UNSW Course Outline

MATH3161 Optimization - 2024

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General Course Information

Course Code : MATH3161
Year : 2024
Term : Term 1
Teaching Period : T1
Is a multi-term course? : No
Faculty : Faculty of Science
Academic Unit : School of Mathematics & Statistics
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Undergraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

This is an advanced level course in optimization for undergraduate students from all disciplines. Optimization is a field that develops techniques for finding the best possible choice from numerous available alternatives for a given criterion. It provides mathematical methods and numerical algorithms for solving decision-making problems in industry, commerce and scientific disciplines. Optimization methods are likely to have significant impact in many application areas of optimization, such as inventory management, energy distribution and medical treatment planning, by improving inventory controls or reducing the distribution costs or increasing the efficacy of medical treatments. Topics covered in this course include optimization modelling; convexity of sets and functions; unconstrained and constrained optimization problems; optimality and duality principles; numerical methods such as Newton, conjugate gradient and penalty methods; optimal control problems; differential equations; the Pontryagin Maximum Principle; autonomous control problems with fixed and free targets. This is a mathematics course using linear algebra, multi-variable calculus and differential equation techniques.

Course Aims

The main aim of this course is to provide the mathematical theory of multi-variable optimization and optimal control, and to provide students with the skills to formulate, solve and analyze solutions to certain multi-variable optimization problems and infinite dimensional optimal control problems.

Relationship to Other Courses

This course has a major focus on nonlinear continuous optimization problems, as distinct from linear optimization problems and discrete optimization problems which are covered in MATH3171, Linear and Discrete Optimization Modelling, in Term 3.

The lectures will be common with both MATH3161 and MATH5165 students. Students in the graduate version (MATH5165) are expected to display much more independence, working through all tutoril problems on their own.

Course Learning Outcomes

Course Learning Outcomes
CLO1 : State definitions and theorems in the syllabus and apply them to specific examples.
CLO2 : Apply the concepts and techniques of matrix algebra and multi-variable calculus to solve mathematical optimization problems.
CLO3 : Formulate, solve and analyze solutions to certain optimization problems.
CLO4 : Recognize and create valid optimization models and apply correct mathematical techniques.
CLO5 : Use technology as an aid to solve optimization models and communicate mathematical outcomes.

Course Learning Outcomes	Assessment Item
CLO1 : State definitions and theorems in the syllabus and apply them to specific examples.	• Class Test 1 • Class Test 2 • Assignment • Final Exam
CLO2 : Apply the concepts and techniques of matrix algebra and multi-variable calculus to solve mathematical optimization problems.	• Class Test 1 • Class Test 2 • Assignment • Final Exam
CLO3 : Formulate, solve and analyze solutions to certain optimization problems.	• Class Test 1 • Class Test 2 • Assignment • Final Exam
CLO4 : Recognize and create valid optimization models and apply correct mathematical techniques.	• Class Test 2 • Assignment • Final Exam
CLO5 : Use technology as an aid to solve optimization models and communicate mathematical outcomes.	• Assignment • Final Exam

Learning and Teaching Technologies

Moodle - Learning Management System

Learning and Teaching in this course

Students taking this course will develop an appreciation of the basic problems of optimization and skills to solve optimization problems.

By the end of the course students should be able to:

1. State definitions and theorems in the syllabus and apply them to specific examples.
2. Apply the concepts and techniques of the syllabus to solve appropriate mathematical problems.
3. Solve optimization problems via analytical, numerical and computational methods.
4. Recognize and create valid optimization models and apply correct mathematical techniques.
5. Use technology as an aid to solve optimization models and communicate mathematical outcomes.

Additional Course Information

The concept of optimization, finding the “best” way to do something, arises across all branches of mathematics and in application areas ranging from data science and engineering to finance and medicine. The purpose of this course is to introduce the theory of multi-variable optimization and optimal control, and to provide students with the skills to formulate, solve and analyse solutions to certain multi-variable optimization problems and infinite dimensional optimal control problems.

This course has a major focus on nonlinear continuous optimization problems, as distinct from linear optimization problems and discrete optimization problems which are covered in MATH3171, Linear and Discrete Optimization Modelling, in Term 3.

