Business Q773 / ChE 756/ CSE 776
MATHEMATICAL PROGRAMMING: THEORY AND ALGORITHMS

Winter 2022 Course Outline

Operations Management Area
DeGroote School of Business
McMaster University

COURSE OBJECTIVE

- Understand and use optimisation principles such as optimality conditions, duality theory and computational complexity.
- Discuss different modelling approaches such as linear programming, integer programming and large scale optimization.
- Discuss different optimization techniques and solution methodologies such as simplex method, sensitivity analysis, branch and bound, Lagrange multipliers, Benders decomposition and heuristics.
- Implement the above techniques and models with GAMS and gain familiarity in using optimization solvers such as CPLEX.

INSTRUCTOR AND CONTACT INFORMATION

Dr. Elkafi Hassini

Instructor
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Office: DSB #414
Office Hours: By appointment
Tel: (905) 525-9140 x27467

Time and location: Mon 10:30-1:20 pm MDCL 1115

Course Website: http://avenue.mcmaster.ca/

COURSE DESCRIPTION

The course will cover topics in linear, integer and nonlinear programming. Concepts to be covered include convexity, duality, Karush-Kuhn-Tucker conditions, non-differentiable optimization, Branch and cut, and decomposition methods (Lagrangian, Bender's and Dantzig-Wolf). Software implementation issues will be highlighted via GAMS and its solvers.

LEARNING OUTCOMES

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

- Use optimisation models to solve business decision problems
- Create and solve optimisation models using an algebraic modeling language
- Analyse the convexity of an optimisation problem
- Develop algorithms and heuristics for optimisation problems

REFERENCES

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].
- P.E. Gill, W. Murray and M. Wright, *Practical Optimization* (Academic Press, New York, 1981) [QA402.5.G54 1981].
- **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].
- L.A. Wolsey, *Integer programming* (Wiley, New York, 1998) [T 57.74 .W67 1998]

SOFTWARE APPLICATIONS

GAMS: you can download a free demo version from www.gams.com. The full version can be used with a licence. More details will be provided later in the course.
You may also need to use Maple, Matlab or other computer programming languages depending on your prior experience.

EVALUATION

Components and Weights

Assignments	40%
Term paper	35%
Final Exam	25%
Total	100%

NOTE: The use of a McMaster standard calculator is allowed during examinations in this course. See McMaster calculator policy at the following URL:
www.mcmaster.ca/policy/Students-AcademicStudies/UndergraduateExaminationsPolicy.pdf

Conversion

At the end of the course your overall percentage grade will be converted to your letter grade in accordance with the following conversion scheme.

LETTER GRADE	PERCENT
A+	90 - 100
A	85 - 89
A-	80 - 84
B+	77 - 79
B	73 - 76
B-	70 - 72
F	00 - 69

Final Exam (25%, individual work)

A two hour in-class comprehensive exam. The exam is scheduled for April 25 at 10 am in GS 101.

Assignments (40%, individual work)

There will be four assignments: two theoretical and two computational. A late submission of assignments will be penalised at a rate of 5% per day.

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) perform research; (3) tailor part of the course to your own interests; (3) write a proposal and a final report (4) mimic the process of journal publication; and (5) present project findings.

In your project you are expected to investigate an optimisation technique and then code and test an algorithm that implements the technique. A topic choice has to be finalised 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 term
- First draft due during 8th week of term
- Peer review due 10th week of term
- Final report and presentation due last week of term.

The first draft will have the form of a progress report that 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 and a late submission of other project components will be penalised at a rate of 2% per day.

You are required to follow the guidelines on this website:
http://profs.degroote.mcmaster.ca/ads/hassini/Term_Paper_Guidelines.html
Consider them as the journal's authors guidelines and take them into account when writing your draft, peer review and final report).

ACADEMIC DISHONESTY

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.

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.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at:

www.mcmaster.ca/academicintegrity

The following illustrates only three forms of academic dishonesty:

1. Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. Improper collaboration in group work.
3. Copying or using unauthorized aids in tests and examinations

AUTHENTICITY/PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software.

All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

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* (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 behaviours 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.

MISSED ACADEMIC WORK

Late assignments will not be accepted. No extensions are available except under extraordinary circumstances. Please discuss any extenuating situation with your instructor at the earliest possible opportunity.

ACADEMIC ACCOMMODATION FOR STUDENTS WITH DISABILITIES

Student Accessibility Services (SAS) offers various support services for students with disabilities. Students are required to inform SAS of accommodation needs for course work at the outset of term. Students must forward a copy of such SAS accommodation to the instructor normally, within the first three (3) weeks of classes by setting up an appointment with the instructor. If a student with a disability chooses NOT to take advantage of an SAS accommodation and chooses to sit for a regular exam, a petition for relief may not be filed after the examination is complete. The SAS website is:

http://sas.mcmaster.ca

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 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.

POTENTIAL MODIFICATIONS TO THE COURSE

The instructor and university reserve the right to modify elements of the course during the term. The university may change 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.

ACKNOWLEDGEMENT OF COURSE POLICIES

Your registration and continuous participation (e.g. on A2L, in the classroom, etc.) to the various learning activities of MBA XXXX 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.

COURSE SCHEDULE

WEEK	TOPIC	KEY EVENTS
1	Introduction to optimisation Convex analysis	
2	Generalized convexity Linear Programming: Theory	
3	Linear Programming: Simplex Method	Term Paper Outline
4	Linear Programming: Duality, Sensitivity Analysis	
5	Interior Point Methods Optimality Conditions General Duality	Assignment 1
6	Lagrange Multipliers Theory KKT Conditions	
Family Day (February 21, 2021)		
7	NLP Optimisation Methods	Assignment 2
8	Modeling with Integer Variables Integer Programming Methods Nondifferentiable Optimisation	Term Paper Draft
9		
10	Large Scale Optimisation Decomposition Methods	Term Paper Peer Review
11		Assignment 3
12		
13		
14	Term Paper Presentations	Final Term Paper Assignment 4