City University of Hong Kong
Course Syllabus

offered by School of Data Science
with effect from Semester A 2021/22

Part I Course Overview

Course Title:	**Convex Optimization**
Course Code:	**SDSC2002**
Course Duration:	**One Semester**
Credit Units:	**3**
Level:	**B2**
Proposed Area: *(for GE courses only)*	☐ Arts and Humanities ☐ Study of Societies, Social and Business Organisations ☐ Science and Technology
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**MA1503 Linear Algebra with Applications or MA2503 Linear Algebra and MA2508 Multi-variable Calculus**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**Nil**
Exclusive Courses: *(Course Code and Title)*	**Nil**

Part II Course Details

1. Abstract

(A 150-word description about the course)

This is a fundamental and introductory course on optimization theory and introduces basic concepts, theories and methods of optimization techinques. It emphasizes the fundamental theories of important optimization algorithms with a focus on applications to data science. It also equips students with computing algorithms and techniques of applying taught methods to solve practical problems.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs#	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Explain clearly basic concepts of convex optimzation.	10%	√		
2.	Solve problems of convex optimization with fundamental methods by characterizing and identifying the properties of the solutions.	25%	√	√	
3.	Explain and apply the math theories of convex optimization without or with constraints.	25%	√	√	
4.	Explain the derivation and development of classic modern optimization algorithms and be familiar with distinctive properties of different methods;	20%		√	√
5.	Apply mathematical and computational methods of optimization to solving real-life problems in context of data science and machine learning.	20%		√	√
	** If weighting is assigned to CILOs, they should add up to 100%.*	100%			

 # Please specify the alignment of CILOs to the Gateway Education Programme Intended Learning outcomes (PILOs) in Section A of Annex.

A1: *Attitude*
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: *Ability*
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to self-life problems.

A3: *Accomplishments*
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

3. Teaching and Learning Activities (TLAs)

(TLAs designed to facilitate students' achievement of the CILOs.)

TLA	Brief Description	CILO No.					Hours/week (if applicable)
		1	2	3	4	5	
Lecture	Learning through **teaching** is primarily based on lectures.	√	√	√	√	√	39 hours in total
Take-home assignments	Learning through **take-home assignments** helps students understand techniques of basic methods in as well as their applications in solving optimization problems.	√	√	√	√		after-class
Online applications	Learning through **online examples for applications** helps students create and formulate mathematical models and apply to a range of practical problems in economics/science.				√		after-class

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.					Weighting*	Remarks
	1	2	3	4	5		
Continuous Assessment: 40%							
Test and quiz	√	√	√			30%	Questions are designed for the part of the course to see how well the students have learned basic concepts of methods in convex optimization and recognized their applications in solving optimization problems.
Hand-in assignments	√	√	√	√	√	10%	These are skills based assessment to enable students to demonstrate the understanding of theories and the ability of applying optimization methods in a diversity of problems.
Formative take-home assignments		√	√	√	√	0%	The assignments provide students chances to demonstrate their achievements on techniques of optimization learned in this course.
Examination: 60% (duration: 2 hours)							
Examination	√	√	√	√	√	60%	
The weightings should add up to 100%.						100%	

For a student to pass the course, at least 30% of the maximum mark for the examination must be obtained.

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Test and quiz	Ability to understand the basic concepts of methods in convex optimization and recognize their applications in solving optimization problems	High	Significant	Moderate	Basic	Not even reaching marginal levels
2. Hand-in assignments	Ability to apply the techniques of optimization methods in a diversity of problems	High	Significant	Moderate	Basic	Not even reaching marginal levels
3. Examination	Ability to solve optimization problems with fundamental methods in optimization.	High	Significant	Moderate	Basic	Not even reaching marginal levels
4. Formative take-home assignments	Ability to demonstrate students' achievements on techniques of optimization learned in this course	High	Significant	Moderate	Basic	Not even reaching marginal levels

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

(An indication of the key topics of the course.)

- Review of elementary theory of (univariate and multivariate) functions, gradient, Hessian matrix, Taylor expansion and basics of numerical linear algebra (quadratic form, positive definite matrix, L_p norms);
- Definitions and elementary properties of convex set and convex/concave function; strict convexity and strong convexity, examples of convex functions and log-convex functions;
- Concepts in optimization theory: critical points, saddle points, local minima and global minima; local optimization and global optimization; convex/non-convex problem; constrained/unconstrained optimization;
- Recognize a local minimum: first/second order necessary/sufficient condition for optimality; properties of solution to convex problem;
- Examples of convex optimization problems: Least square problem in linear regression; loss function of logistic regression;
- Nonlinear programming algorithms: (1) gradient descent method; (2) Newton's method; (3) conjugate gradient method;
- Theory of convex optimization with (equality/inequality) constraints: feasible set, feasible direction, KKT conditions, KKT multiplier, Lagrangian multiplier, Lagrangian function;
- Nonlinear programming algorithms with constraints: log barrier method, penalty method; method of Lagrangian multiplier;
- Introductory use of one software for optimization (scipy. optimize or cvxpy).

2. Reading List

2.1. Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

1.	Lecture notes provided by the instructor

2.2. Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

1.	"Convex Optimization", by Stephen Boyd and Lieven Vandenberghe, Cambridge University Press, 2004
2.	Paul R. Thie, "An Introduction to Linear Programming and Game Theory", John Wiley & Sons, 1988.