Algorithms (CS 5800)

Graduate Course, Khoury College of Computer Sciences
Northeastern University, Vancouver Campus
Spring 2021 Semester

We acknowledge that the land on which we gather is the unceded territory of the Coast Salish Peoples, including the territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh) Nations.

Class Hours:	Wednesday 6:30PM-8:30PM (Pacific time)
Class Location:	Northeastern Vancouver Campus (333 Seymour), Room 901C
Instructor:	Richard Hoshino (r.hoshino@northeastern.edu)
Teaching Assistants	Cheng Zhao (zhao.cheng1@northeastern.edu) Daniel Zhenjie Zhou (zhou.zhenj@northeastern.edu)
Textbook:	Introduction to Algorithms (3rd Edition) By Thomas Cormen, Charles Leiserson, Ronald Rivest, Clifford Stein

CS 5800 presents the mathematical techniques used for the design and analysis of computer algorithms. We will focus on algorithmic design paradigms and techniques for analyzing the correctness, time, and space complexity of algorithms. Topics may include asymptotic notation, recurrences, loop invariants, sorting and searching, advanced data structures, lower bounds, hashing, greedy algorithms, dynamic programming, graph algorithms, and NP-completeness.

NOTE: in addition to our class time every Wednesday (6:30PM to 8:30PM), I will also hold an informal and optional "Problem-Solving Workshop" on Monday afternoons (3:30PM to 4:30PM), where I will be available to answer any questions you have on the weekly Problem Sets.

Course Objectives

This course is open to all graduate students in the MSCS program, and fulfills the following MSCS program objectives.

1. Exhibit proficiency in the design, implementation and testing of software.
2. Demonstrate skills and experience working in small teams.
3. Apply algorithmic and theoretical computer-science principles to solve computing problems from a variety of application areas.
4. Demonstrate the ability to learn and develop competencies in specialized or emerging computer science fields.

Course Overview

The word "Algorithm" is derived from Algoritmi, the Latin name of the ninth century Persian scholar Abu al-Khwarizmi. While algorithms have existed for centuries, they are especially relevant today as nearly every cutting-edge 21st century job requires the ability to design and code algorithms that solve real-world problems.

Within one hour of you waking up this morning, you will have completed at least ten different algorithms to solve a routine problem: shutting off your alarm, having a shower, brushing your teeth, checking your phone, eating breakfast, getting yourself dressed, and so on. In this course, we will limit ourselves to computer algorithms, though the skills you gain from the analysis and design of computer algorithms will impact the way you live your lives, through heightened focus, efficiency, effectiveness, intention, and purpose.

The goal of this course is to learn how to design great algorithms, and how to analyze their performance. There are three key goals you want to pursue every time you create a computer program: accuracy (the output is always correct), efficiency (the output returns quickly), and simplicity (the program is clean, easy to understand, and easy to debug).

In this course, we will explore and unpack the following topics. (The corresponding textbook chapters are indicated.)

Module 1 (Foundations)

- Growth of Functions — Chapter 2 + 3
- Divide-and-Conquer — Chapter 4
- Probabilistic Analysis — Chapter 5

Module 2 (Sorting and Order Statistics)

- Heapsort and Quicksort — Chapter 6 + 7
- Linear Sorting and Selection — Chapter 8 + 9

Module 3 (Advanced Design and Analysis Techniques)

- Dynamic Programming — Chapter 15
- Greedy Algorithms — Chapter 16

Module 4 (Graph Algorithms)

- Elementary Graph Algorithms — Chapter 22
- Spanning Trees and Shortest Paths — Chapter 23 + 24

Module 5 (Selected Topics)

Students will form groups and deliver a group seminar on one of the following topics:

- All-Pairs Shortest Paths — Chapter 25
- Maximum Flow — Chapter 26
- Multithreaded Algorithms — Chapter 27
- Matrix Operations — Chapter 28
- Linear Programming — Chapter 29
- Polynomials and the Fast Fourier Transform — Chapter 30
- Number-Theoretic Algorithms — Chapter 31
- String Matching — Chapter 32
- Computational Geometry — Chapter 33

Module 6 (NP-Completeness)

