Vanderbilt University — Civil and Environmental Engineering

CE 5999-02 Special Topics — Intro to Optimization

Spring 2023

Instructor:	Ahmad F. Taha	**Time:**	T,TH 9:30 – 10:45
Email:	ahmad.taha@vanderbilt.edu	**Place:**	Featheringill Hall 300

Course Pages:

- Vanderbilt Brightplace: https://brightspace.vanderbilt.edu

Office Hours:

- Tuesdays and Thursdays, 11:00 – 12:30
- Or by appointment

Course Description: Introduction to optimization theory and methods, with applications in machine learning, systems control, and urban infrastructure design. In particular, this course offers a first look at optimization problem formulations, mathematical methods to solve optimization problems, and specifically convex optimization. Majority of machine learning, optimal control, and infrastructure (energy, water, transportation systems) design problems are posed as optimization problems, and this course presents the basics needed to understand these multidisciplinary engineering areas. Topics covered include: nonlinear unconstrained optimization, linear programming, nonlinear constrained optimization, various algorithms and search methods for optimization, and their analysis. Examples from various engineering applications and machine learning are given.

Main References: No textbook is required for the class. **Lecture notes will be provided as handouts or presentation slides.** However, you may need to refer to this textbook:

- S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004. YouTube videos for the class: https://www.youtube.com/watch?v=McLq1hEq3UY and book webpage: http://web.stanford.edu/~boyd/cvxbook/.

Course Objectives & Expected Outcomes:

The course deals with the analysis and solution of problems involving finding minima and maxima of functions, or optimization problems. Mathematical optimization finds numerous applications in Engineering, Computer Science, Statistics, Learning and AI, Management Science, and Economics. This course provides an overview of optimization theory and algorithms, and emphasizes its applications in different areas of Electrical Engineering, ranging from Communications and Networking to Signal Processing, Control, Power Systems, Water Systems, Transportation, and Machine Learning. Applications in other areas of Engineering may be covered, depending on the students' interests.

Prerequisites:

An undergraduate-level understanding of multi-variable calculus, high-level programming language, linear algebra, and algorithms is assumed. Nonetheless, basics related to the aforementioned topics will be covered in the first two weeks of classes.

Grading Policy

- Homework assignments and quizzes (25%)
- Midterm exam (30%)
- Final exam (40%)
- Attendance and instructor evaluation (5%)

Course Grade Cutoffs:

- A-, A, A+: 85–100
- B-, B, B+: 70–84
- C-, C, C+: 55–69
- D-, D, D+: 40–54
- F: ≤ 39

Class Policy:

- **Regular attendance** is essential and expected. The course instructor will occasionally take attendance and this will be counted towards the overall course grade. Students are allowed to miss at most two classes when the attendance is recorded.
- Students are expected to show few minutes **before** the start of the class. It is the student's responsibility to plan ahead of time and inform the course instructor of any emergencies. In case the student anticipates that they will be late for class, he/she should email the instructor before the class starts. Late arrival to class will negatively influence the attendance and instructor's evaluation grade.
- **Late submission policy:** besides medical and family emergencies (a written verification is required), there will be no extensions granted for homework submissions. Late submissions will be scaled according to lateness, removing 10% from your assignment grade per day late, up to a maximum of 50%. Submissions more than 5 days late will be assigned a score of 0.
- **Changes to the syllabus:** students will be regularly informed about any changes for the course syllabus.

Tentative Course Outline:

Part I — Optimization Class Review & Background ..... ≈ 1 class
Course introduction & syllabus, prerequisites, major applications, course overview
Part II — Mathematical Background and Intro to Optimization ..... ≈ 2–3 class
Review of needed mathematical background
Part III — Convex Sets and Convex Functions ..... ≈ 3–4 classes
Description of what makes a convex function/set a convex one
Part IV — Convex Optimization Classes ..... ≈ 3–4 classes
Classes of various optimization problems and their difficulty
Part V — Duality ..... ≈ 2–3 classes
Introduction to a core principle in optimization: duality
Part VI — Optimization Algorithms ..... ≈ 3–4 classes
Solving optimization problems using mainstream algorithms
Part VII — Relaxation of Nonconvex Problems ..... 2–3 class
Transforming difficult optimization problems into easier ones to solve
Part VIII — Optimization Under Uncertainty ..... ≈ 2–3 classes
Optimization algorithms to solve problems with uncertain variables/parameters
Part IX — Applications ..... ≈ 6–7 classes
Water systems, power networks, machine learning, transportation, etc...

