

# MATH 340-101 Introduction to Linear Programming

**Course schedule:** Term 1, 2021/2022: Sept 2021 -> Dec 2021

**Instructor:** [Matthieu Heitz](#)

**Email:** mheitz@math.ubc.ca

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

**Classroom:** [Leonard S. Klinck \(LSK\) Building, Room #201](#)

**Office hours:** (subject to change)

- Monday, 16:00 - 17:00 (Vancouver Time), in-person (office TBA)
- Wednesday, 16:00 - 17:00 (Vancouver Time), online
- Thursday, 10:00 - 11:00 (Vancouver Time), online
- If you can't make it to any of the office hours, please email me for scheduling a meeting.

**First class:** Wednesday, Sept 8th, 2021

**Last class:** Monday, Dec 6th, 2021

## About the course

- Prerequisites: One of [MATH 152](#), [MATH 221](#), [MATH 223](#).
- **It is highly recommended that students have taken a multi-variable calculus course (e.g. Math 200, 253, etc.). Also, basic knowledge of mathematical proofs (e.g. Math 220) is highly recommended for taking this 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](#).

## Main reference

- **Linear Programming, by Robert Vanderbei, 4th edition, 2014.**

A PDF of the book is available in Files:

[Vanderbei2014 Book LinearProgramming.pdf](#)

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)

- Simplex Method and related geometry, 3-4 weeks.
- Duality Theory, 2-3 weeks.
- Revised Simplex Method, 1-2 weeks.
- Sensitivity Analysis, 1-2 weeks.
- Optional topics as time permits: Matrix games, Optimal Transport, etc., 1-3 weeks.

# Learning goals

- To be able to translate practical (high dimensional) optimization problems into linear programming
- To understand (and to 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..

# 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 struggle 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](#).

# Grading

- Your grade for the course will be computed roughly as follows:
  - Assignments: 40%
  - Midterm: 20%
  - Final Exam: 40%
- All marks are subject to scaling.
- If you feel that a returned assessment is incorrectly marked, you can appeal that mark by submitting a remark 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 midterms: 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](#) 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](#). 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(s) 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 8:** 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 29:** 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.
- The report should be **original**. 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:**

Assignments are due **every Friday at noon** (12:00pm). There will be a total of 10 assignments throughout the term:

- Sept 17 (Friday): HW 1 due
- Sept 24 (Friday): HW 2 due
- Oct 1 (Friday): HW 3 due
- Oct 8 (Friday): HW 4 due
- Oct 15 (Friday): **Midterm**
- Oct 22 (Friday): HW 5 due
- Oct 29 (Friday): HW 6 due
- Nov 5 (Friday): HW 7 due
- Nov 12 (Friday): HW 8 due
- Nov 19 (Friday): HW 9 due
- Nov 26 (Friday): HW 10 due

At the end of the semester, your **two lowest homework 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 for 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 15th, 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.

- Many programming languages, including Matlab, Python, R, etc, have linear programming packages.
- Our default is Python language via Jupyter Notebook, which is available via UBC syzygy server. 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/>
- Vanderbei has an [online pivoting tool](#) 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!
- Excel has linear programming package in it.

## Covid safety in the classroom

**Masks:** Masks are **required** for all indoor classes, as per the BC Public Health Officer orders. For our in-person meetings in this class, it is important that all of us feel as comfortable as possible engaging in class activities while sharing an indoor space. For the purposes of this order, the term “masks” refers to medical and non-medical masks that cover our noses and mouths. Masks are a primary tool to make it harder for Covid-19 to find a new host. You will need to wear a medical or non-medical mask for the duration of our class meetings, for your own protection, and the safety and comfort of everyone else in the class. You may be asked to remove your mask briefly for an ID check for an exam, but otherwise, your mask should cover your nose and mouth. Please do not eat in class. If you need to drink water/coffee/tea/etc, please keep your mask on between sips. Please note that there are some people who cannot wear a mask. These individuals are equally welcome in our class.

**Vaccination:** If you have not yet had a chance to get vaccinated against Covid-19, vaccines are available to you, free, and on campus (see [this link](#)). The higher the rate of vaccination in our community overall, the lower the chance of spreading this virus. You are an important part of the UBC community. Please arrange to get vaccinated if you have not already done so.

## 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>
- 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>.
- 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>.

For additional information about academic concessions, see the [UBC policy](#).

## 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.

## Academic Misconduct:

- University is the time in your life when you're deciding what kind of person you want to be as an adult. Therefore, commit to integrity.
- The biggest reason not to cheat is because you have integrity.
- UBC takes cheating incidents very seriously. After due investigation, students found guilty of cheating on tests and examinations are usually given a final grade of 0 in the course and suspended from UBC for one year. [More information](#).
- While students are encouraged to study together, they should be aware that blatant copying of another student's work is a serious breach of academic integrity. Please discuss with your instructors their expectations for acceptable collaboration on any assigned coursework. Cases of suspected cheating will be investigated thoroughly.
- Note that academic misconduct includes misrepresenting a medical excuse or other personal situation for the purposes of postponing an examination or quiz or otherwise obtaining an academic concession.

The UBC Vancouver Senate's [Academic Concession Policy V-135](#) applies to all assignments in this course, and students are advised to read this policy carefully.

## UBC's Policies and Resources to Support Student Success

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 and cultural 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 [here](#).

## **Copyright:**

All materials of this course (course handouts, lecture notes, assessments, course readings, etc.) are the intellectual property of the Course Instructors or licensed to be used in this course by the copyright owner. Redistribution of these materials by any means without permission of the copyright holder(s) constitutes a breach of copyright and may lead to academic discipline.