

#### Instructor Information

**Instructor:** Dr. Norbert Zeh      **Office:** MC 4246  
**Email:** [nzeh@cs.dal.ca](mailto:nzeh@cs.dal.ca)      **Office hours:** T 10:30–12:30  
R 13:00–15:00  
F 10:00–12:00

#### Course Information

**Class meeting time:** TR 8:35–9:55  
**Room no:** Tupper 14B2  
**Course homepage:** <https://web.cs.dal.ca/~nzeh/teaching/4113+6101>

#### Important Dates

|                                    |                                                                              |
|------------------------------------|------------------------------------------------------------------------------|
| First day of class                 | Sep 23                                                                       |
| Holidays (no classes)              | Sep 30, Oct 13, Nov 11                                                       |
| Study break (no classes)           | Nov 10–14                                                                    |
| Final exam                         | Individual oral exams to be scheduled Dec 11–21                              |
| Last day to withdraw without a “W” | Oct 22                                                                       |
| Last day to withdraw with a “W”    | Nov 20                                                                       |
| Deadlines                          | 8 assignments due at 23:59 on<br>Oct 7, 14, 21 & 28;<br>Nov 4, 18, 25; Dec 2 |

#### Course Description

This course is divided into two parts. Part I focuses on advanced techniques for solving optimization problems that are widely applicable. Topics include linear programming, network flows, matchings in graphs, and graph cuts. These techniques will be used as building blocks for the algorithms discussed in Part II of the course. Part II focuses on approaches to solve NP-hard problems and is divided into three blocks. The first block focuses on approximation algorithms, that is, algorithms with polynomial running time that provide a guaranteed bound on the deviation of the computed solution from the correct answer. If we want an exact solution to an NP-hard problem, we have no choice but to accept an exponential running time. The second block of Part II focuses on techniques to make exponential algorithms as efficient as possible. The third block focuses on fixed-parameter algorithms, which limit

the exponential explosion of the running time to a hopefully small hardness parameter of the input and take polynomial time in the size of the input. In all three blocks, we will discuss various techniques for designing the types of algorithms covered in the block.

## Learning Outcomes

- Model various optimization problems as (integer) linear programs
- Understand how the simplex algorithm solves linear programs efficiently
- Understand techniques for solving network flow problems
- Understand techniques for solving matching problems
- Design exact exponential algorithms based on dynamic programming, branching search, and inclusion exclusion
- Construct a problem kernel for a fixed-parameter tractable problem
- Design fixed-parameter algorithms based on dynamic programming, branching search, inclusion-exclusion, iterative compression, and colour coding

## Class Format and Course Communication

- Content will be delivered in the form of lectures that include active discussion.
- Detailed lecture notes and slides will be available on the course webpage.
- Course announcements will be posted to the course webpage and on Teams.
- Assignment submissions are handled through Crowdmark.

## Evaluation Criteria

### Assignments (A)

- 8 assignments
- Late assignments will not be accepted
- Assignments must be uploaded to Crowdmark before the deadline
- All assignments must be submitted for formative assessment before the deadline.
  - Each is worth 3.75% of your grade (30% total)
  - Marks are given for making an honest effort to answer the assignment questions
  - Assignment receives feedback but marks do not depend on correctness of answers
- Assignments 1–6 are summative assignments
  - To be resubmitted one week after receiving feedback on the formative submission
  - Feedback will be given within 1 week after the submission deadline
  - Summative evaluation based on correctness of answers
  - Summative evaluation of 5 best assignments contributes 6% to your final grade per assignment (30% total)

## Final Exam (F)

- Individual oral exams will be scheduled December 11–21
- Covers all material in the course
- Worth 40% of your grade

## Final grade

- Default calculation based on the above weighting:  $40\% * F + 60\% * A$
- If your final exam score is better than your assignment score, the final exam determines your grade
- To pass the course, you must achieve at least 50% in each of assignments and final

## Notes

- You may be worried about having an oral final exam. Don't be. Students tend to score higher grades in oral exams than they would in written exams, for good reason. If you have questions about this, talk to me and I'm happy to explain. The only psychological hurdle is that you will be sitting face-to-face with me during the exam. To put your mind at ease, remember that I want you to succeed, not fail.
- The grade conversion scale in Section 17.1 of the Academic Regulations, Undergraduate Calendar will be used.