- NP-Completeness — Chapter 34
- Approximation Algorithms — Chapter 35

Course Schedule

Week	Work Due (by Tuesday 6:30PM)	% of Grade	Date of Class	Topic in Class
1	-	-	Wednesday, January 20	*Growth of Functions*
2	**Problem Set 0**	**2%**	Wednesday, January 27	*Divide-and-Conquer*
3	**Problem Set 1**	**8%**	Wednesday, February 3	*Probabilistic Analysis*
4	**Problem Set 2**	**8%**	Wednesday, February 10	*Heapsort and Quicksort*
5	**Programming Project 1**	**5%**	Wednesday, February 17	*Linear Sorting and Selection*
6	**Problem Set 3**	**8%**	Wednesday, February 24	*Dynamic Programming*
7	**Problem Set 4**	**8%**	Wednesday, March 3	*Greedy Algorithms*
8	**Programming Project 2**	**5%**	Wednesday, March 10	*Elementary Graph Algorithms*
9	**Course Synthesis 1**	**10%**	Wednesday, March 17	*Spanning Trees & Shortest Paths*
10	**Group Seminars**	**6%**	Wednesday, March 24	*Selected Topics*
11	**Group Seminars**		Wednesday, March 31	*Selected Topics*
12	**Problem Set 5**	**8%**	Wednesday, April 7	*NP-Completeness*
13	**Final Project Proposal**	**0%**	Wednesday, April 14	*Approximation Algorithms*
14	**Course Synthesis 2**	**10%**	Wednesday, April 21	*Final Project Work*
15	**Final Project Report**	**10%**	Wednesday, April 28	*Final Project Presentations*

The above percentages add up to 88%. The remaining 12% come from weekly in-class quizzes (10%) and personal SAIL reflections (2%), both of which are explained on the next page.

IMPORTANT NOTE: if you do not have sufficient programming experience, you are welcome to "opt out" of the two Programming Projects (worth 10%) and replace your grade on these two assessments with your average grade on the five main Problem Sets (worth 40%).

Course Assessment

- **5 Problem Sets (42%)** consist of five multi-part questions that are based on key concepts and ideas that are uncovered during class. The first three questions are to be done individually, while the last two questions are to be done in pre-assigned teams of three.

- **2 Programming Projects (10%)** are inspired by various Algorithms challenges found on Leetcode (leetcode.com). These programming projects will enable you to apply the Algorithms concepts you will learn in this course and develop your skills in designing, implementing, and testing programs in the programming language of your choice.

- **10 In-Class Quizzes (10%)** take place at the beginning of each class, based on the weekly course readings that you are to complete in preparation for that class. Half of the grade will be based on your individual responses, while the other half will be based on group responses to the same questions in your pre-assigned teams.

- **1 Group Seminar (6%)** will consist of you teaching us one of the chapters from the course textbook. This Group Seminar will be conducted in small teams. Each group will be assigned one chapter from the course textbook (Chapters 25 to 33).

- **2 Course Syntheses (20%)** consist of short answer questions, as well as several multi-part problems connecting different areas of the course, allowing you to synthesize what you have learned. Think of the Course Synthesis as a week-long individual take-home exam where you may consult your class notes but not your classmates or any online resources other than the ones that are explicitly permitted by the course instructor.

- **4 SAIL Reflections (2%)** are your personal reflections on your journey of self-authored integrated learning (SAIL) in this course. You will reflect on your growth across five learning dimensions: Intellectual Agility, Global Mindset, Social Consciousness and Commitment, Professional and Personal Effectiveness, and Well-Being. For more details, check out https://sail.northeastern.edu/about/.

- **1 Final Project (10%)** work occurs during the last two weeks of the course, in lieu of a final examination. Each group will select any topic relating to the design and/or analysis of Algorithms. Your group will submit a project proposal, a written report, and also deliver a presentation on the last day of the course.

We will use the following scale to convert numerical scores into letter grades:

A	93.00% – 100.00%
A-	90.00% – 92.99%
B+	86.00% – 89.99%
B	82.00% – 85.99%
B-	77.00% – 81.99%
C+	73.00% – 76.99%
C	69.00% – 72.99%
C-	65.00% – 68.99%
F	Less than 65.00%

Your final grade will be determined by the quality of your five Problem Sets (210 marks), two Programming Projects (50 marks), ten In-Class Quizzes (50 marks), Group Seminar (30 marks), two Course Syntheses (100 marks), four SAIL Reflections (10 marks), and your Final Project proposal, report, and presentation (50 marks).

To calculate your final grade, I will add up your marks for these assessments and simply divide by five. If an assessment is marked out of 5***x***, then it counts ***x***% towards your final grade.

Whenever I return an assessment, I will always post a "model solution" on our Canvas Page. If you wish to respectfully ask why you received a certain mark on a question, you must first carefully review the online model solution that was posted for that question and compare that solution with the comments I have provided for you. If you still disagree with the mark you received, you must email me to request an appointment, and we will set up a time to meet. At this time (and not before), we will discuss your concerns.

Please do not debate grades with me. I find it an incredible drain on my time and energy, and prevents me from serving students well.

