

## MATH 340: Introduction to Linear Programming

**Instructor:** Mathav Murugan (email: [mathav@math.ubc.ca](mailto:mathav@math.ubc.ca))

**Lectures:** Sec 201: TuTh 9:30-11 at Forest Sciences Centre 1221;

Section 202: MWF 12-13 at Woodward Instructional Resources Centre 4

**Office hours:** Tuesday 11-12:30, Wednesday 13-14:30 at Math Annex 1104 starting from the second week of classes.

**Course webpage:** We will use Canvas.

Section 201: <https://canvas.ubc.ca/courses/131838>

Section 202: <https://canvas.ubc.ca/courses/131839>

**Piazza:** There is a link to Piazza on Canvas. Please use Piazza for questions that arise in your learning and for questions about all issues related to the course.

**Text:** The course text is Linear Programming: Foundations and Extensions (5th Edition) by Robert J. Vanderbei. An electronic copy of this textbook is available to download through the UBC library (<https://link.springer.com/book/10.1007/978-3-030-39415-8>).

**Outline.** The course will cover the following topics (subject to change).

1. Basics of LP problems and computer packages. (1-2 weeks).
2. Simplex method and related geometry (2-3 weeks).
3. Duality theory (3 weeks).
4. Matrix notation and sensitivity analysis (2 weeks).
5. Matrix games (1-2 weeks).
6. Other applications such as Optimal transport (1-2 weeks).

### Learning Goals:

- To be familiar with basic concepts of optimization
- To be able to translate practical (high dimensional) optimization problems into linear programming
- To understand the basic geometry of convex sets and its relation to linear programming
- To be able to compute solutions of linear programming by the simplex method and its variants
- To be able to manipulate matrix calculations to analyze linear optimization problems
- To understand and utilize duality to analyze linear optimization problems
- To be able to give mathematical proofs for simple statements regarding convex sets, optimization, simplex method, duality, etc.
- To be familiar with computer packages for doing mathematics

**Expectations:** Students are expected to attend all lectures and complete all assignments, quizzes, and exams to their full extent. Students should expect to spend between 9 and 12 hours per week outside of lectures. In the case a class meeting has to be missed, it is the student's responsibility to make up the missed material.

How to succeed in this course:

- It is very important to learn mathematics by *doing*. For example, it is not enough to read a worked out example from a book or lecture notes. It is not enough to understand each step in the solution. You have to struggle to work out examples or problems by yourself, without looking at the solutions. This way, you build up mathematical intuition on the subject.

- Very useful advice on how to solve problems due to Polya (<http://www.math.utah.edu/%7Epa/math/polya.html>) .

**Homework:** Homework will be given regularly according to the following schedule. Homework are to be submitted on Canvas by 10:00 AM on the due date. This is a strict deadline: *no late homework will be accepted.*

Assignment given	Assignment due
January 18	January 25
January 25	February 1
February 1	February 8
February 8	February 15
February 15	February 29
February 29	March 7
March 7	March 14
March 14	March 21
March 21	March 28
March 28	April 4

At the end of the term, your lowest homework grade will be dropped. This policy is intended to cover situations where you may miss an assignment for whatever reason, without you needing to ask for a concession. Most academic concession requests for assignments will be addressed by this policy.

- Students may work together on the HW assignments but must write up their solutions independently.
- Copying is forbidden. Any 2 (or more) assignments with some virtually identical answers deemed the result of copying will be given 0 total credit, and there will be further consequences for such dishonest actions. Please read the section on academic integrity below.
- Unreadable homework will get a zero mark. You should write neatly and organize your material for a third party to be able to clearly understand. Work must be shown.
- Missed homework will count as a zero mark.
- The number of each homework problem should be clearly written. It is probable that only a subset of those problems turned in would be graded, and you will not be informed (in advance) which ones these are. For example, if your homework does not contain any of the problems to be graded (which will be known only after the due date), you will get zero mark. So, it would be better for you to do all the problems to be handed in. For selected problems, only some important steps and/or the final answer will be checked.
- How to ask for change of marking: If you feel that a returned assessment is incorrectly marked, you can appeal that mark by submitting a regrade request statement to the instructor within one week of the return of the marked assignment. The statement should include a summary of what you feel was incorrectly evaluated with some justification of the claim. Your work will be re-evaluated in accordance with the established grading procedures, and re-marked if necessary. Note in unusual circumstances, if you mistakenly received a higher grade than earned, your final grade might decrease upon re-marking.

**Computing:** For certain assignments, you will need to use software packages for computing linear programming problems. Our default programming language is Python language via Jupyter Notebook, which is available available via the UBC syzygy server (<https://ubc.syzygy.ca/jupyter/hub/>). You can use this using your UBC CWL. There is Python library for linear programming, called Pulp. More details will be given later in the class. For learning python language, there are many sources; e.g. the online book: <https://automatetheboringstuff.com/>. Further resources will be mentioned in the course webpage.

**Midterm:**

- A take-home midterm will be provided on Monday, March 11.
- This is administered take home exam (2hr exam).
- Students write the exam simulating an in-class exam.
- Students mark their own exam and then submit the graded papers.
- The solutions and marking schemes will be provided by the instructor.
- The graded take-home midterm is due Friday, March 15.
- Students will get full official mark as long as they submit their self graded exam. One of the points is to honestly assess one's own work.
- Students who do not submit the graded exam will get zero mark.
- We will still record the students' self mark, only to keep record of students' progress.

**Final exam:** There will be a final exam during the regular examination period. **Evaluation:** The final mark will be calculated as follows:

Homework: 35% (lowest assignment score will be dropped)

Take-home midterm: 5%

Final exam: 60%

**Prerequisites:** You must have taken one of MATH 152, MATH 221, MATH 223.

**Academic integrity:** By enrolling as a student at UBC, you have agreed to abide by the University Rules on Academic Honesty. Here is what you have agreed to and are bound by: "Academic honesty is essential to the continued functioning of the University of British Columbia as an institution of higher learning and research. All UBC students are expected to behave as honest and responsible members of an academic community. Breach of those expectations or failure to follow the appropriate policies, principles, rules, and guidelines of the University with respect to academic honesty may result in disciplinary action. It is the student's obligation to inform himself or herself of the applicable standards for academic honesty. Students must be aware that standards at the University of British Columbia may be different from those in secondary schools or at other institutions. If a student is in any doubt as to the standard of academic honesty in a particular course or assignment, then the student must consult with the instructor as soon as possible, and in no case should a student submit an assignment if the student is not clear on the relevant standard of academic honesty. If an allegation is made against a student, the Registrar may place the student on academic hold until the President has made his or her final decision. When a student is placed on academic hold, the student is blocked from all activity in the Student Service Centre."

**University policies:** UBC provides resources to support student learning and to maintain healthy lifestyles but recognizes that sometimes crises arise and so there are additional resources to access including those for survivors of sexual violence. UBC values respect for the person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is

suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious observances. UBC values academic honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions. Details of the policies and how to access support are available on the UBC Senate website <https://senate.ubc.ca/policies-resources-support-student-success>.

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