BUS Q773 / CSE 776

Mathematical Programming: Theory and Algorithms

Winter 2024 Course Outline

Operations Management Area

DeGroote School of Business

McMaster University

Course Objective

* Understand and use optimization principles encompassing optimality conditions, duality theory and computational complexity.
* Learn different modelling approaches such as linear programming, integer programming and large-scale optimization.
* Evaluate a spectrum of optimization techniques and solution methodologies, such as the simplex method, sensitivity analysis, branch and bound, Lagrange multipliers, Bender’s decomposition and heuristics methods.
* Apply practical implementation of the above techniques and models with GAMS and gain familiarity with using successful optimization solvers such as CPLEX.

Instructor and Contact Information

**Lecture:** Wednesdays, 8:30am – 11:30am

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| **Dr. Berk Gorgulu** |
| Instructor |
| Email: [gorgulub@mcmaster.ca](mailto:gorgulub@mcmaster.ca) |
| Office: DSB 411 |
| Office Hours: Wednesday, 11:30am – 1:30pm  Class Location: Please refer to Avenue to Learn or Mosaic. |
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**Course Website:** <http://avenue.mcmaster.ca/>

Course Elements

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Credit Value: | 3 | Leadership: | Yes | IT skills: | Yes | Global view: | Yes |
| A2L: | Yes | Ethics: | Yes | Numeracy: | Yes | Written skills: | Yes |
| Participation: | Yes | Innovation: | No | Group work: | Yes | Oral skills: | Yes |
| Evidence-based: | Yes | Experiential: | Yes | Final Exam: | Yes | Guest speaker(s): | No |

Course Description

The course focuses on a comprehensive range of programming topics including linear, integer and nonlinear programming. Key concepts to be covered include convexity, simplex, interior point methods, duality, Karush-Kuhn-Tucker conditions, non-differentiable optimization, Branch and cut, and decomposition methods (Lagrangian, Bender’s and Dantzig-Wolf). Practical aspects of the software implementation will be emphasized using GAMS and its solvers.

Learning Outcomes

Upon successful completion of this course, students will be able to complete the following key tasks:

* Construct mathematical optimization models that represent decision problems
* Use optimization models to solve business decision problems
* Create and solve optimization models using an algebraic modelling language
* Analyze the convexity of an optimization problem
* Develop algorithms and heuristics for optimization problems

Course Materials and Readings

There is no required textbook for this course. The following texts, especially those in bold, include elaborate expositions of most of the topics we will cover in this course:

* M.S. Bazaraa, J.J. Jarvis and H.D. Sherali, Linear Programming and Network Flows (Wiley, New York, 1990)
* **M.S. Bazaraa, H.D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms (Wiley, New York, 1993)**
* D.P. Bertsekas, Nonlinear Programming (Athena Scientific, Massachusetts, 1995) [T 57.8.B47 1995]
* **Martin, R. K. Large Scale Linear and Integer Optimization: A Unified Approach (Springer , 1999)**
* G.L Nemhauser and L.A. Wolsey, Integer and Combinatorial Optimization (Wiley, New York, 1988) [QA 402.5 .N453 1988]

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| --- | --- | --- | --- |
| Activity | Delivery | Description | Tool(s) |
| **Lecture Core Content** | In-person | Live in-person lectures |  |

Course Overview and Assessment

Missed tests/exams will receive a grade of zero unless the student has submitted and been approved for a Notification of Absence or MSAF. Late submissions will be penalized at a rate of 25% of the assignment per day (You will receive 0% if an assignment is submitted 4 days after the deadline). Your final grade will be calculated as follows:

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| --- | --- | --- |
| Grade Component | Weight | Description |
| **Assignments** | **40%** | 4 x 10% each |
| **Midterm Exam** | **25%** | 2-hour in-class comprehensive exam |
| **Term Paper** | **35%** | Topic outline (10%), Peer review (20%), Presentation (20%) and Final report with response to reviewers (50%) |

Course Deliverables

## Midterm Exam (25%, individual work)

A two-hour in-class comprehensive exam. The exact date will be announced later.

## Assignments (40%, in groups)

There will be four assignments: two theoretical and two computational. Assignments will be done in groups of two students. You will be able to self-enroll in groups. All unenrolled students will be randomly added to unfilled groups. Late submissions will be penalized at a rate of 25% of the assignment per day (You will receive 0% if an assignment is submitted 4 days after the deadline).

## Term Paper (35%, individual work)

The purpose of the term paper is to: (1) research a topic that might not otherwise be covered in the course; (2) engage in rigorous research activity and tailor part of the course to your interests; (3) write a proposal and a final report, mimicking the procedural aspects of journal publication; and (5) articulate and present the findings of the projects. Collaboration is encouraged, allowing groups of two to collaborate on the term paper.

In your project, you are expected to investigate an optimization technique. You will code and test an algorithm that implements this technique. A topic choice has to be finalized by the third week of the term and I encourage you to discuss your topic choice with me during that period. To train PhD students for the academic world, we will mimic a journal’s review process. You are required to submit the following:

* Topic outline due 3rd week of the term
* Draft due during 12th week of the term
* Peer review due 13th week of the term
* Final report, with response to reviewer(s) and a statement of contribution for group work, and presentation due 14th week of term.