Course Pedagogy

This course, as well as other MSCS courses at the Vancouver campus of Northeastern University, will be taught using a pedagogical technique known as the Flipped/Hybrid classroom. This approach makes the most of our precious class time by eliminating the standard lecturing model, where course material is *introduced* to the students during class, usually via a lengthy PowerPoint presentation. In our Flipped/Hybrid classroom, you will come to class having already completed several readings where you will be introduced to the course material, and complete a pre-class quiz. And then during class, you will *apply* your understanding of these core concepts through carefully-chosen problems and activities, which will enable you to *solidify* your knowledge.

Flipped/Hybrid classrooms require much more focus and preparation time, for both the instructor and the students. After all, it is much easier for the instructor to read a set of pre-prepared slides and for the students to passively observe and listen. But on our campus, we will devote our class time to the computational thinking process: resolving obstacles, developing conceptual understanding, communicating solutions supported by evidence, and creating efficient algorithms that solve our problem. Through this process, you will better develop your confidence, creativity, and critical-thinking skills, preparing you to become *computer scientists* (not just programmers).

In order for this course to be a meaningful learning experience, you will need to come to each class well-prepared, with all assigned readings and videos complete, as well as your individual quiz finished to the best of your ability. This emphasis on pre-class work is the reason why our class meets for only 2 hours each week, compared to other four-credit courses at Northeastern that meet for 3.25 hours each week. If you do not complete the pre-class work, you will have a hard time following the in-class activities, which will make it that much harder for you to successfully complete the Problem Sets, Programming Projects, and Course Syntheses.

Please be prepared to spend a minimum of 20 hours per week on this course!

Course Forum

We have a Canvas page, on which I will post all assessments, class materials, pre-class readings, pre-class videos, and grades. Please bookmark this page as you will check it regularly:

https://northeastern.instructure.com/courses/65476

Canvas has a platform for class discussions and course announcements, enabling you to get timely help from classmates, the TA, and the instructor. If you have any questions about any of the assessments, please post your question on Canvas rather than sending me an email.

We will also have a course Google Doc, which we will use during our classes. The URL is:

http://bit.ly/Vancouver5800

NOTE: a PDF of the course textbook will be provided to you so that you do not have to purchase the textbook yourself.

Course Policies

Accommodations

The goal is for every student to succeed in this course. If you require any accommodations (e.g. child care during class hours, extra time to complete assignments, support for a disability), let me know immediately so that we can work out appropriate arrangements. Speak to me at the end of class or contact me by email, and we will set up a time to meet during the first week of the course. I look forward to learning how I can be of service to you.

Assessments

With the exception of the In-Class Quizzes and Final Project, all assessments are due at **6:30PM** on Tuesday: one day before the start of class. The course assessments are purposely due 24 hours before class, so that you have time on Tuesday evening and all day Wednesday to complete the readings in preparation for the class.

Late Penalties

Any assessment that is late will be subject to a 50% penalty. You are allowed *one* exception to this policy, where you are allowed a reasonable extension to any assessment, with no penalty, provided you have a doctor's note or some other compelling reason. Additional exceptions will only be given under extenuating circumstances.

Note that the Late Penalty only applies to Problem Sets, Programming Projects, and Course Syntheses. The remaining assessments (In-Class Quizzes, SAIL Reflections, Group Seminar, Final Project) must be submitted on time; failure to do so will result in an automatic zero.

Attendance and Participation

It is expected that you attend every class and participate. We begin each day at 6:30PM sharp. If you must miss a class for any reason (e.g. illness, family emergency, religious observance), contact me by email. Regardless of the reason, it is your responsibility to catch up on the material you have missed, and obtain the notes from a classmate (not from me).

Students who are absent repeatedly from class will be evaluated by faculty responsible for the course to ascertain their ability to achieve the course objectives and to continue in the course.

Technology

As part of our commitment to supporting students, NUFlex gives students the option of attending class on campus or attending remotely via video-conference. For each of our 15 classes, you may attend in person or attend remotely: the choice is yours.

For those of you attending the class remotely, we will use Zoom (www.zoom.us). The login details are as follows:

https://northeastern.zoom.us/j/95020298788
(Meeting ID: 950 2029 8788, no password)

Students joining via Zoom will adhere to the same rules and expectations as those attending in person: being present, actively engaging in discussions, asking questions, and participating in group activities. Because you will be working in teams where some of your team members will be on campus while others will be joining remotely, we ask all students to be fully present during the class and ensure a healthy learning environment.

This requires that students in the classroom refrain from using their phones and keep them out of sight, and refrain from browsing non-course related topics. Students joining remotely will ensure that any distractions in their near surroundings are eliminated, or at least minimized to the best of their ability. Please create a distraction-free learning environment to optimize your learning.

For those of you joining via Zoom, I would very much appreciate it if you could leave your video camera ON for the entire class. This enables me to see you all on my screen, so that I can better gauge the reactions of the class, appropriately pace my class, and more quickly respond to any questions you have. (If you prefer to leave your video camera OFF, especially for reasons of personal safety and comfort, then I will fully understand.)

