1   Course Overview

An advanced course building on foundational ideas in the theory of computing. Further properties of regular and context-free languages, language classes beyond context-free, parsing, randomness and probabilistic computation, relativized computation, complexity hierarchies, and circuit complexity will be discussed. Prior experience with theory of computing at the undergraduate level is recommended.

2   Learning Objectives

By the end of this course, you will be able to:

- Using examples, explain each of the foundational complexity classes.
- For each foundational complexity class in this unit, explain an algorithm that demonstrates the associated runtime complexity.
- Informally evaluate the foundational complexity class of simple algorithms.
- Explain examples that illustrate time-space tradeoffs of algorithms.
- Explain to a non-technical audience the significance of tractable versus intractable algorithms using an intuitive explanation of Big-O complexity.
- Explain the significance of NP-completeness.
- Explain how NP-hard is a lower bound and NP is an upper bound for NP-completeness.
- Explain examples of NP-complete problems.
- Explain the classes P and NP.
- Prove that a problem is NP-complete by reducing a classic known NP-complete problem to it.
- Explain the P-space class and its relation to the EXP class.

Objectives from *Computer Science Curricula 2023*, ACM/IEEE-CS/AAAI.

3   Instructor

Taylor J. Smith

- Email: `tjsmith@stfx.ca`
  I check my inbox Monday to Friday, 9am–5pm. I aim to reply within 24 hours.
- Office location: Annex, Room 9A
- Office hours: Monday/Wednesday/Thursday, 10:30am–11:20am, or by appointment

4   Class Time and Location

- Monday, 12:30pm–1:20pm
- Wednesday, 11:30am–12:20pm
- Thursday, 1:30pm–2:20pm

All lectures are held in Mulroney Hall, Room 4032.

5 Evaluations

Your final grade will be based on the following components:

- Two assignments (10% each, total 20%)
- Two quizzes (15% each, total 30%)
- Group lecture (total 30%): a lesson plan (10%) and the lecture itself (20%)
- Individual report on the group lecture (10%)
- Participation (total 10%): class participation (5%) and reviewing group lectures (5%)

Assignments are due at the beginning of class on the due date. Late assignments will be accepted up to the beginning of the first class following the due date. Late assignments are subject to a penalty of 10% deducted from the earned mark.

With the prior approval of the instructor, the weight of a missed quiz will be shifted to the weight of the other quiz (i.e., one quiz will be worth 0% and the other quiz will be worth 30%). Weights of missed assignments will not be shifted.

If you have a concern over how your assignment or quiz was marked, you may submit a remark request by contacting the professor. You must wait at least 24 hours after assignment or quiz papers are returned to students and you must consult the posted solutions before submitting a remark request. All remark requests must clearly state your concern and must be submitted within one week of receiving the assignment or quiz paper. Submitting a remark request does not guarantee a change in your earned mark.

You must complete the group lecture and individual report components in order to pass the course. You may not complete one without completing the other.

Your mid-term grade will be communicated to you by the deadline specified in the university's Academic Regulations. Your mid-term grade will consist of the weighted sum of the grades of your first assignment and your first quiz.

6 Method of Instruction

This course will be delivered face-to-face (i.e., all contact between instructor and students is in a physical classroom on campus). Course materials will be posted to the instructor's website.

7 Tentative Course Schedule

Week/Date	Topic	Due Dates
Week 1	Introduction to course; review of basic notions	
Week 2	Turing machines: deterministic, nondeterministic, variant models	
Week 3	Time and space complexity, resource bounds	
Week 4	Fundamental complexity hierarchy	**Quiz 1** (Jan. 30)
Week 5	NP- and PSPACE-completeness, logspace reductions	**Assn. 1** (Feb. 6)
Week 6	Interactive protocols, probabilistic proof checking	
Week 7	Probabilistic computation, randomized complexity theory	
Week 8	Circuit complexity	**Quiz 2** (Mar. 6)
Week 9	Relativized computation	**Assn. 2** (Mar. 13)
Week 10	Group lectures	
Week 11	Group lectures	
Week 12	Group lectures; course review	**Report** (Apr. 3)

8   Course Materials and Resources

Course notes will be provided for each lecture. The course textbook will be used as an optional supplement.

