MA6635: MATHEMATICAL FOUNDATIONS OF DATA SCIENCE

Effective Term
Semester A 2025/26

Part I Course Overview

Course Title
Mathematical Foundations of Data Science

Subject Code
MA - Mathematics
Course Number
6635

Academic Unit
Mathematics (MA)

College/School
College of Science (SI)

Course Duration
One Semester

Credit Units
3

Level
P5, P6 - Postgraduate Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Nil

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
Nil

Part II Course Details

Abstract

This course introduces the mathematical foundations of data science and the related extension to machine learning. It helps to equip students with the basic concepts, mathematical knowledge, and algorithm tools for understanding and extract usable information from massive data. This course also emphasizes the methodology of using data science to solve challenges in science and engineering.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Explain the basic math and probability foundations, and related models and concepts in data science and learning theory.	20	x	x	
2	Derive the statistical and mathematical models and their properties used in data science and analytics.	25	x	x	
3	Explain the fundamental principles, modellings of numerical algorithms like optimization used in machine learning.	20	x	x	x
4	Write computer programming codes to implement, illustrate, and apply to benchmark datasets and real problems.	25	x	x	
5	Investigate and explore the selective emerging topics in the modern data science.	10		x	x

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 real-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.

Learning and Teaching Activities (LTAs)

	LTAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Students learn the primary knowledge through the lectures.	1, 2, 3, 4, 5	3 hours/week
2	Assignments	Students review the basic concepts and implement advanced theory for better understanding through take-home assignments.	1, 2, 3, 4	after-class

3	Tutorials	Students apply the foundation knowledge and skills to specific examples and real problems in this course.	2, 3, 4, 5	in-class

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Hand-in assignments	1, 2, 3, 4, 5	30	-	Yes
2	Tests	2, 3, 4	30	-	No

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

1

Minimum Examination Passing Requirement (%)

30

Additional Information for ATs

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

Assessment Rubrics (AR)

Assessment Task

1. Hand-in assignments (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

1.1 Demonstration of the understanding of the basic materials

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the foundation of the data science and has strong ability to apply to applications and problems in data science

Good

(B+, B, B-) Adequately demonstrate a good understanding of the foundation of the data science and has good ability to apply to applications and problems in data science

Fair

(C+, C, C-) Demonstrate some understanding of the foundation of the data science and has moderate ability to apply to applications and problems in data science

Marginal

(D) Demonstrates limited understanding thorough understanding of the foundation of the data science and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

1. Hand-in assignments (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

1.2 Ability to build and implement appropriate algorithms to data science problems.

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the mechanism of models and algorithms and has strong ability to apply to applications and problems in data science

Good

(B+, B, B-) Adequately demonstrate a good understanding of the mechanism of models and algorithms and has good ability to apply to applications and problems in data science

Fair

(C+, C, C-) Demonstrate some understanding of the mechanism of models and algorithms and has moderate ability to apply to applications and problems in data science

Marginal

(D) Demonstrate limited understanding of the mechanism of models and algorithms and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

1. Hand-in assignments (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

1.3 Ability to model, implement and analyse the results of specific applications by a rational approach with critical thinking

Excellent

(A+, A, A-) Consistently demonstrate a strong ability to model, implement and analyse various application problems in data science

Good

(B+, B, B-) Adequately demonstrate a good ability to model, implement and analyse various application problems in data science

Fair

(C+, C, C-) Demonstrate a satisfactory ability to model, implement and analyse various application problems in data science

Marginal

(D) Demonstrate a limited ability to model, implement and analyse various application problems in data science

Failure

(F) Demonstrates weak ability to model, implement and analyse various application problems in data science

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Assessment Task

2. Tests (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Demonstration of the understanding of basic theoretic knowledge

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the foundation of the data science and has strong ability to apply to applications and problems in data science

Good

(B+, B, B-) Adequately demonstrate a good understanding of the foundation of the data science and has good ability to apply to applications and problems in data science

Fair

(C+, C, C-) Demonstrate some understanding of the foundation of the data science and has moderate ability to apply to applications and problems in data science

Marginal

(D) Demonstrates limited understanding thorough understanding of the foundation of the data science and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

3. Examinations (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Understanding of the fundamental concepts, principles, and their application scenarios

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the foundation of the data science and has strong ability to apply to applications and problems in data science

Good

(B+, B, B-) Adequately demonstrate a good understanding of the foundation of the data science and has good ability to apply to applications and problems in data science

Fair

(C+, C, C-) Demonstrate some understanding of the foundation of the data science and has moderate ability to apply to applications and problems in data science

Marginal

(D) Demonstrates limited understanding thorough understanding of the foundation of the data science and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

1. Hand-in assignments (Applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

1.1 Demonstration of the understanding of the basic materials

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the foundation of the data science and has strong ability to apply to applications and problems in data science

Good

(B+, B) Adequately demonstrate a good understanding of the foundation of the data science and has good ability to apply to applications and problems in data science

Marginal

(B-, C+, C) Demonstrates limited understanding thorough understanding of the foundation of the data science and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

1. Hand-in assignments (Applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

1.2 Ability to build and implement appropriate algorithms to data science problems

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the mechanism of models and algorithms and has strong ability to apply to applications and problems in data science

Good

(B+, B) Adequately demonstrate a good understanding of the mechanism of models and algorithms and has good ability to apply to applications and problems in data science

Marginal

(B-, C+, C) Demonstrate limited understanding of the mechanism of models and algorithms and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

1. Hand-in assignments (Applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

1.3 Ability to model, implement and analyse the results of specific applications by a rational approach with critical thinking

Excellent

(A+, A, A-) Consistently demonstrate a strong ability to model, implement and analyse various application problems in data science

Good

(B+, B) Adequately demonstrate a good ability to model, implement and analyse various application problems in data science

Marginal

(B-, C+, C) Demonstrate a limited ability to model, implement and analyse various application problems in data science

Failure

(F) Demonstrates weak ability to model, implement and analyse various application problems in data science

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Assessment Task

2. Tests (Applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

Demonstration of the understanding of basic theoretic knowledge

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the foundation of the data science and has strong ability to apply to applications and problems in data science

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(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Assessment Task

3. Examinations (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Understanding of the fundamental concepts, principles, and their application scenarios.

Excellent

(A+, A, A-) Consistently demonstrate a thorough understanding of the foundation of the data science and has strong ability to apply to applications and problems in data science

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(B+, B) Adequately demonstrate a good understanding of the foundation of the data science and has good ability to apply to applications and problems in data science

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(B-, C+, C) Demonstrates limited understanding thorough understanding of the foundation of the data science and has satisfactory ability to apply to applications and problems in data science

Failure

(F) Demonstrates little understanding of the foundation of the data science and has weak ability to apply to applications and problems in data science

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Part III Other Information

Keyword Syllabus

probability distribution for data science; basic linear algebra foundation for data science; elementary statistical knowledge for data science; elementary optimization and programming for data science.

decision theory; empirical risk minimization; supervised learning; unsupervised learning; classification, simple linear regression; clustering; measure of prediction performance; approximation error; estimation error; model complexity; regularization; model selection; Gaussian process regression, PCA, dimensionality reduction; optimization for machine learning; stochastic gradient descent; neural network, reproducible kernel Hilbert space; probabilistic methods; discriminative models; generative models

Reading List

Compulsory Readings

	Title
1	Course materials provided

Additional Readings

	Title
1	Foundations of Data Science by Avrim Blum, John Hopcroft, and Ravindran Kannan , 2020
2	Learning Theory from First Principles by Francis Bach, 2022
3	Understanding Deep Learning by Simon J.D. Prince, 2023