Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year	AY2025-2026
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Chua Chek Beng
Course Author Email	cbchua@ntu.edu.sg
Course Title	MATHEMATICAL PROGRAMMING
Course Code	MH4701
Academic Units	4
Contact Hours	58
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	MH2100, MH3701 OR MH1803, MH3701
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This math elective course aims to introduce you to the basic nonlinear optimization models,and the theory and analysis of the algorithms commonly used to solve these models. With the knowledge and skills acquired from analysing standard algorithms for basic nonlinear optimization models, you will be able to extend your understanding and appreciation to other solution algorithms for more general nonlinear optimization models that you will encounter inyour professional work, in areas such as statistics, finance, artificial intelligence, logistics, healthcare, etc.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	State and prove necessary optimality conditions and sufficient optimality conditions for a) unconstrained optimization models, b) set-constrained optimization models, and c) constrained optimization models
ILO 2	State and prove the convergence of a) Newton's method, b) the steepest decent method, c) the Newton descent method, d) the conditional gradient method, e) the augmented Lagrangian method, and f) the barrier method.
ILO 3	Apply the above algorithms to solve basic nonlinear optimization models.
ILO 4	Analyse the convergence and convergence rates of the above algorithms when applied to basic nonlinear optimization models.

Course Content

One-dimensional optimization: sectioning methods, Newton's method.
Unconstrained optimization: optimality conditions, steepest descent method, Newton descent method.
Set-constrained optimization: optimality conditions, conditional gradient method
Constrained optimization: Lagrange multiplier theory, Karush-Kuhn-Tucker theory, augmented Lagrangian method, barrier method.

Reading and References (if applicable)

Dimitri P. Bertsekas, 'Nonlinear Programming', Second Edition (1999), Athena Scientific, ISBN1886529000

NOTE: The above reading comprises the foundational readings for the course and more up-to-date relevant readings will be provided when they are available.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Mathematical background and elementary convex analysis	1, 2	Lecture notes chapters 1 and 2	Online	In-class tutorial
2	Mathematical background and elementary convex analysis	1, 2	Lecture notes chapters 1 and 2	Online	In-class tutorial
3	Mathematical background and elementary convex analysis	1, 2	Lecture notes chapters 1 and 2	Online	In-class tutorial
4	One-dimensional and unconstrained optimization	1-4	Lecture notes chapters 3–6	Online	In-class tutorial
5	One-dimensional and unconstrained optimization	1-4	Lecture notes chapters 3–6	Online	In-class tutorial
6	One-dimensional and unconstrained optimization	1-4	Lecture notes chapters 3–6	Online	In-class tutorial
7	Set-constrained optimization	1-4	Lecture notes chapters 7 and 8	Online	In-class tutorial
8	Set-constrained optimization	1-4	Lecture notes chapters 7 and 8	Online	In-class tutorial Midterm test
9	Constrained optimization	1-4	Lecture notes chapters 9–12	Online	In-class tutorial
10	Constrained optimization	1-4	Lecture notes chapters 9–12	Online	In-class tutorial
11	Constrained optimization	1-4	Lecture notes chapters 9–12	Online	In-class tutorial

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
12	Constrained optimization	1-4	Lecture notes chapters 9–12	Online	In-class tutorial
13	Constrained optimization	1-4	Lecture notes chapters 9–12	Online	In-class tutorial

