

# ECE367H1 F

## MATRIX ALGEBRA & OPTIMIZATION

### Fall 2024 Syllabus

#### Course Meetings

##### ECE367H1 F

Section	Day & Time	Delivery Mode & Location
LEC0101	Monday, 6:00 PM - 7:00 PM	In Person: BA 1170
	Tuesday, 10:00 AM - 12:00 PM	In Person: BA 1190
TUT0101	Friday, 9:00 AM - 11:00 AM	In Person: WB 219
TUT0102	Friday, 9:00 AM - 11:00 AM	In Person: BA 2159
TUT0103	Friday, 9:00 AM - 11:00 AM	In Person: WB 119

Refer to ACORN for the most up-to-date information about the location of the course meetings.

#### Course Contacts

**Course Website:** <https://q.utoronto.ca/courses/363822>

**Instructor:** Dr. Nadim Ghaddar

**Email:** [nadim.ghaddar@utoronto.ca](mailto:nadim.ghaddar@utoronto.ca)

**Office Hours and Location:** Tuesday, 12:00 PM – 1:00 PM in BA 8180, or by appointment

#### Course Overview

This course will provide students with a grounding in optimization methods and the matrix algebra upon which they are based. The first part of the course focuses on fundamental building blocks in linear algebra and their geometric interpretation: matrices, their use to represent data and as linear operators, and the matrix decompositions (such as eigen-, spectral-, and singular-vector decompositions) that reveal structural and geometric insight. The second part of the course focuses on optimization, both unconstrained and constrained, linear and non-linear, as well as convex and nonconvex; conditions for local and global optimality, as well as basic classes of optimization problems are discussed. Applications from machine learning, signal processing, and engineering are used to illustrate the techniques developed.

#### Course Learning Outcomes

By the end of the course, students will be able to:

- Define the basic concepts of linear algebra (e.g. vectors, matrices, norms, projections, eigenvalues, eigenvectors, etc) and develop an understanding of their geometric interpretations
- Formulate optimization problems and understand the basic optimality conditions for candidate solutions
- Apply the learned concepts to various problems in engineering (e.g. machine learning, signal processing, etc)

**Prerequisites:** AER210H1/MAT290H1, MAT185H1/MAT188H1

**Corequisites:** None

**Exclusions:** None

**Recommended Preparation:** None

**Credit Value:** 0.5

**Graduate Attributes:**

- 1A. Knowledge Base for Engineering: Demonstrate competence in mathematics and modeling. [Applied] **Measured in Course**
- 1C. Knowledge Base for Engineering: Demonstrate competence in specialized engineering knowledge appropriate to the program. [Applied] **Measured in Course**
- 2C. Problem Analysis: Demonstrate the ability to formulate and interpret a model. [Introduced] **Measured in Course**
- 3B. Investigation: Demonstrate the ability to devise and execute a plan to solve a problem. [Applied] **Measured in Course**
- 5A. Use of Engineering Tools: Demonstrate ability to use fundamental modern techniques, resources and engineering tools. [Applied] **Measured in Course**
- 5B. Use of Engineering Tools: Demonstrate ability to use discipline specific techniques, resources and engineering tools. [Applied]

## Course Materials

[1] Giuseppe Calafiore and Laurent El Ghaoui, *Optimization Models*, Cambridge University Press, 2014. (Main textbook)

[2] Stephen Boyd and Lieven Vandenberghe, *Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares*, Cambridge University Press, 2018. (PDF available at authors' website)

## Marking Scheme

Assessment	Percent	Details	Due Date
Homework 1	5%	There will be 5 problems sets, but only the top 4 will count towards the student's grade.	2024-09-17

Assessment	Percent	Details	Due Date
<b>Homework 2</b>	5%	There will be 5 problems sets, but only the top 4 will count towards the student's grade.	2024-10-01
<b>Homework 3</b>	5%	There will be 5 problems sets, but only the top 4 will count towards the student's grade.	2024-10-15
<b>Midterm</b>	35%		2024-10-22
<b>Homework 4</b>	5%	There will be 5 problems sets, but only the top 4 will count towards the student's grade.	2024-11-19
<b>Homework 5</b>	5%	There will be 5 problems sets, but only the top 4 will count towards the student's grade.	2024-12-03
<b>Final Exam</b>	45%	The final exam covers all course material presented during the term.	Final Exam Period

