

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF UTAH
Introduction to Optimization
MATH 5770/6640, ME EN 6025 – Section 001 – Fall 2021
Course Information and Syllabus
Updated December 7, 2021

Instructor: Akil Narayan
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Office: WEB 4666, LCB 116

Office hours: Tuesday, 11am-12pm, Friday 3pm-4pm
Office hours location: WEB 4666 and virtual (<https://utah.zoom.us/j/98428715630>, passcode 577001)

Class type: In Person

Class time and location: TTh, 9:10am-10:30am, WEB L114

Attendance policy: Attendance during synchronous lectures is *not* a part of your grade. However, I strongly recommend that you attend the lectures; attendance is an essential ingredient for success in this course.

Section webpage: <http://www.sci.utah.edu/~akil/math5770>

Note: Scores for graded assignments and any recorded videos will be posted on Canvas.

Course Information: This is a 3-credit course.

Learning objectives: Upon successful completion of this course, a student should be able to:

- understand and articulate basic concepts of finite-dimensional optimization problems
- state conditions ensuring existence and uniqueness of solutions
- formulate basic algorithmic optimizations for linear, quadratic, and convex problems
- implement simple versions of optimization algorithms

Prerequisites: Linear algebra (Math 2270 or equivalent), vector calculus (Math 2210 or equivalent), and basic knowledge of a programming language (e.g., Matlab).

Course description: Existence, uniqueness and characterization of solutions to finite dimensional unconstrained and constrained optimization problems. Solution methods for finite dimensional unconstrained and constrained optimization problems. Newton and Quasi-Newton methods. Globalization strategies. Linear Programming. Least Squares. Quadratic Programming. Convex Programming. Some programming experience is recommended. For graduate students extra work is required.

Text: Required: *Introduction to Nonlinear Optimization*, Amir Beck, SIAM, 2014, ISBN 978-1-61197-364-8. We will largely follow this book, with occasional supplementary notes.

Class lectures will be *heavily* based on textbook material. The textbook provides additional details and alternative interpretations that cannot be covered in class due to time constraints. Homework will be assigned from problems in the textbook. Access to the textbook is mandatory for success in this class.

Class meetings: This class meets in person twice per week. Class meetings will primarily be lecture-based, which will include a discussion of theory and practice examples.

Homework: Problem sets will be announced in-class and subsequently posted on the course website. Homework will be assigned approximately weekly and collected in class on Tuesdays.

Late homework assignments will be accepted, but with a 10% penalty per day late. This penalty will be enforced on Canvas, and can be waived if you provide me documentation demonstrating extenuating circumstances.

Each homework assignment is worth equal weight and your lowest homework score over the semester will be dropped. You are welcome (and encouraged) to work on the homework assignment in groups, but each student must submit individual work.

Exams: This course will have 1 in-class midterm exam, and 1 in-class comprehensive final exam. The midterm exam will be held in class on Thursday, October 7.

The final exam is a cumulative exam in the same format as the midterm exams. Per university policy, the final exam will be held on Wednesday, December 15 from 8:00-10:00am.

Unless otherwise specified, **neither calculators nor notes of any kind are allowed on either of the exams.**

Grading: Your course grade will be computed as follows.

- Homework 45%
- Midterm exam 25%
- Final exam 30%

Final letter grades will be assigned based on the following scheme:

- 92% - 100% — A
- 90% - 91% — A–
- 88% - 89% — B+
- 82% - 87% — B
- 80% - 81% — B–
- 78% - 79% — C+
- 72% - 77% — C
- 70% - 71% — C–
- 68% - 69% — D+
- 62% - 67% — D
- 60% - 61% — D–
- 0% - 59% — E

Important dates:

Sep 3	Last day to add, drop, elect CR/NC or audit classes
Oct 7	Midterm 1
Oct 22	Last day to withdraw from classes
Dec 3	Last day to reverse CR/NC option
Dec 10	Reading Day
Dec 15 8:00am	Final exam

Class communication: An email list is set up with which I shall send out information not communicated during class. This email list will also be used to communicate class information in the case of unusual circumstances affecting the the logistics of the class. If you are not officially registered for the class but wish to be on the roster, please discuss it with me.

If you are registered for the course, but do not receive the course email announcements to your University of Utah email address, please notify me immediately. You can forward your Utah emails to other email addresses. (Navigate to <http://www.cis.utah.edu>, login, and change your UMail settings.)

The section website will be used to communicate more technical matter of the class (e.g. problem sets, lecture summaries, etc.).

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to change that may be necessitated by a revised semester calendar or other circumstances. The above two methods, in addition to the coursewide website, are reliable means of getting information about changes to the course.

Communication with the instructor: The most reliable and preferred means of contacting me is via email. Communication through Canvas will also work. One-on-one meetings can also be set up with me outside of office hours; please set up such meetings with me via email.

