This course provides an introduction to basic mathematical ideas and computational methods for optimization. Topics include linear programming, integer programming, and convex optimization with an emphasis on modeling and data science applications.

Course Information

Class times: MWF, 12:00-01.15 PM, Pierce 301

Instructor: Melanie Weber (mweber@seas.harvard.edu)

Teaching Fellows:

Victoria Tang (xutang@g.harvard.edu), Head Teaching Fellow

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Office hours:

Melanie Weber: Wednesdays, 1.30-3pm, Pierce 311

Teaching Fellows: tba

Prerequisites. Math 21b (or Applied Math 22a, Math 22a, 23a, 25a, 55a), or equivalent background in linear algebra.

Limited Enrollment: This class has limited enrollment (total capacity of 75, **shared** between APMTH 121 and ENG-SCI 121).

~~*Please fill out this form to submit an enrollment petition by **April 9**. Enrollment notifications will be released on April 10. If your petition was accepted, please enroll by April 15. After this date, your spot will be made available to students on the waitlist.*~~

If you did not fill out the enrollment form, please add a comment to your enrollment petition that details how you fulfill the prerequisites.

The class is at capacity for fall 2024. Students with approved petitions can add themselves to the waitlist to be automatically enrolled, if a spot opens up.

Note: Applied Mathematics 121 is also offered as Engineering Sciences 121. Students may not take both for credit. Undergraduate Engineering Students should enroll in Engineering Sciences 121.

Course Description

This course provides an introduction to basic mathematical ideas and computational methods for optimization. Optimization describes the problem of maximizing or minimizing an objective in the presence of constraints. The class will take you through the theory, methods, and applications of linear and integer programming, as well as convex optimization. You will gain a working understanding of these methods and their applications to problems in business, society, engineering, and medicine, where optimization can bring efficiency where resources are constrained. Optimization is also used in the design and analysis of engineered systems of all kinds, including machine learning models.

The course covers three core areas of Optimization:

1. Linear Programming
2. Integer Programming
3. Convex Optimization

Course format. This course follows a flipped classroom format. Class meetings on Mondays and Wednesdays will consist of a combination of short lectures by the instructor and collaborative team-based problem solving. Each class meeting will have a pre-class assignment. Monday/Wednesday class attendance and participation is required, and you will be expected to come to each class with some familiarity of that day's content acquired by completing pre-class assignments. In-class quizzes will be taken during Friday class meetings. In weeks without in-class quizzes, Friday class meetings will serve as review session/ extended office hours lead by Teaching Fellows. Attendance of non-quiz Friday class meetings is optional.

Participation. You are expected to be present at class meetings, to participate in discussions and group work, and to make contributions that forward the learning of our whole class community. If you cannot attend a class meeting you may be able to obtain a waiver from the instructor. In these cases, you'll be expected to individually complete and submit the in-class problems to the instructor after the designated class meeting time. If your participation falls below acceptable standards (either through absence, silence, or counterproductive activity), your final course grade will be reduced accordingly. You should not take this course if you are unable to attend most Monday/Wednesday class meetings. Roughly, this means that you should not miss more than two Monday/Wednesday class meetings. Students who take this course who miss a significant amount of class (more than two Monday/Wednesday classes without a waiver) will not earn an A grade.

Goals. By the end of this course, students will be able to (1) take a real-world optimization problem and transform it into a formulation that can then be solved by the methods taught in class and (2) implement and apply those methods to obtain solutions.

Assignments

Pre-class assignment. A pre-class assignment consists of:

- Completing short readings from the required texts or posted class notes;
- Taking a short quiz based on the reading.

Your scores on short pre-class quizzes will be recorded in the Canvas gradebook and will contribute to your pre-class assignment grade. You will have two attempts for each pre-class quiz, and you may review your responses to your first attempt on the quiz before the second attempt.

Problem sets. There will five problem sets, assigned and due roughly every other week. The problem sets consist of a combination of theoretical and applications based exercises, with an emphasis on (first) understanding the methods we study and (then) applying them. Some of the problem sets will require formulating and solving models in AMPL. You will also benefit from using mathematical software such as Matlab or Mathematica to avoid the tedious and error-prone nature of hand-calculations. Reference material will be posted on the resources section (tba) of the website.

AMPL is provided at the beginning of the course. Please follow the detailed set up instructions from the guides in the resources section of the course website and from the AMPL thread on the Ed Discussion forum. Matlab and Mathematica are available from FAS Computer Services Software Download (you will also need to get KeyServer to make use of the software).

