

# CO 250: Introduction to Optimization

Winter 13 – Course Outline

## 1 Instructor & lectures

Section	Instructor	Office	Phone	Lecture room	Lecture time
1	Jochen Könemann	MC 5174	x32144	RCH 112	10:00-11:20TTh
2	Konstantinos Georgiou	MC 4012	x37563	RCH 112	10:30-11:20MWF

## 2 Tutorials and office hours

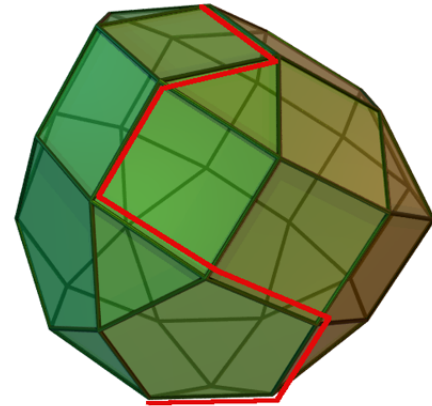
	Room	Time
Office hour	MC 5174 (J. Könemann)	Thu 11:30-1pm
Office hour	MC 4012 (K. Georgiou)	Wed 2:30-4pm
Office hour	DC 3145 (N. Mullin)	Tue 2-3pm
Tutorial	MC 2035	Tue 4-5pm
Tutorial	MC 2035	Wed 4-5pm

The tutorial sessions and office hours will be the appropriate forum for all questions pertaining to the course material and to assignments. Students are encouraged to attend. If you prefer to have your questions answered in a tutorial style meeting and would like to hear the questions of like-minded students and the TA's answers to others' questions, then attend the tutorials. If you need a one-on-one meeting, then choose the regular office hours. Note that you can attend any of the office hours regardless of the section in which you are enrolled.

## 3 Overview

Suppose that the owner of a factory wants to maximize its production for the next 30 days. There is a limit on the resources available. Resources may include, raw materials, labor, machine capacities, etc. This is an example of an *optimization problem*. The function that we are trying to *maximize* is the *objective function*, and the conditions imposed by the available resources are the constraints of the problem. Optimization problems are classified according to the type of objective function and the type of constraints.

The simplest models are *linear programs* where both the constraints and the objective functions are linear. Even though this may appear at a first glance to be overly restrictive, linear programming algorithms are used widely across most branches of industry. Indeed, a recent survey of Fortune 500 companies shows that 85% of all respondents use such algorithms in their operations. It is not hard however, to imagine applications for which fractional variable values are not desirable. For instance a variable may indicate the number of employees to hire, or a variable may be restricted to values 0 or 1 to indicate one of two possible options (e.g., build a factory in Waterloo or don't). In these cases we would like to add the condition that some variables in our linear program take integer values only. These models are known as *integer programs*. Finally, in certain instances, such as portfolio optimization (in financial mathematics), the natural way of formulating the optimization problem may require the use of non-linear constraints, or a non-linear objective function.



Geometric Representation of the Simplex Algorithm  
Picture courtesy Rex K. Kineaid

In the first part of co250, we will illustrate these various models with examples that arise from real problems. The later part of the course addresses the subject of how to solve the aforementioned problems. The *Simplex* algorithm to solve linear programs will be discussed in some detail and general-purpose integer programming techniques such as *branch-and-bound* and *cutting planes* will also be described. These algorithms while guaranteed to terminate, may in the worst case (and often do in practice) take a prohibitively long time. No fast general algorithm is known for integer programs (and none is believed to exist), however, there are efficient algorithms for many important special cases such as the Shortest Path problem. An indispensable tool for the design of such fast algorithms is the theory of *duality*, which will be a main focus of this course. We will move towards the conclusion of the course with a review of the various techniques used to solve linear and integer programs and by providing a geometric interpretation of these algorithms. This discussion will lead us to *non-linear convex optimization* problems. Also included in this last part of the material are approximation algorithms. These are the algorithms that are guaranteed to be computationally efficient, at the cost of finding solutions which are not necessarily optimal, but their objective values are within a guaranteed small factor of the best possible (optimal) objective value.

## 4 Schedule

Week	Topic
1-2	Formulations (linear, integer, and non-linear)
3-5	Solving linear programs
5-9	Duality theory
10-11	Integer programming (cutting planes & branch & bound)
12	Non-linear convex optimization

## 5 Objectives

After completing the class, students will be expected to master the following tasks and concepts:

- Formulate simple real life problems as linear, integer, or continuous (non-linear) optimization problem,

- Carry out the computations by hand for simple instances of various algorithms such as the simplex,
- Formulate the dual of various linear programs,
- Explain how duality theory is used to develop the shortest path algorithm,
- Ability to reproduce the main proofs in the course as well as proving simple related concepts independently,
- Being able to explain the geometric interpretation of the various algorithms covered.