Course Overview

Optimization is an area of mathematics that directly deals with the problem of making the best possible choice from a set of numerous feasible choices. It seeks to understand how we achieve the best possible choice and how we can use this knowledge to improve management and technical decisions in science, engineering, and commerce. Thinking in terms of choices is common in our cognitive culture and searching for the best possible choice is a basic human desire. There are countless examples where we make optimal (best) choices in our daily lives, such as finding the fastest way to work, searching for the shortest line at the supermarket checkout or finding the cheapest mobile phone plans. Thus, models of optimization arise every day as management and technical decisions in many areas of human activity.

Problems of engineering design (such as the design of electronic circuits subject to a tolerancing and tuning provision), models of data science (such as the extraction of meaningful information from large databases and the classification of data), financial decision-making and investment planning (such as the selection of optimal investment portfolios), and transportation management and so on arise in the form of a multi-variable optimization problem or an optimal control problem.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Class Test 1 Assessment Format: Individual	15%	Start Date: 13/03/2024 02:00 PM Due Date: 13/03/2024 02:50 PM
Class Test 2 Assessment Format: Individual	20%	Start Date: 10/04/2024 02:00 PM Due Date: 10/04/2024 02:50 PM
Assignment Assessment Format: Individual	5%	Start Date: Not Applicable Due Date: Not Applicable
Final Exam Assessment Format: Individual	60%	Start Date: Not Applicable Due Date: Not Applicable

Assessment Details

Class Test 1

<u>**Assessment Overview**</u>

Class test 1 is designed to assess your mathematical background and knowledge of the topics covered in the course. Details of the class tests will be announced during lectures and will also be available through Moodle. The test is typically 45 minutes in length and held during Week 5.

Feedback will be given in the form of marks and comments from academic staff within 10 days of completing the test.

<u>**Course Learning Outcomes**</u>

- CLO1 : State definitions and theorems in the syllabus and apply them to specific examples.
- CLO2 : Apply the concepts and techniques of matrix algebra and multi-variable calculus to solve mathematical optimization problems.
- CLO3 : Formulate, solve and analyze solutions to certain optimization problems.

<u>**Detailed Assessment Description**</u>

Further details will be made available on Moodle.

<u>**Assessment Length**</u>

Not applicable

<u>**Submission notes**</u>

Hand-written submission only

Assessment information

Further details will be made available on Moodle.

Assignment submission Turnitin type

Not Applicable

Class Test 2

Assessment Overview

Class test 2 is designed to assess knowledge of topics covered in applying concepts and techniques and solving optimization problems via analytical and numerical methods.

Details of the class tests will be announced during lectures and will also be available on the course website through UNSW Moodle. The test is typically 45 minutes in length and held during Week 9.
Feedback will be given in the form of marks and comments from academic staff within 10 days of completing the test.

Course Learning Outcomes

- CLO1 : State definitions and theorems in the syllabus and apply them to specific examples.
- CLO2 : Apply the concepts and techniques of matrix algebra and multi-variable calculus to solve mathematical optimization problems.
- CLO3 : Formulate, solve and analyze solutions to certain optimization problems.
- CLO4 : Recognize and create valid optimization models and apply correct mathematical techniques.

Detailed Assessment Description

Further details will be made available on Moodle

Submission notes

Hand written submission only

Assessment information

Further details will be made available on Moodle.

Assignment submission Turnitin type

Not Applicable

Assignment

Assessment Overview

This task involves using the Matlab software package for implementing numerical optimization methods to model and solve practical optimization problems. You will submit a short written report summarising your answers.

Feedback will be given in the form of marks and comments from academic staff within 10 working days of submitting the task which is due in Week 10.

Course Learning Outcomes

- CLO1 : State definitions and theorems in the syllabus and apply them to specific examples.
- CLO2 : Apply the concepts and techniques of matrix algebra and multi-variable calculus to solve mathematical optimization problems.
- CLO3 : Formulate, solve and analyze solutions to certain optimization problems.
- CLO4 : Recognize and create valid optimization models and apply correct mathematical techniques.
- CLO5 : Use technology as an aid to solve optimization models and communicate mathematical outcomes.

Detailed Assessment Description

Assignment: It is an assignment to model practical optimization problems and write a short report. You will be expected to use the MATLAB software package for implementing numerical optimization methods to solve practical optimization problems. You are not required to know *MATLAB* before this course. On-line help on *MATLAB* will be available. It is not assumed that you have done computing subjects.

