

# Course Schedule

**IMPORTANT: ALL TIMES EASTERN** - Please see the [University Policies](#) section of your Syllabus for details

Module	Week	Activities and Assignments	
<a href="#">Module 1: Modelling Optimization Problems</a>	Week 1	<a href="#">Assignment 1</a>	Friday,
	Week 2	<a href="#">Assignment 2</a>	Friday,
<a href="#">Module 2: Solving Linear Programs</a>	Week 3	<a href="#">Assignment 3</a>	Friday,
	Week 4	<a href="#">Assignment 4</a>	Friday,
	Week 5	<a href="#">Assignment 5</a>	Friday,
	Week 6	<a href="#">Assignment 6</a>	Friday,
<b>Reading Week (Saturday, February)</b>			
<a href="#">Module 3: Duality Through Examples</a>	Week 7+8A	<a href="#">Assignment 7</a>	Friday,
<a href="#">Module 4: Duality Theory</a>	Week 8B+9A	<a href="#">Assignment 8</a>	Friday,
<a href="#">Module 5: Solving Integer Programs</a>	Week 9B+10	<a href="#">Assignment 9</a>	Friday,
<a href="#">Module 6: Nonlinear Optimization</a>	Week 11	<a href="#">Assignment 10</a>	Friday,
	Week 12		
<a href="#">Final Examination</a>			

**Note:** You must pass the final examination (earn at least 50%) in order to pass this course.

**Note:** [Piazza Participation](#) is worth **5%** of your final grade.

## Final Examination Arrangements and Schedule

Please carefully review the information about [writing exams](#) for online courses, including dates, locations,

how to make examination arrangements, writing with a proctor, and deadlines.

If you are taking **any on-campus courses**, you will automatically be scheduled to write your exam on campus. No action is required.

If you are taking **only online courses**, do one of the following:

- If your **address in QUEST is within 100 km** of an [examination centre](#), you must choose an exam centre in [Quest](#) by the end of the second week of term. This must be done each term.
- If your address in Quest is **more than 100 km from an exam centre**, you must arrange for a **proctor**. Please review the guidelines and deadlines for [writing with a proctor](#). This must be done each term.

Your online course exam schedule will be available in Quest approximately four weeks before your exam date(s). Instructions on how to find your schedule are posted on the [Quest Help](#) page.

University of Waterloo Senate-approved [academic regulations related to assignments, tests, and final exams](#) can be found on the Registrar's website.

## Official Grades and Course Access

Official Grades and Academic Standings are available through [Quest](#).

Your access to this course will continue for the duration of the current term. You will not have access to this course once the next term begins.

# Contact Information

## Announcements

Your instructor uses the **Announcements** widget on the **Course Home** page during the term to communicate new or changing information regarding due dates, instructor absence, etc., as needed. You are expected to read the announcements on a regular basis.

To ensure you are viewing the complete list of announcements, you may need to click **Show All Announcements**.

## Discussions

Your instructor will be using [Piazza](#) to facilitate discussions during this course. If you do not already have a Piazza account, you will be prompted to create one. Learn about [Piazza Registration and Data Collection](#).

If you encounter any difficulties using Piazza, please email your instructor.

Your instructor will visit Piazza on a regular basis and will try to answer questions in a timely manner. While it is acceptable for students to discuss the course material and the assignments, you are expected to do the assignments on your own.

## Contact Us

Who and Why	Contact Details
<p><b>Instructor</b></p> <ul style="list-style-type: none"> <li>• Course-related questions (e.g., course content, deadlines, assignments, etc.)</li> <li>• Questions of a personal nature</li> <li>• Questions about Piazza or Crowdmark</li> </ul>	<p><b>Post your course-related questions</b> on <a href="#">Piazza</a>. This allows other students to benefit from your question as well.</p> <p><b>Questions of a personal nature</b> can be directed to your instructor. Please use your UWaterloo email account to send email to your instructor, and please include your full name and UWaterloo student number.</p> <p>Instructor: Martin Pei  <a href="mailto:mpei@uwaterloo.ca">mpei@uwaterloo.ca</a></p>

Your instructor checks email and [Piazza](#) frequently and will make every effort to reply to your questions within 24–48 hours, Monday to Friday.

**Technical Support,**  
Centre for Extended  
Learning

- Technical problems with Waterloo LEARN

[learnhelp@uwaterloo.ca](mailto:learnhelp@uwaterloo.ca)

Include your full name, WatIAM user ID, student number, and course name and number.

Technical support is available during regular business hours, Monday to Friday, 8:30 AM to 4:30 PM (Eastern Time).