## Late Assessment Submissions Policy

## Course Schedule

Week	Description
<b>Week 1</b> Date	Vectors, Norms, Inner Products Readings: Ch. 2.1-2.2
<b>Week 2</b> Date	Orthogonal Decomposition, Projection onto Subspaces, Gram-Schmidt, QR decomposition, Hyperplanes and Half-Spaces Readings: Ch. 2.2-2.3
<b>Week 3</b> Date	Non-Euclidean Projection, Projection onto Affine Sets, Functions, Gradients and Hessians Readings: Ch. 2.3-2.4
<b>Week 4</b> Date	Matrices, Range, Null Space, Eigenvalues, Eigenvectors, Matrix Diagonalization Readings: Ch. 3.1-3.5
<b>Week 5</b>	Symmetric matrices, Orthogonal Matrices, Spectral Decomposition, Positive

Date	Semidefinite Matrices, Ellipsoids Readings: Ch. 4.1-4.4
<b>Week 6</b> Date	Singular Value Decomposition, Principal Component Analysis Readings: Ch. 5.1, 5.3.2
<b>Week 7</b> Date	Interpretations of SVD, Low-Rank Approximation Readings: Ch. 5.2, 5.3.1
<b>Week 8</b> Date	Midterm Review
<b>Week 9</b> Date	Least Squares, Overdetermined and Underdetermined Linear Equations Readings: Ch. 6.1-6.4
<b>Week 10</b> Date	Regularized Least-Squares, Convex Sets and Convex Functions Readings: Ch. 6.7.3, Ch. 8.1-8.4
<b>Week 11</b> Date	Lagrangian Method for Constrained Optimization, Linear Programming and Quadratic Programming Readings: Ch. 8.5, Ch. 9.1-9.6
<b>Week 12</b> Date	Numerical Algorithms for Unconstrained and Constrained Optimization Readings: Ch. 12.1-12.3

## Policies & Statements

### University Land Acknowledgement

I wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca, and the Mississaugas of the Credit. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

Learn more about Canada's relationship with Indigenous Peoples [here](#).

### Indigenous Students' Supports

If you are an Indigenous engineering student, you are invited to join a private Discord channel to meet other Indigenous students, professors, and staff, chat about scholarships, awards, work opportunities, Indigenous-related events, and receive mentorship. Email [Professor Bazylak](#) if you are interested.

Indigenous students at U of T are also invited to visit Nations House's (FNH) Indigenous Student Services for culturally relevant programs and services. If you want more information on how to apply for Indigenous specific funding opportunities, cultural programs, traditional medicines, academic support, monthly social events or receive the weekly newsletter, go to the FNH [website](#), [email](#) or follow FNH on social media: [Facebook](#), [Instagram](#), or [TikTok](#). A full event calendar is on the CLNX platform. Check CLNX often to see what new events are added!

## Wellness and Mental Health Support

Your personal wellness and mental health are important. The University of Toronto and the Faculty of Applied Science & Engineering offer a wide range of free and confidential services that can support your well-being.

As a U of T Engineering student, you have a Departmental [Undergraduate Advisor](#) or a Departmental [Graduate Administrator](#) who can support you by advising on personal matters that impact your academics. Other resources that you may find helpful are listed on the [U of T Engineering Mental Health & Wellness webpage](#), and a small selection are also included here:

- [U of T Engineering's Student & Community Wellness Coordinator](#)
- [Health & Wellness](#) and the [On-Location Engineering Wellness Counsellor](#)
- [Health & Wellness Peer Support Program](#)
- [Accessibility Services](#) & the [On-Location Advisor](#)
- [Graduate Engineering Council of Students' Mental Wellness Commission](#)
- [SKULE™ Mental Wellness](#)
- [U of T Engineering's Learning Strategist](#) and [Centre for Learning Strategy Support](#)
- [Registrar's Office](#) and [Scholarships & Financial Aid Office & Advisor](#)

We encourage you to access these resources as soon as you feel you need support; no issue is too small. You may reach out to the counsellors at [U of T Telus Health Student Support](#) for 24/7 free and confidential counselling support.

If you find yourself feeling distressed and in need of more immediate support visit [uoft.me/feelingdistressed](https://uoft.me/feelingdistressed) or U of T Engineering's [Urgent Support – Talk to Someone Right Now](#).

## Accommodations

The University of Toronto supports accommodations for students with diverse learning needs, which may be associated with mental health conditions, learning disabilities, autism spectrum, ADHD, mobility impairments, functional/fine motor impairments, concussion or head injury, visual impairments, chronic health conditions, addictions, D/deaf, deafened or hard of hearing, communication disorders and/or temporary disabilities, such as fractures and severe sprains, or recovery from an operation.

If you have a learning need requiring an accommodation the University of Toronto recommends that students [register with Accessibility Services](#) as soon as possible.

