations for missed work can be made through the requiz system.

5.2 Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Code of Conduct.

5.3 Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

5.4 Student Pronouns and Preferred Names

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

5.5 Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

5.6 Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please contact the instructor within the first two weeks to discuss any conflicts with religious events.

6 Schedule (Tentative)

Note that this schedule is subject to change, including the dates of Requizzing Periods 1 and 2.

Class	Date	Topic
1	June 1	Syllabus, Proof by Induction
2	June 2	Breadth-First and Depth-First Search, Begin Dijkstra's Algorithm
3	June 3-4	Recitation: Graph Theory Review
4	June 7	Finish Dijkstra's Algorithm, Proof of Correctness
5	June 8	Exchange Arguments
6	June 9	Interval Scheduling, Matchings (Where Greedy Algorithm Fails)
7	June 10-11	Recitation: Trees
8	June 14	Begin Spanning Trees, Safe and Useless Edges
9	June 15	Kruskal's Algorithm, Prim's Algorithm
10	June 16	Network Flows: Terminology
11	June 17-18	Recitation: Network Flows
12	June 21	Network Flows: Ford-Fulkerson
13	June 22	Network Flows: Max-Flow, Min-Cut Theorem
14	June 23	Network Flows: Finish Max-Flow, Min-Cut Theorem
15	June 24-25	Recitation: TBD
16	June 28	Network Flows: Reductions and Applications
17	June 29	Asymptotics: Definitions, Transitivity, Limit Comparison Test
18	June 30	Analyzing Code: Independent and Dependent Nested Loops, Recursion
19	July 1-2	Requizzing Period 1 (Tentatively Standards 1-10); No Recitation
	July 5	No Class (Independence Day; University Closed)
20	July 6	Analyzing Recurrence: Geometric Series, Unrolling and Tree Methods
21	July 7	Divide & Conquer: Mergesort, Quicksort
22	July 8	Recitation: Quickselect
23	July 12	Dynamic Programming: Rod Cutting
24	July 13	Dynamic Programming: Writing Down Recurrences and Identifying Subproblems (Active Learning)
25	July 14-15	Recitation: Rod Cutting Problems
26	July 19	Dynamic Programming: Longest-Common Subsequence
27	July 20	Dynamic Programming: TBD
28	July 21	Begin P vs. NP.
29	July 22-23	Requizzing Period 2 (Tentatively Standards 11-24); No Recitation
30	July 26	NP-completeness
31	July 27	Hashing and Collisions
32	July 28	Finish Hashing
33	July 29-30	Recitation: P vs. NP.
34	August 2	Special Topics: TBD (Not Assessed)
35	August 3	No Class (Extended Office Hours)
36	August 4-6	Final Requizzing Opportunity (All Standards)

References

[CLRS09] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, *Introduction to algorithms, third edition*, 3rd ed., The MIT Press, 2009.

[DPV06] Sanjoy Dasgupta, Christos H. Papadimitriou, and Umesh Vazirani, *Algorithms*, 1 ed., McGraw-Hill, Inc., USA, 2006.

[Err] Jeff Errickson, *Algorithms homepage*, Available at `https://jeffe.cs.illinois.edu/teaching/algorithms/`.

[KT05] Jon Kleinberg and Eva Tardos, *Algorithm design*, Addison-Wesley Longman Publishing Co., Inc., USA, 2005.

[MIT11] *Mit open courseware algorithms lecture notes*, 2011, Available at `https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-006-introduction-to-algorithms-fall-2011/lecture-notes/`.