

## AMSI Online: Honours and Masters Subject Guide

### Methods and Theory of Modern Optimisation

#### Semester One, 2026

#### Administration and contact details

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#### Subject details

<b>Handbook entry URL</b>	NA
<b>Subject homepage URL</b>	(will be on MoCaO website with password protection)
<b>Honours student hand-out URL</b>	On the MoCaO webpage
<b>Teaching period (start and end date):</b>	02/03/2026 to 31/05/2026
<b>Exam period (start and end date):</b>	25/05/2026 to 28/06/2026
<b>Contact hours per week:</b>	2 hours lectures + 1 hour online consultation
<b>ACE enrolment closure date:</b>	23/02/2026
<b>Lecture day(s) and time(s):</b>	(times TBA)
<b>Description of electronic access arrangements for students (for example, LMS)</b>	There will be a webpage hosted on the MoCaO website and a dropbox folder for access to files and for submission of assessment.

## Subject content

### 1. Subject content description

Nonlinear and convex optimisation has gained wide use in data mining and machine learning in recent years. This has spawned new research and renewed interest in the underlying mathematical foundations behind descent methods. The main tool of machine learning is stochastic gradient descent, which corresponds to a statistically unbiased approximation of a deterministic descent method and is used widely in regression and classification problems. Thus, a renewed interest in first order gradient-based convex optimisation has arisen out of the study of this and similar problems. The nonsmooth version arises in other problems found in Machine learning, such as the regularised risk minimisation with binary hinge loss. In the area of signal processing, similar nonsmooth problems are faced when recovering corrupted signals with sparse support (compressed sensing). Moreover, optimisation under uncertainty also draws its techniques from similar sources, with methods used to solve stochastic optimisation problems exploiting decomposition methods to create parallel programming approaches based on constrained convex optimisation, such as the so-called alternating direction method of multipliers (ADMM). Other feasibility methods based on projection-based methods also can be viewed as arising out of special cases of these general methods.

In the course we will take a modern view of the study of these and related problems, and the algorithms used to solve them. You will be introduced to the language of convex and nonsmooth optimisation, and shown how this powerful mathematical machinery allows one to analyse optimisation problems and develop algorithms for the solution of these problems. We will study the application of ADMM to various problem sets, including stochastic optimisation and feasibility problems. The ability to apply these techniques within the hyperspace of symmetric matrices allows the same methods to be applicable to a wider class of problems, and this aspect will also be explored.

Ultimately, we will look at the use of these techniques to some of the areas of application discussed above. Depending on the background of the student, scope is available in this course for projects involving theoretical work and/or more practical work involving the coding of methods.

### 2. Week-by-week topic overview

Week 1: Convexity Preserving Operations, inner product spaces, symmetric matrices and Frobenius norm.

Week 2: Supports, Separation, relative interior and Subdifferentiability

Week 3: Fenchel Conjugate, Fenchel duality and Application in Optimization

Week 4: Lagrangian Duality and Penalty methods

Week 5: Introduction to Positive Semi-Definite problems.

Week 6: Subgradient methods, Fast gradient methods and convergence

Week 7: The method of multipliers and alternating direction method of multipliers (ADMM).

Week 8: Using ADMM: Linear and Quadratic Programming Convex optimisation and Alternating Projections.

Week 9: Stochastic optimisation and versions of Progressive Hedging

Week 10: The Douglas–Rachford Algorithm and applications

Week 11: Applications of ADMM and duality in Machine Learning and Data science

Week 12: Inverse problems and Compressed sensing

### 3. Assumed prerequisite knowledge and capabilities

Necessary: Any under-graduate courses in real analysis, basic vector calculus and linear algebra.

Desirable: Familiarity with a computer programming language like Matlab, Julia, Python, etc.

### 4. Learning outcomes and objectives

On completion of this course student should have gained:

- Knowledge of advanced mathematical techniques in convex optimisation;
- The ability to reformulate problems and identify and/or develop numerical algorithms for the solution of these problems;
- Exposure to important classes of real world problems in areas like stochastic optimisation problems, machine learning and signal processing.

#### AQF specific Program Learning Outcomes and Learning Outcome Descriptors (if available):

AQF Program Learning Outcomes addressed in this subject	Associated AQF Learning Outcome Descriptors for this subject
Knowledge of advanced mathematical techniques in convex optimisation	K1 (knowledge)
The ability to reformulate problems and identify and/or develop numerical algorithms for the solution of these problems	S1 (Skills)
Exposure to important classes of real work problems in areas like machine learning and signal processing	S2 (Skills), A2 (Application of Skills)

## Learning Outcome Descriptors at AQF Level 8

### Knowledge

K1: coherent and advanced knowledge of the underlying principles and concepts in one or more disciplines

K2: knowledge of research principles and methods

### Skills

S1: cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problem with intellectual independence

S2: cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas

S3: cognitive skills to exercise critical thinking and judgement in developing new understanding

S4: technical skills to design and use in a research project

S5: communication skills to present clear and coherent exposition of knowledge and ideas to a variety of audiences

### Application of Knowledge and Skills

A1: with initiative and judgement in professional practice and/or scholarship

A2: to adapt knowledge and skills in diverse contexts

A3: with responsibility and accountability for own learning and practice and in collaboration with others within broad parameters

A4: to plan and execute project work and/or a piece of research and scholarship with some independence

## 5. Learning resources

Students will be provided with a full set of lecture notes that are typeset in Latex. Preferred computing platforms include Matlab or Python.

## 6. Assessment breakdown

Exam/assignment/classwork breakdown					
<b>Exam/End of year project</b>	40%	<b>Weekly Assignments</b>	60%		
<b>Assignment due dates</b>		<b>Weekly on weeks 2 to 12</b>		Click here to enter a date.	Click here to enter a date.
<b>Approximate exam date</b>			<b>Weeks 13 to 16</b>		

## Institution honours program details

<b>Weight of subject in total honours assessment at host department</b>	12.5%
<b>Thesis/subject split at host department</b>	25%thesis / 75% course work
<b>Honours grade ranges at host department</b>	
<b>H1</b>	80 - 100%
<b>H2a</b>	75 - 79%
<b>H2b</b>	70 - 79 %
<b>H3</b>	60 - 79%