MATH 340 101 2022W1 Introduction to Linear Programming

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Course schedule (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subjsection&dept=MATH&course=340&section=101) : Term 1, 2022/2023: Sept 2022 -> Dec 2022

Instructor: Matthieu Heitz

Email: **please use Canvas Mail (Inbox)** for course-related questions, see below. Otherwise, you can contact me by **email** (mailto:mheitz@math.ubc.ca) .

TA: TBA

Class: Monday, Wednesday, Friday, 14:00 - 15:00 (Vancouver Time)

Classroom: **Chemistry Building, Room B150** (https://learningspaces.ubc.ca/classrooms/chem-b150)

Office hours: (subject to change)

- Monday, 15:00 - 16:00 (Vancouver Time), in-person, in **Math 203** (https://learningspaces.ubc.ca/classrooms/math-203)
- Wednesday, 16:00 - 17:00 (Vancouver Time), **online** (https://ubc.zoom.us/j/66655916084?pwd=L1F4T3RhRUhCZFUxQlBlNEJWdlVnZz09)
- Thursday, 10:00 - 11:00 (Vancouver Time), **online** (https://ubc.zoom.us/j/66655916084?pwd=L1F4T3RhRUhCZFUxQlBlNEJWdlVnZz09)
- If you can't make it to any of the office hours, please email me for scheduling a meeting.

First class: Tuesday, Sept 6th, 2022

Last class: Wednesday, Dec 7th, 2022

No class or office hours on:

- Fri Sept. 30: National Day for Truth and Reconciliation
- Mon Oct. 10: Thanksgiving Day
- Wed Nov. 9 and 11: Midterm break

About the course

This course would be more properly called Linear Optimization: optimizing a linear objective function subject to linear constraints. The word 'programming' is not used in the sense of computer programming. Instead, it refers to a 'program' in the sense of planning or scheduling of activities. The reason is that George Dantzig, one of the pioneers of this field, studied these types of problems in application to logistics and planning in the US military after World War II. At that time, sets of instructions for computers were simply called "codes". More information on that **here** (https://mathoverflow.net/questions/145077/why-are-optimization-problems-often-called-programs?newreg=ecc71fe2a5e34bc6a8cc5169e40503e1) .

Prerequisites

- Matrix algebra: one of **MATH 152** (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subj-course&dept=MATH&course=152) , **MATH 221** (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subj-course&dept=MATH&course=221) , **MATH 223** (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subj-course&dept=MATH&course=223)

The following prerequisites are **highly recommended:**

- Multi-variable calculus: e.g **MATH 200** (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subj-course&dept=MATH&course=200) , **MATH 253** (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subj-course&dept=MATH&course=253) , etc.
- Basic knowledge of mathematical proofs: e.g. **Math 220** (https://courses.students.ubc.ca/cs/courseschedule?pname=subjarea&tname=subj-course&dept=MATH&course=220)

If you need a **refresher on the pre-requisites**:

- for matrix/linear algebra, you can look at this book: **Linear Algebra and its Applications, by David C. Lay** (https://home.cs.colorado.edu/~alko5368/lecturesCSCI2820/mathbook.pdf) . What you will need is mostly covered in 1.1 -> 1.5, 1.7, and 2.1 -> 2.5.
- for mathematical proofs, you can look at this document: **Common proof techniques, by Ian Adelstein** (http://commons.trincoll.edu/math228adelstein/files/2015/11/proof_techniques.pdf)

Main reference

Linear Programming, by Robert Vanderbei, 5th edition, 2020.

A PDF of the book is available on Canvas:

Book-Vanderbei-2020.pdf (https://canvas.ubc.ca/courses/103724/files/22033943/download?

download_frd=1)

Nearly any book on linear programming will cover the main topics in this course, but the notation used for the simplex method may be quite different (and take some effort to translate to the notation we'll use).

Course Outline (subject to change)

- Basics of LP problems, computing and convex geometry, 2 week
- Simplex Method, 2-3 weeks.
- Duality Theory, 3-4 weeks.
- Revised Simplex Method (matrix notation), 1-2 weeks.
- Optional topics as time permits: Matrix games, Optimal Transport, etc., 1-3 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 (and be able to visualize) 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 solve linear optimization problems
- To understand and utilize duality to solve linear optimization problems
- To be able to give mathematical proofs for simple mathematical statements about concepts covered throughout the course, including and not restricted to 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 on this course in order to be able to pass. Students should take notes during lectures as presentation of material may deviate at times from what is offered in the assigned reading material (the textbook and references). In the case a class meeting has to be missed for a serious reason, it is the student's responsibility to make up for any 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 work out examples or problems by yourself, without looking at the solutions.

This way, you build mathematical intuition on the subject.
- Very useful advice on how to solve problems are in **Polya** (http://www.math.utah.edu/%7Epa/math/polya.html) .