Required Text. None.

Recommended Texts.

Undergraduate-level review material: M. Sipser, *Introduction to the Theory of Computation.* Cengage, 3rd edition, 2012.

Graduate-level material: S. Arora and B. Barak, *Computational Complexity: A Modern Approach.* Cambridge University Press, 2009.

A free electronic copy of a draft edition of the textbook is available online at `https://theory.cs.princeton.edu/complexity/`.

9   Method of Evaluation

Assignments. This component will give you an opportunity to both demonstrate your understanding of course material and apply your understanding to a variety of problems. Each of the two assignments will consist of questions relating to material covered in the course between the assignment being issued and the due date. Assignments may be completed either individually or in groups of up to two people; however, if an assignment is completed as a group, each member of the group will receive the same grade for that assignment.

Quizzes. This component will serve as a diagnostic to gauge your individual understanding of course material. Each of the two quizzes will consist of questions relating to material covered in the course up to the date of that quiz. You will have 50 minutes (i.e., the duration of one lecture) to complete each quiz. Quizzes must be completed individually.

Group Lecture. This component consists of two submissions: a lesson plan and the lecture itself.

- The lesson plan is a one- to two-page document outlining what your group intends to cover in your lecture and how you are going to structure your lecture. The lesson plan will be graded primarily in terms of completeness and relevance.

- The lecture component is designed to give you and other members of your group experience both with studying a topic in this course that most interests you as well as with communicating that topic to others. The lecture itself will be graded primarily in terms of delivery.

Further details will be distributed later in the term.

Individual Report. This component is a follow-up to the group lecture, where you will submit a reflection on your group's performance in planning, designing, and delivering your lecture. In contrast to the group lecture, the report will be graded primarily in terms of content. The report will be an individual submission. Further details will be distributed later in the term.

Participation. This component is designed to encourage active engagement with the course material during lectures; for example, by asking questions or by involving yourself in discussions. As long as you consistently attend lectures and engage with the material, you will receive 5% for this component. The other 5% is obtained by providing short reviews for each group lecture, which will be distributed to the presenters as peer feedback.

A   Statement on Preferred Pronouns

Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, culture, religion, politics, sexual orientation, gender, gender variance, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honour your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records.

See policies at `https://www.stfx.ca/human-rights-equity/policies`.

B   Statement on Electronic Devices

During Exams: Unless you have medical accommodations that require you to do so, or explicit permission from the instructor of the course, you may not use any of the following electronic devices during ANY of the tests, midterms, examinations, or other in-class evaluations: cellphones, smart phones, smart watches, smart glasses, audio players or recorders of any sort, video cameras, video games, DVD players, televisions, laptop/notebook/netbook computers, flashlights or laser pointers.

During Lectures and Tutorials: Course instructors may permit the use of a computer during lecture and tutorial periods. If so, you are expected to use the computer for scholastic purposes only, and refrain from engaging in any activities that may distract other students from learning. From time to time, your professor may ask the class to turn off all computers, to facilitate learning or discussion of the material presented in a particular class. *Unless explicitly noted otherwise, you may not make audio or video recordings of lectures – nor may you edit, re-use, distribute, or re-broadcast any of the material posted to the course website.*

C   Copyright

All materials in this course are designed for use in CSCI 541: Theory of Computing at StFX University and are the property of the instructor, unless otherwise stated by the instructor. Copying this material for distribution, online posting, or selling of this material to third parties without permission is subject to Canadian Copyright Law and is strictly prohibited.

D   Policy on Academic Integrity

StFX recognizes that academic integrity is essential to scholarship and learning, and as such students are expected to understand the meaning and consequences of plagiarism and other forms of cheating. These are defined in Section 3.8 of the Academic Calendar and in the StFX Academic Integrity Policy.