Note, regarding algorithms, while it is necessary to know how to carry simple computations by hand, it is not sufficient. We will expect students to have a good understanding of why algorithms return correct answers and how they are derived.

## 6 Grades

We will use the following weights to compute your final mark in the course:

- Assignments: 15%,
- Midterm 30%,
- Final 50%
- Participation 5%

### 6.1 Assignments

There will be eight to ten assignments to be handed in. We will post assignments on Friday, and they are due the following week on Friday before class. Late assignments will not be graded and a mark of zero will be assigned. The assignments and their solutions will be posted on the course website. We will ignore the one assignment with the lowest grade when computing the average. You will find a discussion board on the third party web site [PIAZZA](#). We will visit the board on a regular basis and will try to answer questions in a timely manner.

Note, that it is not acceptable to discuss the assignments on any other discussion board. While it is acceptable for students to discuss the course material and the assignments, you are expected to do the assignments on your own. For example, copying or paraphrasing a solution from some fellow student or old solutions from previous offerings of related courses qualifies as cheating and we will instruct the TA's to actively look for suspicious similarities and evidence of academic offenses when grading. **All students found to be cheating will automatically be given a mark of 0 on the assignment (where that grade will not be ignored as the lowest assignment). In addition, all academic offenses are reported to the Associate Dean for Undergraduate Studies and are recorded in the student's file (this may lead to further, more severe consequences). Furthermore, cheating students will receive a 10% penalty on their final mark; i.e., a mark of 74% would be reduced to 64%.**

If you have any complaints about the marking of assignments, then you should first check your solutions against the posted solutions. After that if you see any marking error, then you should return your assignment paper to the instructor of your section within one week and with written notes on all the marking errors; please write the notes on a new sheet and attach it to your assignment paper.

## 6.2 Exams

A midterm will be held on February 27, 7-9pm. **Please contact your instructor as soon as possible if you have a conflict with this date.** A final exam will be scheduled later. Missed exams will count as 0 unless suitable medical documentation is provided. There will not be any make-up exams.

## 6.3 Participation

It has been the instructors' experience that students that do not attend class regularly, and who are not engaged in class tend to get grades much below average. Indeed the gap in performance (for similar courses) between students that attend class and turn in assignments regularly and those who do not, has been between ten and fifteen points. Uniform class participation in large classes such as co250 is hard to achieve. In this term, we have therefore decided to use clickers. Clickers allow large groups of students and instructors to engage in class in a non-intrusive way, and generally lead to a more active learning experience.

Clicker policy in co250 in W13: Clickers are **mandatory**. If you do not yet own a clicker, you will need to purchase such a device at the campus bookstore; clickers can be sold back to the bookstore at the end of the term. You will also need to register your device; see the course home page for a link. During class, we will frequently ask questions that students answer via their clicker.

We expect students to participate (via their clicker) in at least 50% of all questions; this is worth 5% of the final mark. Note: marks will assigned for participation, and not for correctness. You may only use your own clicker (registered in your name). Students found using a fellow student's clicker will be assigned a mark of 0 for class participation. Furthermore, such students will be reported to the Associate Dean for Undergraduate Studies.

In case there are special circumstances (such as an ongoing medical condition) that makes it difficult for you to be present at every class, please inform your instructor as soon as possible.

## 7 Website

We will be using **LEARN** this term as our course website. Log on using your username and password (same as your UW email account). All course related information including additional reading material, assignments, and announcements will be posted there. It is the responsibility of the students to check the web page regularly.

Like in previous terms, we will use third party web site **PIAZZA** to host the discussion forum for co250. We will monitor this site constantly, and strongly encourage students to post assignment and other course related questions there.

## 8 INC Grade

A grade of INC (incomplete) will be only awarded to students who cannot write the final exam for reasons acceptable to the instructor, such as a medical certificate by a recognized medical professional. In addition such students need to be in good standing prior to the final exam. To be in good standing a student must

- submit and pass at least 5 of the assignments,
- write and pass the midterm exam, and

- attend classes regularly.

## 9 Academic Integrity/Students with Disabilities

The following is reproduced from

<http://www.uwaterloo.ca/accountability/documents/courseoutlinestmts.pdf>.

**Academic Integrity** In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Check <http://www.uwaterloo.ca/academicintegrity/> for more information.

**Grievance** A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, <http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm>. When in doubt please be certain to contact the departments administrative assistant who will provide further assistance.

**Discipline** A student is expected to know what constitutes academic integrity to avoid committing academic offenses and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about rules for group work/collaboration should seek guidance from the course professor, academic advisor, or the undergraduate associate dean. For information on categories of offenses and types of penalties, students should refer to Policy 71, Student Discipline, <http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm>. For typical penalties check Guidelines for the Assessment of Penalties, <http://www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm>.

**Appeals** A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72, Student Appeals, <http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm>.

**Note for students with disabilities** The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.