Communication

- The piazza forum is for discussions between students. The TA will monitor it.
- **Please use Canvas Mail** to contact the instructor.
- **Visiting the office hours** is also a great way to communicate with the instructor.
- Please **avoid using my math email address** to help me keep my math mailbox under the storage limit; using the Canvas email will also help your message to be not classified as a spam and missed.

Grading

- Your grade for the course will be computed roughly as follows:
  - Assignments: 30% (HWs: 25%, Quizzes: 5%)
  - Midterm: 20%
  - Final Exam: 50%
  - Optional project: 10% bonus (see below)
- All marks are subject to scaling.
- If you feel that a returned assessment is incorrectly marked, you can appeal that mark by submitting a re-mark 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 that in unusual circumstances, if you mistakenly received a higher grade than earned, your final grade might decrease upon re-marking.
- **Missing the midterm**: There are no make-up midterms in this course. Missing the midterm for a valid reason normally results in the weight of that midterm being transferred to the final exam. Examples of valid reasons include illness and travel to play a scheduled game for a varsity team. Examples of reasons that are not valid include conflicts with personal travel schedules or conflicts with work schedules or with other classes. Any student who misses the midterm is to present to their instructor the **Department of Mathematics self-declaration form** for reporting a missed assessment to their instructor within 72 hours of the midterm date. This policy conforms with the UBC Vancouver Senate's **Academic Concession Policy V-135** (http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,329,0,0) and students are advised to read this policy carefully.

- Please note that a student who misses the midterm and has otherwise not completed a substantial portion of the term work normally shall not be admitted to the final examination.
- **Missing the Final Exam**: You will need to present your situation to the Dean's Office of your Faculty to be considered for a deferred exam. See the **detailed regulations (http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,41,94,0)** . Your performance in a course up to the exam is taken into consideration in granting a deferred exam status (e.g. failing badly generally means you will not be granted a deferred exam). In Mathematics, generally students sit the next available exam for the course they are taking, which could be several months after the original exam was scheduled. Note that your personal travel schedule is NOT a valid reason for missing a final exam and students who miss the MATH 340 exam for this reason will receive a grade of 0 on the exam and fail the course.
- Passing the MATH 340 final exam may not be sufficient to ensure a student passes MATH 340 if they have failed the term work.
- IT IS ESPECIALLY IMPORTANT that students know that IF THEY DO NOT FULFILL THE COURSE REQUIREMENTS DURING THE TERM (including not writing the midterm test even if you agree to transfer the weight to the final) AND THEN MISS THE FINAL EXAMINATION, THEY MAY BE DEEMED INELIGIBLE FOR A DEFERRED FINAL.

Optional project for bonus points

This is optional and there will be little instructional support for this. Students should learn the related material, including necessary software packages by themselves. **Students can earn up to additional bonus 10%** to their final course grade, by submitting an optional term project: for example, if your course grade after the final exam is 80 and you get a perfect project mark then your final course grade will be 80+10 = 90. We will follow the following policy STRICTLY:

- Deadlines for projects are firm
- **October 7**: Submission of initial proposal, containing:
  - The proposal to explain what problem will be considered in the project.
  - The background and aim of the project should be properly demonstrated.
  - It should be typed in 11pt and 2-3 pages long.
- **October 28**: Submission of any changes of the proposal. In case the students want to change their intended project, they can submit a revised proposal by this time.
- The project is **due around 2 weeks before the final**.
- Up to TWO people can work together as a team.
- The project should be **original**, be an **application of linear programming to practical problems**, and it should be specifically targeted to solving problems **related to UBC and British Columbia**; e.g. transportation in Vancouver, housing market in Vancouver, UBC students' scheduling problem, reducing carbon exhaustion in British Columbia, etc.

- Plagiarism will not be tolerated, and will result in academic discipline.
- The project should be in the form of a typed written report. The expected length is 10-15 pages (or more if you have many pictures and datasets), in 11pt.
- The project will be marked under the following rubrics:
  - Originality of the project and how it is formulated: 30%. Is the project interesting? Are the problems formulated properly and in an original way?
  - Mathematical content: 20%. How well are the contents of the course embedded in the project? Is the mathematics correctly applied?
  - Supporting data: 20%. Is the supporting data for the project adequate, and well explained?
  - Presentation of the material: 30%. This includes: whether the presentation is to the point, and logically well organized.

Assignments

Reminder: Careful work on the assignments is the best way to prepare for the midterm and the final exam.

Assignments schedule: There will be a total of 10 assignments throughout the term, 6 homeworks (HW) and 4 quizzes. Homeworks are due **every Friday at 1pm**.

- Sept 16 (Friday): HW 1 due
- Sept 23 (Friday): Quiz 1, in class
- Sept 30 (Friday): HW 2 due
- Oct 7 (Friday): Quiz 2, in class
- Oct 14 (Friday): HW 3 due
- Oct 21 (Friday): **Midterm**
- Oct 28 (Friday): HW 4 due
- Nov 4 (Friday): Quiz 3, in class
- Nov 11 (Friday): HW 5 due
- Nov 18 (Friday): Quiz 4, in class
- Nov 25 (Friday): HW 6, in class

At the end of the semester, your **lowest HW grade and lowest quiz grade will be dropped**. This policy is intended to cover situations where you may miss a quiz or 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. The students are reminded of the plagiarism policies of UBC.
- We will be using Canvas for collecting the HWs.
- Late homework is not accepted.
- Unreadable homework will get a zero mark. You should write neatly and organize your material so that a third party can understand.
- Work must be shown.
- Missed homework will count as a zero mark.
- The number of each homework problem should be clearly printed.
- 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.