Potential offences include:

1. Using someone else's words, ideas, or any other form of intellectual property without proper acknowledgement;

2. Submitting material for assessment that already has been submitted elsewhere;

3. Falsifying sources or facts;

4. Using or possessing unauthorized aids in a test setting;

5. Misrepresenting your identity in a test setting;

6. Falsifying any official document or record;

7. Collaborating with someone else in the production of work for assessment.

The university takes seriously its responsibility to preserve academic integrity, and the consequences of these acts and others outlined in the policy can be severe, often including the loss of grade value for an assignment and the loss of credit for the courses in which the offence happened. Learn the rules and find help at the following site: `https://www.stfx.ca/student-services/academic-services/academic-success-centre/academic-integrity`.

Statement on the Use of Generative Artificial Intelligence Tools. You may use generative AI tools to learn and practice the concepts presented in this course, but you may NOT use these tools to complete academic work in this course.

The use of generative AI tools in any form of academic work for this course, as well as copying, paraphrasing, or representing as one's own any idea that was generated by AI, will be considered a violation of academic integrity.

This course policy is designed to promote your learning and intellectual development and to help you reach the course learning outcomes.

E   Statement on Equitable Learning

Everyone learns more effectively in a respectful, safe and equitable learning environment, free from discrimination and harassment. Instructors and students are invited to work together to create a classroom space – both real and virtual – that fosters and promotes values of human dignity, equity, non-discrimination, and respect for diversity. Please feel free to talk with your course instructor about your questions or concerns about equity in our classroom or in the StFX community in general.

Should students have additional questions, they are encouraged to talk to the Chair/Coordinator of the Department/Program or the Human Rights and Equity Advisor. Contact information can be found at `https://www.stfx.ca/human-rights-equity`.

F   Information about Requesting an Accommodation at StFX

If you have a different learning ability and would like to request accommodations, please contact the instructor during the first week of the semester so that your accommodations may be provided in a timely manner. Centre for Accessible Learning (CAL) provides assistance in determining and facilitating appropriate accommodations for students with verified disabilities.

The Tramble Center for Accessible Learning welcomes students with documented permanent disabilities and offers them a student-centered program of support. Located in Room 108 of the Angus L. MacDonald Library, new and returning students meet with program staff to discuss options for support. Deadline for registering with the Center is two weeks prior to the end of classes each semester and three business days notice is required for booking all accommodated tests and exams.

To book an appointment, please use the following link: `https://tramblecentre.stfx.ca/user/appt/default.aspx`.

Phone: (902) 867-5349
Email: `tramble@stfx.ca`

G   Support Services

There are various support services around campus and these include, but are not limited to:

1. Student Life: `https://www.stfx.ca/student-life-support/student-services`

2. Office of the Registrar: `https://www.stfx.ca/applications-admissions/registrars-office`

3. Health & Counselling Centre: `https://www.stfx.ca/student-life-support/health-counselling-centre`

4. Academic Advising: `https://www.stfx.ca/student-life-support/academic-advising`

5. Student Success Centre: `https://www.stfx.ca/student-life-support/student-services/academic-success-centre`

6. Student Career Centre: `https://www.stfx.ca/student-life-support/student-services/student-career-centre`

7. Office of Internationalization: `https://www.stfx.ca/student-life-support/internationalization`

8. Financial Aid Office: `https://www.stfx.ca/applications-admissions/financial-support/financial-aid-office`

H   Health and Wellness

As part of a successful undergraduate experience at St. Francis Xavier University, we encourage you to make your health and wellness a priority. StFX provides several on-campus health-related services to help you achieve optimum health and engage in healthy living while pursuing your degree. For example, to support physical activity, all students receive membership to the StFX Athletics & Recreation Centre as part of their registration fees. Please visit the Athletics & Recreation website (`https://www.stfx.ca/student-life-support/campus-life/campus-recreation`) for opportunities including intramural sports. Numerous cultural events are offered throughout the year. Please check out the Department of Music web page (`https://www.stfx.ca/department/music/visiting-artist-program`), the StFX Art Gallery (`https://www.stfx.ca/art-gallery`) or Theatre Antigonish (`https://www.festivalantigonish.ca/theatreantigonish/`) for various events.

Further information regarding health and wellness-related services available to students may be found at `https://www.stfx.ca/student-life-support/health-counselling-centre`. If you are in emotional or mental distress please refer to the various mental health supports provided through Health & Counselling at `https://www.stfx.ca/student-life-support/health-counselling-centre`.