COVID-19 considerations: All class activities will take place in person. University leadership urges all faculty, students, and staff to model the vaccination, testing, and masking behaviors we want to see in our campus community. These include:

Vaccination: Get a COVID-19 vaccination if you have not already done so. Vaccination is proving highly effective in preventing severe COVID-19 symptoms, hospitalization and death from coronavirus. Vaccination is the single best way to stop this COVID resurgence in its tracks. Visit <http://mychart.med.utah.edu>, <http://alert.utah.edu/covid/vaccine>, or <http://vaccines.gov> to schedule your vaccination.

Masking: While masks are no longer required outside of Health Sciences facilities, UTA buses and campus shuttles, CDC guidelines now call for everyone to wear face masks indoors.

Testing: If you are not yet vaccinated, get weekly asymptomatic coronavirus tests. This is a helpful way to protect yourself and those around you because asymptomatic individuals can unknowingly spread the coronavirus to others. Saliva based testing is available at alert.utah.edu/covid/testing

Self-reporting: All of us, including faculty, students, and staff, must self-report if we test positive for COVID-19 via this website: <https://coronavirus.utah.edu>.

According to the CDC, wearing a mask remains an effective means of preventing infection for both unvaccinated and vaccinated people. Regardless of what someone chooses (mask or no mask), the university seeks to foster a sense of community and asks everyone on campus to be respectful of individual decisions on mask wearing.

Vaccination is proving highly effective in preventing severe COVID-19 symptoms, hospitalization, and death from coronavirus. Vaccinations are available to everyone 12 years and older. Appointments are open in the University of Utah Health system for patients as well as additional vaccine providers throughout Utah. For up-to-date campus vaccination information go to <https://alert.utah.edu/covid/vaccine/>.

If you have been exposed, or are experiencing symptoms self report and follow university guidelines for exposure.

Regardless of your status regarding COVID-19, I **strongly urge** you to take advantage of university COVID-19 testing services at <https://alert.utah.edu/covid-19-testing>, including free asymptomatic testing.

Student responsibilities and integrity: All students are expected to maintain professional

behavior in the classroom setting, according to the Student Code, spelled out in the Student Handbook. Students have specific rights in the classroom as detailed in Article III of the Code. The Code also specifies proscribed conduct (Article XI) that involves cheating on tests, plagiarism, and/or collusion, as well as fraud, theft, etc. Students should read the Code carefully and know they are responsible for the content. According to Faculty Rules and Regulations, it is the faculty responsibility to enforce responsible classroom behaviors, and I will do so, beginning with verbal warnings and progressing to dismissal from and class and a failing grade. Students have the right to appeal such action to the Student Behavior Committee.

<http://regulations.utah.edu/academics/6-400.php>

Inclusivity: It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you.

Discrimination and Harassment: If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or Office of the Dean of Students, 270 Union Building, 801-581-7066. To report to the police, contact the Department of Public Safety, 801-585-2677(COPS). Please see Student Bill of Rights, section E <http://regulations.utah.edu/academics/6-400.php>. I will listen and believe you if someone is threatening you.

Names/Pronouns: Canvas allows students to change the name that is displayed AND allows them to add their pronouns to their Canvas name. Class rosters are provided to the instructor with the student's legal name as well as "Preferred first name" (if previously entered by you in the Student Profile section of your CIS account, which managed can be managed at any time). While CIS refers to this as merely a preference, I will honor you by referring to you with the name and pronoun that feels best for you in class or on assignments. Please advise me of any name or pronoun changes so I can help create a learning environment in which you, your name, and your pronoun are respected. If you need any assistance or support, please reach out to the LGBT Resource Center: https://lgbt.utah.edu/campus/faculty_resources.php

English Language Learners: If you are an English language learner, please be aware of several resources on campus that will support you with your language and writing development. These resources include: the Writing Center (<http://writingcenter.utah.edu/>); the Writing Program (<http://writing-program.utah.edu/>); the English Language Institute (<http://continue.utah.edu/eli/>). Please let me know if there is any additional support you would like to discuss for this class.

Undocumented Student Support: Immigration is a complex phenomenon with broad impact—those who are directly affected by it, as well as those who are indirectly affected by their relationships with family members, friends, and loved ones. If your immigration status presents obstacles to engaging in specific activities or fulfilling specific course criteria, confidential arrangements may be requested from the Dream Center. Arrangements with the Dream Center will not jeopardize your student status, your financial aid, or any other part of your residence. The Dream Center offers a wide range of resources to support undocumented students (with and without DACA) as well as students from mixed-status families. To learn more, please contact

the Dream Center at 801-213-3697 or visit dream.utah.edu.