Exams

There will be two exams:

- Midterm: Friday, October 21st, in class, 50 min.
- Final Exam: TBA.

Exam conditions (applies to both the mid-term and the final):

- Students will be required to bring Photo ID
- Students should submit all the scratch work
- Students will need to sign up an `integrity contract' of pledging integrity
- More details will be given closer to the exams

Computing

For certain assignments and if you opt for the optional project, you will need to use software packages for computing linear programming problems. The percentage of coding questions will be 10-15% of all assignments. It is not a large portion of the class, however it should not be neglected. If you don't know how to program (in Python or other languages), this is a **great opportunity to start!** I can guarantee you that you will find it helpful for more than this particular course.

- Many programming languages, including Mathlab, Python, R, etc, have linear programming packages.
- Our default language is Python via Jupyter notebooks, which is available via the **UBC syzygy server (https://ubc.syzygy.ca/jupyter/hub/)**. You can use this using your UBC CWL.

- If you're not familiar with this environment, Patrick Walls at UBC has good tutorials on many useful topics, including Python and Jupyter notebooks. To access them, go to **his website** (https://patrickwalls.github.io/mathematicalpython/) , and click on the sandwich menu on the top left.
- We will use the Python library **PuLP** for linear programming.
- [This will be useful once we have seen the simplex method] Robert Vanderbei has an **online pivoting tool** (https://vanderbei.princeton.edu/JAVA/pivot/simple.html) that lets you choose entering and exiting variables and performs the pivot automatically. This is a good way to get an idea of how the simplex method will work on larger problems without having to do all of the algebra by hand! I really recommend using this tool.

Your personal health

If you're sick, it's important that you stay home – no matter what you think you may be sick with (e.g., cold, flu, other).

- A daily self-health assessment is required before attending campus. Every day, before coming to class, complete the self-assessment for Covid symptoms using this tool: **https://bc.thrive.health/covid19/en** (https://bc.thrive.health/covid19/en)
- Do not come to class if you have Covid symptoms, have recently tested positive for Covid, or are required to quarantine. You can check this website to find out if you should self-isolate or self-monitor: **http://www.bccdc.ca/health-info/diseases-conditions/covid-19/self-isolation#Who** (http://www.bccdc.ca/health-info/diseases-conditions/covid-19/self-isolation#Who) .
- Your precautions will help reduce risk and keep everyone safer. In this class, the marking scheme is intended to provide flexibility so that you can prioritize your health and still be able to succeed. See the "Grading" and "Assignments" sections.

If you do miss class because of illness:

- I will try to record classes in one way or another, so that students that get sick are not left behind. Recordings will be available upon request.
- Use the online discussion forum for help (which you can use even if you are not sick!)
- Come to office hours

If you are sick on a midterm exam day:

Please email the instructor as soon as you are confident you will not come to the scheduled exam. We would strongly prefer that you contact us to make an alternate arrangement than for you to come to the exam while you are ill. If you do show up for an exam and you are clearly ill, you will not be able to write the exam and we will make alternate arrangements with you. It is much better for you to email ahead of time and not attend. Remember to include your full name and student number in your message.

If you are sick on a final exam day: Do not attend the exam. You must apply for deferred standing (an academic concession) through Science Advising no later than 48 hours after the missed final exam/assignment. Students who are granted deferred standing write the final exam/assignment at a later date. Learn more and find the application online: **https://science.ubc.ca/students/advising/concession (https://science.ubc.ca/students/advising/concession.)** .

For additional information about academic concessions, see the **UBC policy (http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,329,0,0)** .

Instructor health

If I (the instructor) am sick: I will do my best to stay well, but if I am ill, develop Covid symptoms, or test positive for Covid, then I will not come to class. If that happens, here's what you can expect:

- If I am well enough to teach, but am taking precautions to avoid infecting others,
  - we may have a synchronous online session or two. If this happens, you will receive (an email, an announcement in Canvas,...) telling you how to join the class. You can anticipate that this would very likely be a last minute email. Our classroom will still be available for you to sit and attend an online session, in this (hopefully rare) instance.
  - or you may receive a message from me with a recording of the lecture material for you to watch on your own time.
- If I am not well enough to teach, a colleague or TA will substitute.

Math department and UBC policies

For department-level policies on academic concessions, academic integrity, access and diversity, registriation, standing deferred (SD), student resources, and UBC resources to support student success, please consult this page: **General syllabus information - Department of Mathematics (https://www.math.ubc.ca/syllabus-policies)**

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Course Summary:

Date	Details	Due