## Student Declaration of Absence

The Student Declaration of Absence policy shall apply. [https://www.dal.ca/campus\\_life/safety-respect/student-rights-and-responsibilities/academic-policies/student-absence.html](https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/academic-policies/student-absence.html)

## Academic Standards

Failure to properly attribute sources in your work will be treated as an academic standards issue and points may be deducted for not following citation requirements. For example, forgetting to quote text taken from other sources, failure to include in-text citations, or a failure to include required information in the citations or references. Please see the resources on proper citation provided by the Dalhousie Writing Center (<https://dal.ca/libguides.com/c.php?g=257176&p=5001261>).

Please note that if it appears that the error was made with intent to claim other people's work as your own such as a lack of both citations and references, an allegation of plagiarism will be submitted to the Faculty Academic Integrity Officer, which could result in consequences such as a course failure.

## Required Texts and Resources

- The main text for the course is provided in the form of lecture notes shared on the course webpage.

- The following books are valuable additional resources that explore various topics covered in the course in greater depth:
  - Cormen, Leiserson, Rivest, Stein. *Introduction to Algorithms*. MIT Press, 2009. (Earlier editions are fine; covers linear programming and some network flow algorithms in greater detail than the next book. Call# QA 76.6 C662 2009 (3<sup>rd</sup> ed.), 2001 (2<sup>nd</sup> ed.), 1990 (1<sup>st</sup> ed.)
  - Ahuja, Magnanti, Orlin. *Network Flows*. Prentice Hall, 1993. (Still the bible on all things related to flows. Call# T 57.85 A37 1993)
  - Vazirani. *Approximation Algorithms*. Springer-Verlag, 2001. (Covers a wide range of approximation algorithms. Call# QA 76.9 A43 V39 2003 (StFX library, can be ordered).
  - Niedermeier. *Invitation to Fixed-Parameter Algorithms*. Oxford University Press, 2006. (Covers a wide range of techniques for designing fixed-parameter algorithms. Available as electronic resource from the library.)
  - Fomin, Kratsch. *Exact Exponential Algorithms*. Springer-Verlag, 2010. (Covers a wide range of techniques for designing exact exponential algorithms. Available for download from <http://www.ii.uib.no/~fomin/BookEA/BookEA.pdf>.)
  - Cygan, Fomin, Kowalik, Lokshtanov, Marx, Pilipczuk, Pilipczuk, Saurabh. *Parameterized Algorithms*. Springer-Verlag, 2015. (Another book on parameterized algorithms, written by the current kings of the area; downloadable from <http://parameterized-algorithms.mimuw.edu.pl/parameterized-algorithms.pdf>.)

## Prerequisites

CSCI 3110

## Tentative List of Topics

- Linear programming
  - Modelling shortest paths and MST as linear programs
  - The simplex algorithm
- Maximum flows
  - Augmenting path algorithms
  - Preflow-push algorithms
- Minimum-cost flows
  - Negative cycle cancelling algorithms
  - Successive shortest paths algorithms
  - Scaling techniques
- Matchings
  - Maximum cardinality/weight matching
  - Minimum-weight perfect matching
- Exact exponential algorithms
  - Branching search

- Dynamic programming
- Inclusion-exclusion
- Fixed-parameter algorithms
  - Kernelization
  - Branching search
- Dynamic programming
- Inclusion-exclusion
- Iterative compression
- Colour coding

## Responsible Computing Policy

Usage of all computing resources in the Faculty of Computer Science must be within the Dalhousie Acceptable Use Policies (<http://its.dal.ca/policies/>) and the Faculty of Computer Science Responsible Computing Policy. For more information please see [https://www.cs.dal.ca/downloads/fcs\\_policy\\_local.pdf](https://www.cs.dal.ca/downloads/fcs_policy_local.pdf)

## Use of Artificial Intelligence Tools

You may use AI-driven tools to assist you in learning but remember that your objective is to understand, achieve, and apply the course competencies and outcomes. While you may use tools for learning, specific assessments in this course will disallow the use of AI-driven tools to assert that you have attained course learning outcomes. This is because a graduate must be able to analyze, assess and produce work unassisted by AI technology. Where tools are allowed: you must acknowledge all tools used to assist you. If applicable, you must provide links to chat logs. Using AI-driven tools where prohibited constitutes an academic offence.

## Culture of Respect<sup>1</sup>

Every person has a right to respect and safety. We believe inclusiveness is fundamental to education and learning. Misogyny and other disrespectful behaviour in our classrooms, on our campus, on social media, and in our community is unacceptable. As a community, we must stand for equality and hold ourselves to a higher standard.