Extreme optimization. In addition to problem sets, there will be two team â€œExtreme Optimizationâ€ assignments. These assignments will present you with real world scenarios: large-scale problems that are non-trivial, yet (to-an-extent) solvable through the optimization techniques covered in this course. Your team will work together to formulate basic models and refinements, and implement and solve formulations using AMPL.

In-class quizzes. There will be five in-class quizzes during Friday class meetings.

Grading

Your grade will be determined from your work on pre-class assignments, problem sets, extreme optimization projects, and in-class quizzes. Pre-class assignments, problem sets, and extreme optimization projects will be graded on the following standards-based grading scale:

4: Exceeds expectations

3: Meets expectations

2: Approaching expectations

1: Falls well below expectations

In-class quizzes will be graded on the more traditional 0 - 100% scale. Quiz grades above 50% are considered satisfactory. If your quiz scores are all satisfactory, your lowest quiz score will be dropped from your quiz score average. Your final course grade will be determined based on a combination of the standards based grading and traditional grading scales, outlined in the table below.

Letter grade	**In-class quizzes**	**Problem sets and pre-class assignments**
A	all satisfactory with average > 75%	3 or 4 on at least 50% of assignments, and all problem sets satisfactory
B	all satisfactory with average > 65%	3 or 4 on at least 40% of assignments, and all problem sets satisfactory
C	all satisfactory with average > 50%	3 or 4 on at least 25% of assignments, and all problem sets satisfactory
D/E	average < 50%	3 or 4 on fewer 25% of assignments, some problem sets unsatisfactory

For example, a student with satisfactory scores on all in-class quizzes with average > 75% **AND** scores of 3 or 4 on > 50% of problem sets and pre-class assignments will earn an A in the course, provided that all problem sets are satisfactory. A student with satisfactory scores on all in-class quizzes with average > 75% but with scores of 3 or 4 on < 50% of problem sets and pre-class assignments will not receive a full A. The plus/minus modifier on the final letter grade is at the discretion of the instructor.

Note: The extreme optimization projects are also scored on the 1 - 4 standard based scale. However, the project score will not raise your letter grade. Projects that meet or exceed expectations (3 or 4) maintains your letter grade in the table above. Projects that don't meet expectations (1 or 2) will lower your letter grade.

Late Submission Policy. You will receive **3 late days over the semester, each allowing you to turn in a problem set 24 hours late without penalty**. You may only use **1 late day per problem set.** Late days are not allowed on extreme optimization assignments. Flexibility around deadlines for pre-class assignments is more difficult, but not impossible. *In cases of medical or other emergencies which interfere with your work, please have your Resident Dean contact the instructor.*

Academic Integrity. We support and adhere to the principles of academic integrity described in Harvardâ€™s honor code. *â€œWe -- the academic community of Harvard College, including the faculty and students -- view integrity as the basis for intellectual discovery, artistic creation, independent scholarship, and meaningful collaboration. We thus hold honesty in the representation of our work and in our interactions with teachers, advisers, peers, and students -- as the foundation of our community.â€*

At its core is an expectation that you will not take unfair advantage of your fellow community members. We will assume your trustworthiness in interactions with us, and with your fellow students.   Your work for this class should be your own. You may not consult outside solutions, read the completed solutions of your classmates, or copy solutions from common work. We also specifically forbid the use of ChatGPT or any other generative artificial intelligence (AI) tools at all stages of the work process. In the interest of fairness of those who adhere to this code of conduct, if a violation of this trust is discovered, it will be reported to the Honor Council. If you are ever in doubt, ask the course staff to clarify what is and isnâ€™t appropriate.

Accommodations for students with disabilities

Harvard University values inclusive excellence and providing equal educational opportunities for all students. Our goal is to remove barriers for disabled students related to inaccessible elements of instruction or design in this course. If reasonable accommodations are necessary to provide access, please contact the Disability Access Office (DAO). Accommodations do not alter fundamental requirements of the course and are not retroactive. Students should request accommodations as early as possible, since they may take time to implement. Students should notify DAO at any time during the semester if adjustments to their communicated accommodation plan are needed.

Class Schedule

The course schedule will be updated throughout the semester. Assignments and materials for in-class team exercises will be linked below.

Date	Topic	Material	Assignments
09/04	Lecture 1 **-** Introduction to Linear Programs	team problems 01	Pre-Class (due 09/04, 11.45am)
09/06	no class meeting		HW1 posted (due 09/20)
09/09	Lecture 2 - Modeling, AMPL		
09/11	Lecture 3 â€“ Modeling (continued), canonical forms		
09/13	Problem Solving/ Review		