Academic honesty:
Cheating, plagiarism, or any act of dishonesty will NOT be tolerated. This includes, but is not limited to, copying from another student's paper or assignment and copying from published material. Students are responsible for the content of the Honor Code. Any violation will be reported to the Honor Council. Students are bound by all provisions of the Honor Code, found in the Vanderbilt Student Handbook (http://www.vanderbilt.edu/student_handbook/the-honor-system/).

Other pertinent material may be found at the Honor Council's website, https://studentorg.vanderbilt.edu/honorcouncil/. Report any violation of the Honor Code at https://cm.maxient.com/reportingform.php?VanderbiltUniv&layout_id=2

Specific considerations for this course include:

- Use of Chegg, Slader, Course Hero or similar sites is not allowed in this course.
- Collaborative work with classmates is encouraged, however all work you submit must be your own. Copying someone else's work, with or without their permission, is an Honor Code violation in this class.
- If you have questions or concerns about Honor Code issues in this class, please talk with me

Excellence and Inclusion
It is my belief that everyone in this class can excel and that our collective learning experience is improved by including everyone fully. Toward that end, I commit to doing my best to use inclusive language and practices. If you observe actions in which I am not respectful or inclusive, please bring those to my attention.

Accommodation Policy
Vanderbilt is committed to equal opportunity for students with disabilities, as am I. If you need course accommodations due to a disability, please contact VU Student Access Services (https://www.vanderbilt.

edu/student-access/) to initiate that process. After SAS has notified me of relevant accommodation(s) and you and I have discussed how this(these) may best be approached in this class, I will facilitate the accommodation(s).

Mental Health & Wellness
If you are experiencing undue stress that may be interfering with your ability to perform academically, Vanderbilt's Student Care Network offers you a range of support services. The Office of Student Care Coordination (OSCC) is the central and first point of contact to help you navigate and connect to appropriate resources. You can schedule an appointment with the OSCC at https://www.vanderbilt.edu/carecoordination/ or call 615-343-WELL.
If you or someone you know needs to speak with a professional counselor immediately, the University Counseling Center offers Urgent Care Counseling. Students should call the UCC at (615) 322-2571 during office hours to speak with an urgent care clinician. You can also reach an on-call counselor after hours or on the weekends by calling (615) 322-2571 and pressing option 2 at any time. You can find additional information at https://www.vanderbilt.edu//ucc/.

Sexual Misconduct or Power-Based Personal Violence
If you have experienced sexual misconduct or power-based personal violence, please contact Project Safe (https://www.vanderbilt.edu/projectsafe/), VU Police Department, or the nearest emergency room as best fits your needs. If you share with me any information about such experiences, I am required by law to report this to Vanderbilt's Title IX Coordinator.

Emergency Evacuation Plan
In the event of a fire or other emergency requiring evacuation, the occupants of this class should leave the building through the exits closest to the classroom. If you need special assistance during an evacuation, please discuss this with me as soon as possible. Vanderbilt University policy forbids reentry to a building in which an alarm has occurred without authorization by Vanderbilt Security.

Important information – COVID-19
Health and Safety: Our mutual commitment to health and safety is vital. Toward that end, in this class we will all: Wear masks that fully cover nose and mouth at all times; Maintain 6' or greater separation from each other; Stay away from the classroom when not feeling well, when instructed to isolate or quarantine, and when not scheduled to be present in person.
Attendance: If you have any reason to believe that you may be ill or have been a close contact of someone who is COVID-19 positive, do NOT come to class in person. Contact Student Health right away. Participate remotely until you are cleared to return to classes.
No portion of your grade will be tied to in-person attendance.
Online Engagement/Technology Requirements

- All students in this class must have a portable computer that meets the specifications at https://engineering.vanderbilt.edu/transit/ComputerRecommendation.php or those that were in effect during year of entry to VU.
- You must have internet access with a minimum bandwidth of 3 Mbps.
- You must have earphones/headphones with a microphone. These need not be fancy. I do recommend ones that fully occlude the ear canal to cut down on extraneous noise.

- Your full engagement in class sessions is essential not only for your own learning but for the shared educational experience of the class. Toward that end, no use of social media, email, etc. during class is permitted. When participating remotely, you must have your video camera on unless I have granted specific permission otherwise.