### What we all need to do:

1. **Be Ready to Act:** This starts with promising yourself to speak up to help prevent it from happening again. Whatever it takes, summon your courage to address the issue. Try to approach

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<sup>1</sup> Source: Speak Up! © 2005 Southern Poverty Law Center. First Printing. This publication was produced by Teaching Tolerance, a project of the Southern Poverty Law Center. Full "Speak Up" document found at: <http://www.dal.ca/dept/dalrespect.html>. Revised by Susan Holmes from a document provided April 2015 by Lyndsay Anderson, Manager, Student Dispute Resolution, Dalhousie University, 902.494.4140, [lyndsay.anderson@dal.ca](mailto:lyndsay.anderson@dal.ca) [www.dal.ca/think](http://www.dal.ca/think).

the issue with open-ended questions like “Why did you say that?” or “How did you develop that belief?”

2. **Identify the Behaviour:** Use reflective listening and avoid labeling, name-calling, or assigning blame to the person. Focus the conversation on the behaviour, not on the person. For example, “The comment you just made sounded racist, is that what you intended?” is a better approach than “You’re a racist if you make comments like that.”
3. **Appeal to Principles:** This can work well if the person is known to you, like a friend, sibling, or co-worker. For example, “I have always thought of you as a fair-minded person, so it shocks me when I hear you say something like that.”
4. **Set Limits:** You cannot control another person’s actions, but you can control what happens in your space. Do not be afraid to ask someone “Please do not tell racist jokes in my presence anymore” or state “This classroom is not a place where I allow homophobia to occur.” After you have set that expectation, make sure you consistently maintain it.
5. **Find or be an Ally:** Seek out like-minded people that support your views, and help support others in their challenges. Leading by example can be a powerful way to inspire others to do the same.
6. **Be Vigilant:** Change can happen slowly, but do not let this deter you. Stay prepared, keep speaking up, and do not let yourself be silenced.

## University Statements

This course is governed by the academic rules and regulations set forth in the University Calendar and the Senate.

<https://academiccalendar.dal.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog&catalogid=117&loaduseredits=False>

## Territorial Acknowledgement

Dalhousie University is located in Mi’kma’ki, the ancestral and unceded territory of the Mi’kmaq. We are all Treaty people.

## Internationalization

At Dalhousie, “thinking and acting globally” enhances the quality and impact of education, supporting learning that is “interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders.”

<https://www.dal.ca/about-dal/internationalization.html>

## Academic Integrity

At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect. As a student, you are required to demonstrate these values in all of the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity.

(Read more: [http://www.dal.ca/dept/university\\_secretariat/academic-integrity.html](http://www.dal.ca/dept/university_secretariat/academic-integrity.html))

## **Accessibility**

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion please contact: [https://www.dal.ca/campus\\_life/academic-support/accessibility.html](https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro.

## **Conduct in the Classroom — Culture of Respect**

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view.

Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

## **Diversity and Inclusion — Culture of Respect**

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2).

(Read more: <http://www.dal.ca/cultureofrespect.html>)

## **Student Code of Conduct**

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner — perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution.

(Read more: [https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/university\\_secretariat/policy-repository/Code%20of%20Student%20Conduct%20rev%20Sept%202021.pdf](https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/university_secretariat/policy-repository/Code%20of%20Student%20Conduct%20rev%20Sept%202021.pdf))

## **Fair Dealing Policy**

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie.

(Read more: [https://www.dal.ca/dept/university\\_secretariat/policies/academic/fair-dealing-policy.html](https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy.html))

## **Originality Checking Software**

The course instructor may use Dalhousie's approved originality checking software and Google to check the originality of any work submitted for credit, in accordance with the Student Submission of Assignments and Use of Originality Checking Software Policy. Students are free, without penalty of

grade, to choose an alternative method of attesting to the authenticity of their work, and must inform the instructor no later than the last day to add/drop classes of their intent to choose an alternate method.

(Read more: [https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/university\\_secretariat/policy-repository/OriginalitySoftwarePolicy.pdf](https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/university_secretariat/policy-repository/OriginalitySoftwarePolicy.pdf))

## **Student Use of Course Materials**

These course materials are designed for use as part of the CSCI courses at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading material to a commercial third party website) may lead to a violation of Copyright law.

## **Learning and Support Resources**

Please see [https://www.dal.ca/campus\\_life/academic-support.html](https://www.dal.ca/campus_life/academic-support.html)