We know that many students may be hesitant to reach out to Accessibility Services for

accommodations. The process of accommodation is private; we will not share details of your needs or condition with any instructor.

If you feel hesitant to register with us, we encourage you to reach out for further information and resources on how we can support. It may feel difficult to ask for help, but it can make all the difference during your time here.

Phone: 416-978-8060

Email: [accessibility.services@utoronto.ca](mailto:accessibility.services@utoronto.ca)

## Equity, Diversity and Inclusion

### Looking for community? Feeling isolated? Not being understood or heard?

**You are not alone.** You can talk to anyone in the Faculty that you feel comfortable approaching, anytime – professors, instructors, teaching assistants, [first-year](#) or [upper years](#) academic advisors, student leaders or the [Assistant Dean of Diversity, Inclusion and Professionalism](#).

**You belong here.** In this class, the participation and perspectives of everyone is invited and encouraged. The broad range of identities and the intersections of those identities are valued and create an inclusive team environment that will help you achieve academic success. You can read the evidence for this approach [here](#).

**You have rights.** The [University Code of Student Conduct](#) and the [Ontario Human Rights Code](#) protect you against all forms of harassment or discrimination, including but not limited to acts of racism, sexism, Islamophobia, antisemitism, homophobia, transphobia, ableism, classism and ageism. Engineering denounces unprofessionalism or intolerance in language, actions or interactions, in person or online, on- or off-campus. Engineering takes these concerns extremely seriously and you can confidentially disclose directly to the Assistant Dean for help [here](#).

Resource List:

- [Engineering Equity, Diversity & Inclusion Groups, Initiatives & Student Resources](#)
- [Engineering Positive Space Resources](#)
- Request a religious-based accommodation [here](#)
- Email Marisa Sterling, P.Eng, the Assistant Dean, Diversity, Inclusion & Professionalism [here](#)
- Make a confidential disclosure of harassment, discrimination or unprofessionalism [here](#) or email [engineering@utoronto.ca](mailto:engineering@utoronto.ca) or call 416.946.3986
- Email the Engineering Society Equity & Inclusivity Director [here](#)
- [U of T Equity Offices & First Nations House Resources](#)

## Academic Integrity

All students, faculty and staff are expected to follow the University's guidelines and policies on academic integrity. For students, this means following the standards of academic honesty when

writing assignments, collaborating with fellow students, and writing tests and exams. Ensure that the work you submit for grading represents your own honest efforts.

Plagiarism—representing someone else's work as your own or submitting work that you have previously submitted for marks in another class or program—is a serious offence that can result in sanctions. Speak to me or your TA for advice on anything that you find unclear. To learn more about how to cite and use source material appropriately and for other writing support, see the [U of T writing support website](#). Consult the [Code of Behaviour on Academic Matters](#) for a complete outline of the University's policy and expectations. For more information, please see the [U of T Academic Integrity website](#).

## **Quercus Information**

This course uses the University's learning management system, Quercus, to post information about the course. This includes posting readings and other materials required to complete class activities and course assignments, as well as sharing important announcements and updates. The site is dynamic and new information and resources will be posted regularly as we move through the term, so please make it a habit to log in to the site on a regular, even daily, basis. To access the course website, go to the U of T Quercus log-in page at <https://q.utoronto.ca>. Once you have logged in to Quercus using your UTORid and password, you should see the link or "card" for this course. You may need to scroll through other cards to find this. Click on this link to open our course area, view the latest announcements and access your course resources. There are Quercus help guides for students that you can access by clicking on the "?" icon in the left side column.

**SPECIAL NOTE ABOUT GRADES POSTED ONLINE:** Please also note that any grades posted are for your information only, so you can view and track your progress through the course. No grades are considered official, including any posted in Quercus at any point in the term, until they have been formally approved and posted on ACORN at the end of the course. Please contact me as soon as possible if you think there is an error in any grade posted on Quercus.

## **Cell Phones and Laptop Usage**

Technology can support student learning, but it can also become a distraction. Research indicates that multi-tasking (texting, surfing the Internet, using social networks) during class time can have a negative impact on learning (Clapp, Rubens, Sabharwal & Gazzaley, 2011; Ellis, Daniels, Jauregui, 2010; Hembrooke & Gay, 2003). Out of respect for your fellow learners in this class, please refrain from using laptops or mobile phones for entertainment during class and do not display any material on a laptop which may be distracting or offensive to your fellow students. Laptops may be used only for legitimate classroom purposes, such as taking notes, downloading course information from Portal, or working on an assigned in-class exercise. Checking social media, email, texting, games, and surfing the Web are not legitimate classroom purposes. Such inappropriate laptop and mobile phone use is distracting to those seated around you.