Students in the graduate version (MATH5165) are expected to complete additional work in the assignment

Further details will be made available on Moodle.

Assessment Length

Not applicable

Submission notes

Details will be available on Moodle.

Assessment information

Further details will be made available on Moodle.

Assignment submission Turnitin type

Not Applicable

Final Exam

Assessment Overview

The final exam is designed to summarize your learning and problem-solving skills on all topics delivered across the term, including material from lectures, tutorials and supplementary materials. The exam is typically 2hrs in duration. Details will be confirmed during the course. The examination will occur during the official university examination period.

Course Learning Outcomes

- CLO1 : State definitions and theorems in the syllabus and apply them to specific examples.
- CLO2 : Apply the concepts and techniques of matrix algebra and multi-variable calculus to solve mathematical optimization problems.
- CLO3 : Formulate, solve and analyze solutions to certain optimization problems.
- CLO4 : Recognize and create valid optimization models and apply correct mathematical techniques.
- CLO5 : Use technology as an aid to solve optimization models and communicate mathematical outcomes.

Detailed Assessment Description

Further details will be made available on Moodle.

Submission notes

Hand-written submission only

Assessment information

Further details will be made available on Moodle.

Assignment submission Turnitin type

Not Applicable

General Assessment Information

Details will be availabe on Moodle.

Grading Basis

Standard

Requirements to pass course

Achieve a composite mark of at least 50 out of 100

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 1 : 12 February - 18 February	Topic	Optimization- What is it? Modelling; standard form formulations, norms, existence, relaxation, gradients and Hessians; positive definite matrices.
Week 2 : 19 February - 25 February	Topic	Convexity of Sets and Functions: Convex stes, extreme points, convex combinations, convex functions, epigraphs, extrema of convex functions
Week 3 : 26 February - 3 March	Topic	Optimization: unconstrained & Equality constraints: First order optimality principles; Second-order optimality principles; necessary conditions; sufficient conditions; convexity and global optimality conditions, Equality constraints, regularity conditions, method of Lagrange multipliers; first-and second-order optimality conditions
Week 4 : 4 March - 10 March	Topic	Optimization: inequality constraints, global optimality and duality: KKT conditions; convex optimization; necessary and sufficient global optimality conditions; duality; right-hand side perturbations
Week 5 : 11 March - 17 March	Topic	Numerical Methods: Rates of convergence, iterative methods, descent methods, line search methods; steepest descent methods.
Week 6 : 18 March - 24 March	Topic	NONE
Week 7 : 25 March - 31 March	Topic	Newton and conjugate gradient methods: Basic Newton's methods, conjugate gradient methods
Week 8 : 1 April - 7 April	Topic	Penalty methods & introduction to optimal control: Penalty functions, penalty function methods for constrained optimization, optimal control models.
Week 9 : 8 April - 14 April	Topic	Optimal control problems & PMP: systems of differential equations; Pontryagin Maximum Principle (PMP)
Week 10 : 15 April - 21 April	Topic	Applications of PMP: Autonomous control problems with fixed targets, free time problems; Extension of PMP to problems with general targets; non-autonomous problems.

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

General Schedule Information

The course will include material taken from some of the following topics. This should only serve as a guide as it is not an extensive list of the material to be covered and the timings are approximate. The course content is ultimately defined by the material covered in lectures and provided in Moodle.

Course Resources

Prescribed Resources

Textbooks and Additional Resources and Support

There is **NO textbook** which covers all aspects of this course.

Tutorial Exercises and Videos

Problem sheets for tutorials will be provided via UNSW Moodle. These problems are for you to do to enhance mastery of the course.

SOME of the problems will be done in tutorials, but you will learn a lot more if you try to do them before the tutorial. Tutorial videos will demonstrate how hard tutorial problems are solved.

Lecture Notes and Mini-Lecture Videos

A set of skeleton notes and summary sheets containing only definitions, theorems and proofs will be provided for SOME components of the course on UNSW Moodle.

Mini-lecture videos will cover some background materials for the course and give proofs of key optimization theorems.

Sample test videos

Sample test videos will cover some past class test questions.

Calculators

You may bring your own UNSW approved Scientific Calculator to the class tests and the final exam.