[LEARN Help Student Documentation](#)

**Learner Support Services,**  
Centre for Extended  
Learning

- General inquiries
- WatCards (Student ID Cards)
- Examination information

[Student Resources](#)

[extendedlearning@uwaterloo.ca](mailto:extendedlearning@uwaterloo.ca)

+1 519-888-4002

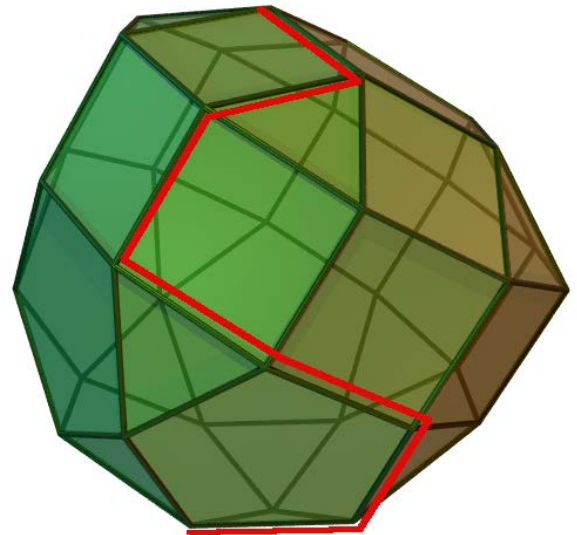
Include your full name, WatIAM user ID, student number, and course name and number.

# Course Overview and Outcomes

## 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, labour, 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.



Sdo. (2006, October 21). Shows a linear programming polytope together with a possible path (red) taken by the simplex method to solve the corresponding LP.

Retrieved from

<https://commons.wikimedia.org/wiki/File:Simplex-method-3-dimensions.png>

In the first part of this course, we will illustrate these various models with examples that arise from real problems. The latter 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.

## Outcomes

After completing the class, you are expected to master the following tasks and concepts:

- Formulate simple real life problems as linear, integer, or continuous (nonlinear) optimization problems.
- 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.
- Reproduce the main proofs in the course and prove simple related concepts independently.
- Explain the geometric interpretation of the various algorithms covered.

*This online course was developed by Jochen Könemann and Bertrand Guenin, with instructional design and multimedia development support provided by the Centre for Extended Learning.*

# About the Course Authors

## Course Author — Jochen Könemann

Jochen Könemann is a Professor in the Department of Combinatorics and Optimization at the University of Waterloo. He received an IBM Corporation Faculty Award in 2005, and an Early Research Award from the Government of Ontario, Canada, in 2007. He served on the program committees of several major conferences in Mathematical Optimization and Computer Science, and is a member of the editorial board of *Elsevier's Surveys in Operations Research and Management Science*.



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## Course Author — Bertrand Guenin



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Bertrand Guenin is a Professor in the Department of Combinatorics and Optimization at the University of Waterloo. He received a Fulkerson Prize awarded jointly by the Mathematical Programming Society and the American Mathematical Society in 2003. He is also the recipient of a Premier's Research Excellence Award in 2001 from the Government of Ontario, Canada. Guenin currently serves on the Editorial Board of the *SIAM Journal of Discrete Mathematics*.

# Materials and Resources

## Textbook

### Required

- a. Guenin, B., Könemann, J., & Tunçel, L. (2014). *A Gentle Introduction to Optimization*. Cambridge University Press.

For textbook ordering information, please contact the [W Store | Course Materials + Supplies](#).

For your convenience, you can compile a list of required and optional course materials through [BookLook](#) using your Quest userID and password. If you are having difficulties ordering online and wish to call the Waterloo Bookstore, their phone number is +1 519-888-4673 or toll-free at +1 866-330-7933. Please be aware that textbook orders **CANNOT** be taken over the phone.

## Resources

- [Library services for Co-op students on work term and Extended Learning students](#)



# Grade Breakdown

The following table represents the grade breakdown of this course.

<b>Activities and Assignments</b>	<b>Weight</b>
Weekly Assignments (Best 9 of 10 assignments)	15%
Piazza Participation	5%
Final Examination	80%

**Note:** You must pass the final examination (earn at least 50%) in order to pass this course.

# Course and Faculty Policies

## Course Policies

You must pass the final examination (earn at least 50%) to pass the course. Calculators are **not permitted** for the final examination.

## Illness and assignments

In case of illness during the term that causes you to miss assignments, please provide documentation to CEL and contact the instructor. The course grade allows you to miss one assignment for any reason, including illness. If your illness forces you to miss more than one assignment, then you can discuss with the instructor on the possibility of shifting some weight of the assignments to the final exam. However, if you miss more than 4 assignments due to illness, it is highly recommended that you should drop the course instead.

## INC Grade

A grade of INC (incomplete) will be only awarded to students who cannot write the final examination for reasons acceptable to the instructor, such as a medical certificate by a recognized medical professional provided to the instructor promptly. In addition, such students need to be in **good standing in CO 250 online** (in the following sense) prior to the final examination. To be in good standing in CO 250, a student must submit and **pass (earn at least 50% in) at least 6 of the assignments**.

# University Policies

## Submission Times

Please be aware that the University of Waterloo is located in the **Eastern Time Zone** (GMT or UTC-5 during standard time and UTC-4 during daylight saving time) and, as such, the time that your activities and/or assignments are due is based on this zone. If you are outside the Eastern Time Zone and require assistance with converting your time, please try the [Ontario, Canada Time Converter](#).

