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

Winter 2020 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, MINOS and BARON.

INSTRUCTOR AND CONTACT INFORMATION

Dr. Elkafi Hassini

Instructor
hassini@mcmaster.ca
Office: DSB #414
Office Hours: By appointment
Tel: (905) 525-9140 x27467

Time and location: Tue 2:00-5:00 pm DSB B106

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) [older edition: T 57.8 .B39 1979]**
- 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) [T 57.75 .M375 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 and/or Matlab 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:

http://www.mcmaster.ca/policy/Students-AcademicStudies/examinationindex.html

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.

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 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

It is the student's responsibility to understand what constitutes academic dishonesty. Please refer to the University Senate Academic Integrity Policy at the following URL:

http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf

This policy describes the responsibilities, procedures, and guidelines for students and faculty should a case of academic dishonesty arise. Academic dishonesty is defined as to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. Please refer to the policy for a list of examples. The policy also provides faculty with procedures to follow in cases of academic dishonesty as well as general guidelines for penalties. For further information related to the policy, please refer to the Office of Academic Integrity at:

http://www.mcmaster.ca/academicintegrity

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.

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.

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http://library.mcmaster.ca/about/copying.pdf

STUDENT ACCESSIBILITY SERVICES

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

COURSE SCHEDULE

WEEK	TOPIC	KEY EVENTS
1	Introduction to optimisation Convex analysis	
2	Generalized convexity Linear Programming: Simplex method	
3	Linear Programming: Duality, Sensitivity Analysis	Term Paper Outline Due
4	Interior Point Methods Optimality Conditions General Duality	Assignment 1
5	No Classes	
6	Lagrange Multipliers Theory KKT Conditions	
7	NLP Optimisation Methods	Assignment 2
8	Modeling with Integer Variables Integer Programming Methods Nondifferentiable Optimisation	Assignment 3
9		Paper Draft Due
10		
11	Large Scale Optimisation Decomposition Methods	Peer Review Due
12		
13		Paper Presentation + Report Assignment 4