Recommended Resources

The general references on optimization are listed below. The standard of the references is somewhat higher than is required in MATH3161/MATH5165.

Optimization References: General references on multi-variable optimization include [1, 2, 5, 11] and on optimal control include [9, 12]

Linear Algebra and Differential Equations: Solving multi-variable optimization problems requires techniques from linear algebra, whereas solving optimal control problems requires solution methods of differential equations. An elementary treatment of linear algebra can be found in Strang [14], while a reference for differential equations is Zill [15].

References

1. F.J. Aragon-Artacho, M.A. Goberna, M.A. Lopez, M.M.L. Rodriguez, Nonlinear Optimization, Springer, 2019.

2. A. Beck, Introduction to Nonlinear Optimization – Theory, Algorithms and Applications with MATLAB, MOS-SIAM Series on Optimization. SIAM, 2014.
3. D. P. Bertsekas Nonlinear programming: Second edition, Athena Scientific, Belmont, MA, 1999.
4. J. E. Dennis and R. B. Schnabel, Numerical Methods for Unconstrained Optimization and Nonlinear Equations, SIAM Publications, Classics in Applied Mathematics, 1996.
5. R. Fletcher, Practical Methods of Optimization, 2nd Edition, John Wiley, 2000.
6. P. E. Gill, W. Murray, and M. H. Wright, Practical Optimization, Academic Press, New York and London, 1981.
7. G. H. Golub and C. F. Van Loan, Matrix Computations, John Hopkins University Press, Baltimore and London, third ed., 1996.
8. J. B. Hiriart-Urruty and C. Lemarechal, Convex Analysis and Minimization Algorithms, Springer-Verlag, Berlin, 1993
9. L. M. Hocking, Optimal Control: An Introduction to the Theory with Applications, Oxford University Press, Oxford, 1991.
10. MathWorks, MATLAB & Simulink Student Version R2012A, Englewood Cliffs, 2012.
11. J. Nocedal and S. J. Wright, Numerical optimization, Springer, (2nd edition) 2006.
12. E. R. Pinch, Optimal control and the calculus of variations, Oxford University Press, Oxford, 1995.
13. R. Pratap, Getting started with MATLAB: A Quick Introduction for Scientists and Engineers, Oxford University Press, 2009.
14. G. Strang, Linear Algebra and its Applications, Harcourt Brace Jovanovich, San Diego, 3 ed., 1988.
15. D. G. Zill, Differential equations with boundary-value problems, Second Edition, PWS-Kent Publishing company, Boston, 1989.

Additional Costs

Not applicable

Course Evaluation and Development

Course Evaluation and Development (MyExperience)

Student feedback is very important to continual course improvement. This is demonstrated within the School of Mathematics and Statistics by the implementation of the UNSW online student survey *myExperience*, which allows students to evaluate their learning experiences in an anonymous way. *myExperience* survey reports are produced for each survey. They are released to staff after all student assessment results are finalised and released to students. Course convenor will use the feedback to make ongoing improvements to the course.

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Convenor	Jeya Jeyakumar		H13-E-2073	93857046	Deatila will be made available on Moodle	No	Yes

Other Useful Information

Academic Information

Upon your enrolment at UNSW, you share responsibility with us for maintaining a safe, harmonious and tolerant University environment.

You are required to:

- Comply with the University's conditions of enrolment.
- Act responsibly, ethically, safely and with integrity.
- Observe standards of equity and respect in dealing with every member of the UNSW community.
- Engage in lawful behaviour.
- Use and care for University resources in a responsible and appropriate manner.
- Maintain the University's reputation and good standing.

For more information, visit the UNSW Student Code of Conduct Website.

Academic Honesty and Plagarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.
Further information about referencing styles can be located at https://student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits: honesty, trust, fairness, respect, responsibility and courage. At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.
Further information about academic integrity, plagiarism and the use of AI in assessments can

be located at:

- The Current Students site,
- The ELISE training site, and
- The Use of AI for assessments site.

The Student Conduct and Integrity Unit provides further resources to assist you to understand your conduct obligations as a student: https://student.unsw.edu.au/conduct

Submission of Assessment Tasks

Penalty for Late Submissions

UNSW has a standard late submission penalty of:

- 5% per day,
- for all assessments where a penalty applies,
- capped at five days (120 hours) from the assessment deadline, after which a student cannot submit an assessment, and
- no permitted variation.