Scheduling Meetings

At any time during the course, if you have any concerns, contact me by email, and we will set up a one-on-one meeting at a mutually convenient time. Please do NOT message me on Microsoft Teams. Always contact me by writing to me at r.hoshino@northeastern.edu.

I will also dedicate some time every Monday (3:30PM-4:30PM) to providing assistance on the upcoming Problem Set, via this Zoom link: https://northeastern.zoom.us/j/99703751451. If you need hints on these problems, please wait until our Monday sessions which are open to everyone in the class; for all other questions/concerns/issues, let's meet individually.

Classroom Conduct

To create and preserve a classroom atmosphere that optimizes teaching and learning, all participants share a responsibility in creating a civil and non-disruptive forum for the discussion of ideas. Students are expected to conduct themselves at all times in a manner that does not disrupt teaching or learning.

Your comments to others must be constructive and free from harassing statements. You are encouraged to disagree with other students and the instructor, but such disagreements need to be respectful and be based upon facts and documentation, rather than prejudices and personalities. The instructor reserves the right to interrupt conversations that deviate from these expectations.

Repeated unprofessional or disrespectful conduct may result in a lower grade or more severe consequences.

Title IX Policy

Title IX of the USA Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal financial assistance. Though our campus is located in Canada, all Northeastern University campuses follow the Title IX Policy.

Northeastern's Title IX Policy prohibits Prohibited Offenses, which are defined as sexual harassment, sexual assault, relationship or domestic violence, and stalking. The Title IX Policy applies to the entire community, including male, female, transgender students, faculty and staff.

If you or someone you know has been a survivor of a Prohibited Offense, confidential support and guidance can be found through University Health and Counseling Services staff and the Center for Spiritual Dialogue and Service clergy members. By law, those employees are not required to report allegations of sex or gender-based discrimination to the University.

Alleged violations can be reported non-confidentially to the Title IX Coordinator within The Office for Gender Equity and Compliance at: titleix@northeastern.edu and/or through NUPD Emergency 617.373.3333; Non-Emergency 617.373.2121. Reporting Prohibited Offenses to NUPD does NOT commit the victim/affected party to future legal action.

Faculty members are considered "responsible employees" at Northeastern University, meaning they are required to report all allegations of sex or gender-based discrimination to the Title IX Coordinator.

In case of an emergency, please call 911. Please visit http://www.northeastern.edu/titleix for a complete list of reporting options and resources, both on-campus and off-campus.

Academic Honesty

As with all other courses at Northeastern, you are expected to adhere to the university's academic integrity policy (http://www.northeastern.edu/osccr/academic-integrity).

In this course, any act of cheating (e.g. finding an online solution to an assignment problem) will result in an automatic failure from the course.

If you steal someone else's work, you fail the course. If someone uses your work, you fail the course. If you are unsure about the university's academic integrity policy, **ask me**.

Here are some examples of plagiarism:

- Submitting a copy of work done by another student, with or without their knowledge.
- Submitting work that was primarily found on the web or provided by someone else outside of this class.
- Submitting work by anybody who took this course in the past, whether the course was here at Northeastern or at another campus or institution.

So that there is no ambiguity, there are two non-negotiable rules. A violation of either rule constitutes plagiarism and will result in you receiving an F for this course.

- Even if you meet with a classmate to discuss an Individual Problem on the Problem Set, the articulation of your thought process (i.e., what you submit to me), must be an *individual* activity, done in your own words, away from others. Please remember that the solution-writing process is where so much of your learning will occur in this course: much more than anything we do in class, and even more than the time you spend on solving the problems. Do not be surprised if it takes you 3 to 5 times as long to write up a solution than it takes you to actually solve the problem. (For me, as an academic researcher writing formal proofs for publications, my ratio is significantly higher!)
- The Problem Sets, Programming Projects, and Course Syntheses are meant to be demanding, and struggling through a problem is how we learn best. Your educational experience is cheapened by going online and finding the solution to a problem – even using the Internet to look for a "small hint" is unacceptable. If you need support, or would like a hint, please post your query on the Canvas discussion forum and I will respond within 24 hours.

Feedback

Your opinions are very important to me. All students are strongly encouraged to use the Teacher Rating and Course Evaluation (TRACE) system, at https://www.northeastern.edu/trace/, to complete your course evaluations. A reminder about TRACE should arrive via email about two weeks before the end of the course.

In addition, I will be asking for your feedback at least once, about halfway through the semester. However, if you have concerns about the course, do not wait until you are asked. Please schedule a meeting with me, and we will discuss your concerns then.

Thank you for taking this course, and entrusting me to shape your education here at Northeastern. I am so excited to serve as your instructor!