The draft will be reviewed by your peers. The more complete the draft, the more feedback you will get for your final report. Your peer review should mimic the journal review and should be submitted with a cover letter addressed to me.

The grading of the above components of the project is as follows:

* Topic outline 10%
* Peer review 20%
* Presentation 20%
* Final report with response to reviewers’ reports 50%

A late outline will be given a grade of 0 (out of 10%) and a late submission of other project components will be penalized at a rate of 5% of the total project grade per day.

Requesting Relief for Missed Academic Work

In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar [“Requests for Relief for Missed Academic Term Work”](https://secretariat.mcmaster.ca/app/uploads/Requests-for-Relief-for-Missed-Academic-Term-Work-Policy-on.pdf) and the link below;

<http://ug.degroote.mcmaster.ca/forms-and-resources/missed-course-work-policy/>

Academic Integrity

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: “Grade of F assigned for academic dishonesty”), and/or suspension or expulsion from the university.

For information on the various types of academic dishonesty please refer to the [*Academic Integrity Policy*,](https://secretariat.mcmaster.ca/app/uploads/Academic-Integrity-Policy-1-1.pdf) located at https://secretariat.mcmaster.ca/university-policies-procedures- guidelines/

The following illustrates only three forms of academic dishonesty:

* plagiarism, e.g. the submission of work that is not one’s own or for which other credit has been obtained.
* improper collaboration in group work.
* copying or using unauthorized aids in tests and examinations.

Courses With an On-Line Element

***Some courses may*** use on-line elements (e.g. email, Avenue to Learn (A2L), web pages, TopHat, MS Teams, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course.

The available information is dependent on the technology used. Continuation in a course that uses online elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

Conduct Expectations

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the [*Code of Student Rights & Responsibilities*](https://secretariat.mcmaster.ca/app/uploads/Code-of-Student-Rights-and-Responsibilities.pdf) (the “Code”). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviors that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students’ access to these platforms.

Academic Accommodation of Students with Disabilities

Students with disabilities who require academic accommodation must contact [Student Accessibility Services](https://sas.mcmaster.ca/) (SAS) at 905-525-9140 ext. 28652 or [sas@mcmaster.ca](mailto:sas@mcmaster.ca) to make arrangements with a Program Coordinator. For further information, consult McMaster University’s [*Academic Accommodation of Students with Disabilities*](https://secretariat.mcmaster.ca/app/uploads/Academic-Accommodations-Policy.pdf) policy.

Academic Accommodation For Religious, Indigenous or Spiritual Observances (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the [RISO](https://secretariat.mcmaster.ca/app/uploads/2019/02/Academic-Accommodation-for-Religious-Indigenous-and-Spiritual-Observances-Policy-on.pdf) policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also

contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

Copyright and Recording

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors.

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

Research Using Human Subjects

All researchers conducting research that involves human participants, their records or their biological material are required to receive approval from one of McMaster’s Research Ethics Boards before (a) they can recruit participants and (b) collect or access their data. Failure to comply with relevant policies is a research misconduct matter. Contact these boards for further information about your requirements and the application process.

McMaster Research Ethics Board (General board): [https://reo.mcmaster.ca/](https://reo.mcmaster.ca/%20)

Hamilton Integrated Research Ethics Board (Medical board): <http://www.hireb.ca/>

Acknowledgement of Course Policies

Your enrolment in BUS Q773/ CSE 776 will be considered to be an implicit acknowledgement of the course policies outlined above, or of any other that may be announced during lecture and/or on A2L. **It is your responsibility to read this course outline, to familiarize yourself with the course policies and to act accordingly.** Lack of awareness of the course policies **cannot be invoked** at any point during this course for failure to meet them. It is your responsibility to ask for clarification on any policies that you do not understand.

Potential Modifications to The Course

The instructor reserves the right to modify elements of the course during the term. There may be changes to the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given

with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

Course Schedule

BUS Q773 / CSE 776

Mathematical Programming: Theory and Algorithms

Winter 2024 Tentative Course Outline

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| --- | --- | --- | --- |
| Week | Date | Topic | Key Events |
| 1 | Jan. 10 | Introduction to Optimization  Convex Analysis |  |
| 2 | Jan. 17 | Generalized Convexity  Linear Programming: Theory |  |
| 3 | Jan. 24 | Linear Programming: Simplex Method | Term Paper Outline |
| 4 | Jan. 31 | Linear Programming: Duality, Sensitivity Analysis |  |
| 5 | Feb. 7 | Interior Point Methods  Optimality Conditions  General Duality | Assignment 1 |
| 6 | Feb. 14 | Lagrange Multipliers Theory  KKT Conditions |  |
| 7 | MID-TERM RECESS | | |
| 8 | Feb. 28 | NLP Optimization Methods | Assignment 2 |
| 9 | Mar. 6 | Modeling with Integer Variables  Integer Programming Methods  Nondifferentiable Optimizations |  |
| 10 | Mar. 13 | Midterm Exam |
| 11 | Mar. 20 | Large Scale Optimization  Decomposition Methods | Assignment 3 |
| 12 | Mar. 27 | Term Paper Draft |
| 13 | Apr. 3 | Term Paper Peer Review |
| 14 | Apr. 10 | Term Paper Presentations | Final Term Paper  Assignment 4 |