Any variations to the above will be explicitly stated in the Course Outline for a given course or assessment task.

Students are expected to manage their time to meet deadlines and to request extensions as early as possible before the deadline.

Special Consideration

If circumstances prevent you from attending/completing an assessment task, you must officially apply for special consideration, usually within 3 days of the sitting date/due date. You can apply by logging onto myUNSW and following the link in the My Student Profile Tab. Medical documentation or other documentation explaining your absence must be submitted with your application. Once your application has been assessed, you will be contacted via your student email address to be advised of the official outcome and any actions that need to be taken from there. For more information about special consideration, please visit: https://student.unsw.edu.au/special-consideration

Important note: UNSW has a "fit to sit/submit" rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit to do so and cannot later apply for Special Consideration. This is to ensure that if you feel unwell or are faced with significant circumstances beyond your control that affect your ability to study, you do not sit an examination or submit an assessment that does not reflect your best performance. Instead, you should apply for Special Consideration as soon as you realise you are not well enough or are otherwise unable to sit or submit an assessment.

Faculty-specific Information

Additional support for students

- The Current Students Gateway
- Student Support
- Academic Skills and Support
- Student Wellbeing, Health and Safety
- Equitable Learning Services
- UNSW IT Service Centre
- Science EDI Student Initiatives, Offerings and Guidelines

School-specific Information

School of Mathematics and Statistics and UNSW Policies

The School of Mathematics and Statistics has adopted a number of policies relating to enrolment, attendance, assessment, plagiarism, cheating, special consideration etc. These are in addition to the Policies of The University of New South Wales. Individual courses may also adopt other policies in addition to or replacing some of the School ones. These will be clearly notified in the Course Initial Handout and on the Course Home Pages on the Maths Stats web site. Students in courses run by the School of Mathematics and Statistics should be aware of the School and Course policies by reading the appropriate pages on the web site starting at: The School of Mathematics and Statistics assessment policies

The School of Mathematics and Statistics will assume that all its students have read and understood the School policies on the above pages and any individual course policies on the Course Initial Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

Special Consideration - Short Extension Policy

The School of Mathematics and Statistics has carefully reviewed its range of assignments and projects to determine their suitability for automatic short extensions as set out by the UNSW Short Extension Policy. Upon comprehensive examination of our course offerings that incorporate these types of assessments, we have concluded that our current deadline structures already accommodate the possibility of unexpected circumstances that may lead students to require additional days for submission. Consequently, the School of Mathematics and Statistics has decided to universally opt out of the Short Extension provision for all its courses, having pre-emptively integrated flexibility into our assessment deadlines. The decision is subject to revision in response to the introduction of new course offerings. Students may still apply for Special Consideration via the usual procedures.

Computing Lab

The main computing laboratory is room G012 of the Anita B.Lawrence Centre (formerly Red Centre). You can get to this lab by entering the building through the main entrance to the School of Mathematics (on the Mezzanine Level) and then going down the stairs to the Ground Level. A second smaller lab is Room M020, located on the mezzanine level through the glass door (and along the corridor) opposite the School's entrance.

For more information, including opening hours, see the computing facilities webpage. Remember that there will always be unscheduled periods when the computers are not working because of equipment problems and that this is not a valid excuse for not completing assessments on time.

School Contact Information

School Contact Information

Please visit the School of Mathematics and Statistics website for a range of information.

For information on Courses, please go to “Student life & resources” and either Undergraduate and/or Postgraduate and respective "Undergraduate courses" and "Postgraduate courses" for information on all course offerings.

All school policies, forms and help for students can be located by going to the "Student Services" within “Student life & resources” page. We also post notices in "Student noticeboard" for your information. Please familiarise yourself with the information found in these locations. If you cannot find the answer to your queries on the web you are welcome to contact the Student Services Office directly.

Undergraduate

E: ug.mathsstats@unsw.edu.au

P: 9385 7011 or 9385 7053

Postgraduate

E: pg.mathsstats@unsw.edu.au

P: 9385 7053

Should we need to contact you, we will use your official UNSW email address of in the first instance. **It is your responsibility to regularly check your university email account. Please use your UNSW student email and state your student number in all emails to us.**