Veterans: If you are a student veteran, the University of Utah has a Veterans Support Center located in Room 161 in the Olpin Union Building. Hours: M-F 8-5pm. Please visit their website for more information about what support they offer, a list of ongoing events and links to outside resources: <http://veteranscenter.utah.edu/>.

The Americans with Disabilities Act: The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability & Access, 162 Olpin Union Building, 801-581-5020, <https://disability.utah.edu>. CDA will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability & Access.

Student wellness: Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student's ability to succeed and thrive at the University of Utah. For helpful resources contact the Center for Student Wellness at www.wellness.utah.edu or 801-581-7776.

University Counseling Center (UCC): The UCC staff is committed to supporting the mental health needs of our campus community. Their phone number is 801-581-6826. Their hours are Monday-Friday, 8:00am-5:00pm. For after-hours emergencies, contact the 24/7 Crisis Line: 801-587-3000. More information is at <https://counselingcenter.utah.edu/>. **Student Success Advocates:** The mission of Student Success Advocates is to support students in making the most of their University of Utah experience (ssa.utah.edu). They can assist with mentoring, resources, etc. Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact a Student Success Advocate for support (<https://asuu.utah.edu/displaced-students>).

Addressing Sexual Misconduct: Title IX makes it clear that violence and harassment based on sex and gender (which includes sexual orientation and gender identity/expression) is a Civil Rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted on the basis of your sex, office for equal opportunity and affirmative action including sexual orientation or gender identity/expression, you are encouraged to report it to the University's Title IX Coordinator; Director, Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, <https://oeo.utah.edu/contact-us/index.php> or to the Office of the Dean of Students, 270 Union Building, 801-581-7066, <https://deanofstudents.utah.edu>. For support and confidential consultation, contact the Center for Student Wellness, 426 SSB, 801-581-7776. To report to police, contact the Department of Public Safety, 801-585-2677(COPS), <https://police.utah.edu>.

Campus Safety: The University of Utah values the safety of all campus community members. To report suspicious activity or to request a courtesy escort, call campus police at 801-585-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit safeu.utah.edu.

Office of the Dean of Students: The Office of the Dean of Students is dedicated to being a resource to students through support, advocacy, involvement, and accountability. It serves as a support for students facing challenges to their success as students, and assists with the inter-

pretation of University policy and regulations. To contact the Office of the Dean of Students, please email deanofstudents@utah.edu or call 801-581-7066. There is more information at <https://deanofstudents.utah.edu>.

Semester calendar

(Subject to change!)

DAY	DATE	TEXT SECTION(S)	TOPIC
Tuesday	August 24, 2021		Hello
Thursday	August 26, 2021	1.1–1.3	Euclidean space
Tuesday	August 31, 2021	1.4	Eigenvalues, eigenvectors
Thursday	September 2, 2021	1.5	Topology
Tuesday	September 7, 2021	2.1	Optima and extrema
Thursday	September 9, 2021	2.2	Matrix classification
Tuesday	September 14, 2021	2.3–2.4	Second-order and global optimality
Thursday	September 16, 2021	2.3–2.4	Second-order and global optimality
Tuesday	September 21, 2021	3.1–3.2	Data fitting and least squares
Thursday	September 23, 2021	3.3–3.4	Regularization and denoising
Tuesday	September 28, 2021	4.1–4.2	Gradient descent
Thursday	September 30, 2021	4.3–4.5	Algorithmic considerations, Gauss-Newton
Tuesday	October 5, 2021	—	Review
Thursday	October 7, 2021	—	<u>MIDTERM EXAM 1</u>
Tuesday	October 12, 2021	—	Fall break (no class)
Thursday	October 14, 2021	—	Fall break (no class)
Tuesday	October 19, 2021	5.1–5.2	Newton's method
Thursday	October 21, 2021	5.3	Cholesky factorizations
Tuesday	October 26, 2021	6.1–6.3	Convex sets
Thursday	October 28, 2021	6.4–6.5	Utility of convex sets
Tuesday	November 2, 2021	7.1–7.2	Convex functions
Thursday	November 4, 2021	7.3–7.4	Convex functions
Tuesday	November 9, 2021	7.5–7.7	Properties of convex functions
Thursday	November 11, 2021	7.8–7.9	Preliminaries of optimization with convex functions
Tuesday	November 16, 2021	8.1–8.2	Convex optimization
Thursday	November 18, 2021	8.3, 9.1	Convex optimization
Tuesday	November 23, 2021	9.2–9.3	Stationarity and orthogonal projections
Thursday	November 25, 2021	—	Thanksgiving break (no class)
Tuesday	November 30, 2021	10.1–10.2	The KKT conditions
Thursday	December 2, 2021	10.1–10.2	The KKT conditions
Tuesday	December 7, 2021	10.3	Convexity
Thursday	December 9, 2021	—	Review
Wednesday	December 15, 2021	8:00am-10:00am	<u>FINAL EXAM</u>