Western University
Faculty of Engineering
Department of Electrical and Computer Engineering

ECE 9360 – Convex Optimization for Engineering and Science

COURSE OUTLINE 2023-2024

DESCRIPTION

The objective of this course is to provide students a comprehensive coverage of the theoretical foundation and numerical algorithms for convex optimization. The fundamental subjects in convexity, duality, and convex optimization algorithms will be introduced. Upon completion of the course, students should be able to utilize the convex optimization techniques and algorithms to solve optimization problems in various areas of engineering and computer science.

ENROLLMENT RESTRICTIONS

This course is offered for Engineering and Computer Science graduate programs. Enrollment in this course is restricted to graduate students in these programs, and if capacity permits, to any student who has obtained special permission to enroll in this course from the course instructor as well as the Graduate Chair (or equivalent) from the student's home program.

PREREUISTIES

The students are expected to know vector calculus, linear algebra, and have a fair level of mathematical maturity.

COURSE HOURS

3 lecture hours/week, 0.5 course.

COURSE FORMAT

Face-to-face

TOPICS

Topic #	Description	Learning Activities	Tentative timeline
1	Introduction		
	Lesson 1: Basic Concepts	• Vector Space, Norm, Vector Calculus, Linear Algebra. • Additional reading materials	Week 1

2	Lesson 2: Convex Concepts	• Gradient and Hessian of functions. • Functions of matrices. • Convex sets.	Weeks 2
3	Lesson 3: Convex Functions	• First-order and Second-order conditions for differentiable convex functions. • Properties of Convex Functions.	Week 3
4	Convex Optimization Problems	• Local and global optimal solutions of convex optimization problems.	Week 4
	Mathematical Programming	• Linear programming. • Quadratic programming. • Quadratically constrained quadratic programming. • Second-order cone programming.	Week 5
4	Optimization Problems	• Least-square problems. • Geometric programming. • Semi-definite programming. • SDP relaxation.	Week 6
	Reading Break Week		Week 7
5	Dual Theory		
	Lesson 1: Dual Theory	• Lagrangian. • Dual optimization problem. • Duality gap. • Slater's condition. • Sensitivity analysis.	Week 8
	Lesson 2: Duals of LP	• Economics and Pricing Interpretation. • Saddle points. • Game theory. • Duality theory for minimax optimization.	Week 9
	Lesson 3: Duals of Problems	• Dual of QP • Dual of SDP • Dual of QCQP	Week 10
6	Karush-Kuhn-Tucker (KKT) Conditions	• Complementary slackness condition • Interpretation of the KKT condition. • Regularity condition for local optimality. • Generalized inequalities.	Week 11
7	Algorithms	• Descent methods. • Newton's method. • Equality Constrained Minimization. • Infeasible-start Newton's Method. • Interior-point method for constrained optimization.	Week 12
	Project Presentation in Class		Week 13

SPECIFC LEARNING OUTCOMES

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	40%	• Assignments • Project	• Understanding of advanced concepts and theories • Awareness of important current problems in the field of study • Understanding of computational and/or empirical methodologies to solve related problems
Research & scholarship	15%	• Project	• Ability to conduct critical evaluation of current advancements in the field of specialization • Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment
Application of knowledge	30%	• Assignments • Project	• Ability to apply knowledge in a rational way to analyze a particular problem • Ability to use coherent approach to design a particular engineering system using existing design tools
Professional capacity / autonomy	5%	• Project	• Awareness of academic integrity • Ability to implement established procedures and practices in the coursework • Defends own ideas and conclusions • Integrates reflection into his/her learning process
Communication skills	5%	• Project	• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively
Awareness of limits of knowledge	5%	• Project	• Awareness of the need of assumptions/constraints in using convex optimization to solve complex optimization problems in practice. • Ability to acknowledge analytical limitation of optimization algorithms, e.g., computational complexity, due to complexity of practical problems

ASSESSMENTS

Assessment Type	Material Covered	Tentative Due Date	Weight
Homework Assignments (four)	Topic 1, 2, 4, 5, 6, 7		40%
Term tests (two)	Topics 1-3 and topics 4-7		20%
Project report (one)	Project topic to be decided later		20%
Project presentation (one)			20%

Activities in which collaboration is permitted:

- There will be a course project. Students may work in groups of two (2). If so, one report can be submitted by each group.

Activities in which students must work alone (collaboration is not permitted):

- There will be four assignments. All homework assignments have equal weights. Some of the assignments will involve programming in MATLAB. All assignments will be distributed via OWL. All assignments are expected to be submitted via OWL by 11:55 pm on the due date. Each assignment is worth 10% of your overall grade.
- There will be two quizzes to ensure that students keep up with the material being taught. They will each take place during the normal lecture hour. Each quiz will last 50 minutes. Quiz dates are as follows:

REQUIRED TEXTBOOK

Convex Optimization, Stephen Boyd and Lieven Vandenberghe, Cambridge University Press, 2004

OPTIONAL COURSE READINGS

Dimitri P. Bertsekas, *Nonlinear Programming*, Athena Scientific, 1999.
David G. Luenberger, *Optimization by Vector Space Methods*, Wiley, 1969.
R. Tyrell Rockafellar, *Convex Analysis*, Princeton University Press.

CHEATING, PLAGIARISM/ACADEMIC OFFENCES

Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence at the following website: https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf

CONDUCT

Students are expected to follow proper etiquette to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in course activities and/or is not following the rules and responsibilities associated with the course activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

HEALTH/WELLNESS SERVICES

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at http://www.health.uwo.ca/.

Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Faculty of Engineering has a Student Wellness Counsellor. To schedule an appointment with the counsellor, contact Kristen Edwards (khunt29@uwo.ca) via confidential email and you will be contacted by our intake office within 48 hours to schedule an appointment.

Students who are in emotional/mental distress should refer to Mental Health@Western: http://www.uwo.ca/uwocom/mentalhealth/ for a complete list of options about how to obtain help.

SICKNESS

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

Students who are not able to meet certain academic responsibilities due to medical, compassionate or other legitimate reason(s), could request for academic consideration. The Graduate Academic Accommodation Policy and Procedure details are available at:
https://www.eng.uwo.ca/graduate/current-students/academic-support-and-accommodations/index.html

ACCESSIBLE EDUCATION WESTERN (AEW)

Western is committed to achieving barrier-free accessibility for all its members, including graduate students. As part of this commitment, Western provides a variety of services devoted to promoting, advocating, and accommodating persons with disabilities in their respective graduate program. Graduate students with disabilities (for example, chronic illnesses, mental health conditions, mobility impairments) are strongly encouraged to register with Accessible Education Western (AEW): http://academicsupport.uwo.ca/accessible_education/index.html

AEW is a confidential service designed to support graduate and undergraduate students through their academic program. With the appropriate documentation, the student will work with both AEW and their graduate programs (normally their Graduate Chair and/or Course instructor) to ensure that appropriate academic accommodations to program requirements are arranged. These accommodations include individual counselling, alternative formatted literature, accessible campus transportation, learning strategy instruction, writing exams and assistive technology instruction.