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Technology-enhanced Learning	The basic theories and solution techniques will be explained to you in the lectures. You will see illustrative examples which either motivate or reinforce your learning of the algorithms and theorems. The lectures, presented online as short video clips in LAMS, will be followed by short quizzes serving to reinforce your learning.
Tutorials	You will participate in problem-solving tutorial sessions, where problems are designed based on the theories and solution techniques that you should pick up in the lectures prior to each tutorial session. You are expected to complete the designated online LAMS lectures before the tutorial sessions, so that you are well-prepared to actively participate in the discussions. The tutor will facilitate the discussions in the tutorial sessions, guiding the class towards complete and acceptable solutions to the problems. The homework assignments provide a check on your level of mastery of the theories and solution techniques. You are encouraged to discuss the homework assignments with your classmates as a form of peer-to-peer learning. However, you are required to write up the solutions on your own in a clear and logical manner.
Laboratories	You will learn how to model real-world optimization problems as nonlinear programs, and solve instances of these models in the lab sessions. The optimization problem will be introduced, and the nonlinear programming model explained at the beginning of the lab session. You will then have hands-on experience in building a nonlinear programming model, and solve it using a solver of your choice.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Assignment(Homework 1)	2, 4		8	Take-home problem set in elementary convex analysis and one-dimensional optimization.	Individual	Analytic	Relational
2	Continuous Assessment (CA): Assignment(Homework 2)	1, 2, 3, 4		8	Take-home problem set in unconstrained and set-constrained optimization.	Individual	Analytic	Relational
3	Continuous Assessment (CA): Assignment(Homework 3)	1, 2, 3, 4		8	Take-home problem set in general constrained optimization.	Individual	Analytic	Relational
4	Continuous Assessment (CA): Test/Quiz(Midterm test)	1, 2, 3, 4		16	In-person written test on topics in elementary convex analysis, one-dimensional optimization, and unconstrained optimization.	Individual	Analytic	Extended Abstract
5	Summative Assessment (EXAM): Final exam(Final exam)	1, 2, 3, 4		60	In-person written examination on all topics in the course.	Individual	Holistic	Extended Abstract

Description of Assessment Components (if applicable)

Formative Feedback

Comments on your answers to the questions in your homework assignments and in-class testswill be written on your submissions and returned to you upon grading.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Communication	Intermediate
Digital Fluency	Intermediate
Learning Agility	Advanced
Problem Solving	Intermediate
Self-Management	Advanced

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

Students are expected to attend all lecture, tutorial, lab classes, and in-class tests punctually, and complete all scheduled homework assignments by the due dates. Students are expected to take responsibility to follow up with course notes, homework assignments, and course related announcements for assessments they have missed. Students are expected to prepare for and participate in all tutorial discussions and activities.

Policy (Absenteeism)

A missed test will be given a mark of zero, unless prior permission is given by the course coordinator, or a leave of absence is approved by the School. If you miss an in-class test, you must inform the course coordinator via email within 2 working days of the test.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.

You are required to complete all homework assignments by the due dates. Late submissions of homework assignments will draw late penalties.

Appendix 1: Assessment Rubrics

Rubric for Homework 1 (8%), Homework 2 (8%), Homework 3 (8%)

Grade	Description
A	The answer demonstrates full understanding of the problem and the solution process. All arguments are logical and presented with the appropriate use of English and mathematical symbols. The answer is completely correct.
B	The answer demonstrates traits found in the descriptions of both “A” and “C” grades.
C	The answer demonstrates some understanding of the problem and the solution process. Some arguments are logical and they are sometimes presented with the appropriate use of English and of mathematical symbols. The answer is partially correct.
D	The answer demonstrates traits found in the descriptions of both “C” and “F” grades.
F	The answer demonstrate no understanding of the problem or the solution process. Arguments are mostly not logical or they are presented with the inappropriate use of English and of mathematical symbols. The answer is completely incorrect.

Rubric for Mid-term test (16%)

Grade	Description
A	The answer demonstrates full understanding of the problem and the solution process. All arguments are logical and presented with the appropriate use of English and mathematical symbols. The answer is completely correct.
B	The answer demonstrates traits found in the descriptions of both “A” and “C” grades.
C	The answer demonstrates some understanding of the problem and the solution process. Some arguments are logical and they are sometimes presented with the appropriate use of English and of mathematical symbols. The answer is partially correct.
D	The answer demonstrates traits found in the descriptions of both “C” and “F” grades.
F	The answer demonstrate no understanding of the problem or the solution process. Arguments are mostly not logical or they are presented with the inappropriate use of English and of mathematical symbols. The answer is completely incorrect.

Rubric for Examination (60%)

Grade	Description
A	The answer demonstrates full understanding of the problem and the solution process. All arguments are logical and presented with the appropriate use of English and mathematical symbols. The answer is completely correct.
B	The answer demonstrates traits found in the descriptions of both “A” and “C” grades.

C	The answer demonstrates some understanding of the problem and the solution process. Some arguments are logical and they are sometimes presented with the appropriate use of English and of mathematical symbols. The answer is partially correct.
D	The answer demonstrates traits found in the descriptions of both “C” and “F” grades.
F	The answer demonstrate no understanding of the problem or the solution process. Arguments are mostly not logical or they are presented with the inappropriate use of English and of mathematical symbols. The answer is completely incorrect.