MATH 340 201/202 2022W2 Introduction to Linear Programming

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Term 2, 2022/2023: Jan 2023 -- Apr 2023

Math 340 Introduction to Linear Programming

We have two sections:

Section 201 (section page) (https://canvas.ubc.ca/courses/116637/pages/section-201-kim-page)
: Instructor: Young-Heon Kim (http://www.math.ubc.ca/%7Eyhkim/index.html)

Email: Please use the Canvas email.

- **Tue/Thur** 9:30 -11:00
- Location of class: WESB 201

Section 202 (section page) (https://canvas.ubc.ca/courses/116637/pages/section-202-miller-page)
: Instructor: Evan Miller Email: Please use the Canvas email.

- **Mon/Wed/Fri:** 12:00--13:00
- Location: P. A. Woodward Instructional Resources Centre. Room 5.

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. The word `programming' refers to the program of activities given by a solution.
- Prerequisites: 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) .
- **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.

Main Reference:

- ***Linear Programming by Robert Vanderbei*** ***(https://gw2jh3xr2c.search.serialssolutions.com/?sid=sersol&SS_jc=TC0002299077&title=Linear%20Programming%20Foundations%20and%20Extensions)*** (electronic copy available to download through the UBC library!). For your note, I am using the 5th edition, and will use it for referring the numbers of sections and exercise. Vanderbei's webpage: **https://vanderbei.princeton.edu/LPbook/index.html (https://vanderbei.princeton.edu/LPbook/index.html)**

Course topics (subject to changes):

- Basics of LP problems and computer packages. 2 weeks.
- Simplex method and related geometry. 2 weeks.
- Duality theory. 3 weeks.
- Matrix notation and sensitivity analysis. 2 weeks.
- Matrix games. 1 - 2 weeks.
- 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 are in Polya (http://www.math.utah.edu/%7Epa/math/polya.html) .**

Grading

Your grade for the course will be computed as follows:

- **HW Assignments 30%.** 10 weekly HWs. Only the best 9 HWs will be counted toward the course grade.
- **Midterm 5%. Self 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.
  - **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.
- **Participation and attitude 5%.** This is calculated at the end of the semester as follows:
  - All students will start with an INITIAL PARTICIPATION GRADE proportional to the rest of their course work. For example, a student with 57/95 will start with 3/5 participation mark.
  - **To earn more grades than the initial participation grade** you should submit a one page essay discussing your learning experiences and how you have participated throughout the course. For example, you can explain what topic was most interesting to you and why, how the learning experiences have enhanced your mathematical understanding, as well as how you have participated classes/office hours/Piazza discussions. Then the instructor will determine the additional marks.
    - **The essay is due Thursday, April 13.**
  - **Under the decision of instructors, a small portion of the participation mark (maximum 1 out of 5) might be assigned as a bonus mark, e.g. for participating in surveys/evaluations.**
- **Final Exam 60%:**
  - **If you do the optional term project then this mark will be the larger between**
    - **the actual final exam (60%) and**
    - **the actual final exam (40%)+optional term project (20%).**
  - **IMPORTANT: Students with failing term mark (that is, less than 17/35) will not be**

admitted to write the final exam and will fail the course.

- **All marks are subject to scaling.**
- **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 (https://canvas.ubc.ca/courses/75087/files/14028073/download?wrap=1)** ↓ **(https://canvas.ubc.ca/courses/75087/files/14028073/download?download_frd=1)** 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 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 Calendar for **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.***
- 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 term project: This is optional and there will be no instructional support for this.

Students should learn the related material, including necessary software packages by themselves.

- **If you do the optional term project then mark for the final exam will be the larger between [the actual final exam (60%)] and [the actual final exam (40%)+optional term project (20%)].** Note that optional projects will be marked strictly.
- We will also follow the following policy ***STRICTLY***.
- **Deadlines for projects**: These are **firm deadline**s and will not be flexible.

- **February 17 (Friday):** Submission of initial proposal.
  - The proposal is to explain what problem will be considered in the project.
  - The background and aim of the project should be demonstrated.
  - It should be typed in 11pt and two pages long.
  - **Only those students who submit the proposals by this deadline will be marked for their term projects.**
- **March 6 (Monday):** 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.
- **April 14 (Friday).** The final deadline for submission of the final project.

- **Up to TWO people can work together as a team.**
- The project should be **original,** be **application of linear programming to practical problems, and it** SHOULD be specifically targeted to solving problems **RELATED TO UBC and/or British Columbia**; e.g. transportation in Vancouver, housing market in Vancouver, UBC students' scheduling problem, reducing carbon exhaustion in British Columbia, etc.
- The term 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 report should be ORIGINAL. Plagiarism will not be tolerated, and will result in academic discipline.
- The optional term 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 contents: 20%. How well are the contents of the course embedded in the project? Is the mathematics correctly applied?
  - Supporting data: 20%. Are 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.

Exams:

- **Midterm**: Take-home exam. **Tuesday, March 7. Self administered 2hr exam.**
  - **March 10 (Friday): graded take-home midterm exam submission due.**
- **Final Exam: TBA.**

HW Assignments Schedule: All times are the Vancouver time.

There will be a total of 10 HW assignments throughout the term. The best 9 HWs will be counted towards the course grade:

- **Jan 20 (Friday): HW 1 due**

- **Jan 27 (Friday): HW 2 due**
- **Feb 3 (Friday): HW 3 due**
- **Feb 10 (Friday): HW 4 due**
- **Feb 17 (Friday): HW 5 due**
- **UBC break: Feb 20--24.**
- **March 3 (Friday) HW 6 due**
- **March 7 (Tuesday): Take-home midterm exam.**
- **March 10 (Friday): graded take-home midterm exam submission due.**
- **March 10 (Friday): HW 7 due**
- **March 17 (Friday): HW 8 due**
- **March 24 (Friday): HW 9 due**
- **March 31 (Friday): HW 10 due.**

Homework Assignments Policy:

At the end of the semester, **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. 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 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 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.

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 and if you opt for the optional project, 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/
- Vanderbei (**https://vanderbei.princeton.edu/LPbook/index.html (https://vanderbei.princeton.edu/LPbook/index.html)**) 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.

Piazza vs Canvas Discussions and Canvas email:

- **The piazza forum is for discussions between students. Instructors will not monitor it.**
- If you have course related questions for the instructor, then please use the Canvas email. Of course, visiting the office hours is a great way to communicate with the instructor.
- Please avoid using my math email address, unless urgent, 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.

Other general information (academic concessions, access and diversity, academic integrity, etc) please go to:

https://www.math.ubc.ca/general-syllabus-information (https://www.math.ubc.ca/general-syllabus-information)

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Course Summary:

Date	Details	Due
Fri Jan 20, 2023	HW1-1 (https://canvas.ubc.ca/courses/116637/assignments/1464427)	due by 11:59pm
	HW1-2 (https://canvas.ubc.ca/courses/116637/assignments/1464428)	due by 11:59pm
	HW1-3 (https://canvas.ubc.ca/courses/116637/assignments/1464429)	due by 11:59pm
	HW1-4 (https://canvas.ubc.ca/courses/116637/assignments/1464430)	due by 11:59pm