## Accommodation Due to Illness

**If your instructor has provided specific procedures for you to follow if you miss assignment due dates, term tests, or a final examination, adhere to those instructions.** Otherwise:

### Missed Assignments/Tests/Quizzes

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Contact the instructor as soon as you realize there will be a problem, and preferably within 48 hours, but no more than 72 hours, have a medical practitioner complete a [Verification of Illness Form](#).

**Email** a scanned copy of the Verification of Illness Form to your instructor. In your email to the instructor, provide your name, student ID number, and exactly what course activity you missed.

Further information regarding Management of Requests for Accommodation Due to Illness can be found on the [Accommodation due to illness](#) page.

### Missed Final Examinations

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If this course has a final exam and if you are unable to write a final examination due to illness, seek medical treatment and have a medical practitioner complete a [Verification of Illness Form](#). Email a scanned copy to the Centre for Extended Learning (CEL) at [extendedlearning@uwaterloo.ca](mailto:extendedlearning@uwaterloo.ca) within 48 hours of your missed exam. Make sure you include your name, student ID number, and the exam(s) missed. You will be **REQUIRED** to hand in the original completed form before you write the make-up examination.

After your completed Verification of Illness Form has been received and processed, you will be emailed your alternate exam date and time. This can take up to 2 business days. If you are within **150 km** of Waterloo you should be prepared to write in Waterloo on the additional CEL [exam dates](#). If you live outside the 150 km radius, CEL will work with you to make suitable arrangements.

Further information about [Examination Accommodation Due to Illness](#) regulations is available in the

## 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. **If you have not already completed the online tutorial regarding academic integrity you should do so as soon as possible.**

Undergraduate students should see the [Academic Integrity Tutorial](#) and graduate students should see the [Graduate Students and Academic Integrity](#) website.

Proper citations are part of academic integrity. Citations in CEL course materials usually follow CEL style, which is based on APA style. Your course may follow a different style. If you are uncertain which style to use for an assignment, please confirm with your instructor or TA.

For further information on academic integrity, please visit the [Office of Academic Integrity](#).

## Turnitin

**Turnitin.com:** Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin® in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit the alternate assignment.

[Turnitin® at Waterloo](#)

## Discipline

A student is expected to know what constitutes [academic integrity](#) to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration, should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to [Policy 71 - Student Discipline](#). For typical penalties, check [Guidelines for the Assessment of Penalties](#).

## 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](#).

## 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. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

## Final Grades

In accordance with [Policy 46 - Information Management](#), Appendix A - Access to and Release of Student Information, the Centre for Extended Learning does not release final examination grades or final course grades to students. Students must go to [Quest](#) to see all final grades. Any grades posted in Waterloo LEARN are unofficial.

## AccessAbility Services

[AccessAbility Services](#), located in Needles Hall, 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 accommodation to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term and for each course.

## Accessibility Statement

The Centre for Extended Learning strives to meet the needs of all our online learners. Our ongoing efforts to become aligned with the [Accessibility for Ontarians with Disabilities Act \(AODA\)](#) are guided by University of Waterloo accessibility [Legislation](#) and policy and the [World Wide Web Consortium's \(W3C\) Web Content Accessibility Guidelines \(WCAG\) 2.0](#). The majority of our online courses are currently delivered via the Desire2Learn Learning Environment. Learn more about [Desire2Learn's Accessibility Standards Compliance](#).

## Use of Computing and Network Resources

Please see the [Guidelines on Use of Waterloo Computing and Network Resources](#).



# Copyright Information

## UWaterloo's Web Pages

All rights, including copyright, images, slides, audio, and video components, of the content of this course are owned by the course author and the University of Waterloo, unless otherwise stated. By accessing this course, you agree that you may only download the content for your own personal, non-commercial use. You are not permitted to copy, broadcast, download, store (in any medium), transmit, show or play in public, adapt, or change in any way the content of these web pages for any other purpose whatsoever without the prior written permission of the course author and the University of Waterloo, Centre for Extended Learning.

## Other Sources

Respect the copyright of others and abide by all copyright notices and regulations when using the computing facilities provided for your course of study by the University of Waterloo. No material on the Internet or World Wide Web may be reproduced or distributed in any material form or in any medium, without permission from copyright holders or their assignees. To support your course of study, the University of Waterloo has provided hypertext links to relevant websites, resources, and services on the web. These resources must be used in accordance with any registration requirements or conditions which may be specified. You must be aware that in providing such hypertext links, the University of Waterloo has not authorized any acts (including reproduction or distribution) which, if undertaken without permission of copyright owners or their assignees, may be infringement of copyright. Permission for such acts can only be granted by copyright owners or their assignees.

If there are any questions about this notice, please contact the University of Waterloo, Centre for Extended Learning, Waterloo, Ontario, Canada, N2L 3G1 or [extendedlearning@uwaterloo.ca](mailto:extendedlearning@uwaterloo.ca).