Course Description Form

1. Course Name:
Mathematical Methods for Computer Science
2. Course Code:
3. Semester / Year:
First Semester / PhD
4. Description Preparation Date:
1/9/2025
5. Available Attendance Forms:
Attendance Mandatory
6. Number of Credit Hours (Total) / Number of Units (Total)
30 Hours (2 hours theoretical * 15 Weeks) / 2 Units
7. Course administrator's name (mention all, if more than one name)
Name: Assist. Prof. Dr. Zainab Namh Abdula Email: zainab.namhabdula@nahrainuniv.edu.iq
8. Course Objectives

Course Objectives	This course provides PhD students with a mathematical foundation for advanced topics in computer science. It focuses on linear systems, vector spaces, and algebraic structures, enabling students to analyze and solve linear equations using matrix-based methods. The course covers eigenvalues, eigenvectors, and matrix decompositions such as SVD for high-dimensional data analysis, along with approximation techniques including least-squares and orthogonal projections. It also extends linear algebra concepts to infinite-dimensional spaces and Fourier analysis, highlighting their applications in areas such as machine learning, data science and signal processing.

9. Teaching and Learning Strategies	
Strategy	Lectures Seminars Frequent Quizzes HomeWorks

10. Course Structure

Week	Hours	Required Learning Outcomes	Unit or subject name	Learning method	Evaluation method
W1	2	Students will be able to identify sets, relations, and functions, and define Group properties to establish the algebraic foundation for vector spaces	**Foundations and Linear Systems** Mathematical Preliminaries & Algebraic Structures **Sets and Logic:** Numbers, Sets, Relations, and Functions. **Algebraic Structures:** Introduction to Groups. **Abelian Groups:** Definition and properties (contextualizing Vector Spaces). **Introduction to Linear Algebra:** Overview of the field.	Lecture Slides	Oral Questions
W2	2	Students will be able to compute matrix inverses and determinants to classify linear systems as homogeneous or non-homogeneous	**Systems of Linear Equations** Homogeneous vs. Non-Homogeneous Systems. Matrix operations (Addition, Multiplication, Transpose). Matrix Inverses and properties. Determinants**:** Calculation and properties.	Lecture Slides	Oral Questions Homework
W3	2	Students will be able to encode row operations (swapping, scaling, elimination) into elementary matrices for computational manipulation	**Solving System of Linear Equations** Encoding Row Operations Permutation Row Scaling Elimination.	Lecture Slides	Oral Questions
W4	2	Students will be able to apply Gaussian Elimination to convert matrices into RREF and analyze the rank to determine solution existence.	**Gaussian Elimination:** The full algorithmic process. **Echelon Forms:** Row Echelon Form (REF). Reduced Row Echelon Form (RREF). **Rank:** Analyzing solution sets based on pivots.	Lecture Slides	Oral Questions Quiz
W5	2	Students will be able to determine the Linear Independence, Span, Basis, and Dimension of a given Vector Space.	**Vector Spaces** **The Vector Space Definition:** Axioms and examples. **Structure:** Linear Combinations and Span. **Linear Independence:** Concepts and testing.	Lecture Slides	Oral Questions

Week	Hours	Required Learning Outcomes	Unit or subject name	Learning method	Evaluation method
			Basis and Dimension: Determining the basis and rank of a space.		
W6	2	Students will be able to calculate norms, inner products, and angles to determine distance and orthogonality in Euclidean space.	**Analytic Geometry (Euclidean Space)** **Standard Norms:** Vector lengths and distances. **Inner Products:** Dot products in R^n **Geometry:** Angles between vectors. **Orthogonality:** Perpendicular vectors and orthogonal sets.	Lecture Slides	Oral Questions and Homework
W7	2	Mid			
W8	2	Students will be able to construct the characteristic polynomial to compute the Eigenvalues and Eigenvectors of a square matrix.	**Eigenvalues and Eigenvectors** **The Trace:** Definition and properties. **Characteristic Polynomial:** Deriving the polynomial from determinants. **Eigen-theory:** Calculating Eigenvalues and Eigenvectors.	Lecture Slides	Oral Questions
W9	2	Students will be able to diagonalize matrices	**Matrix Decomposition I** **Eigendecomposition:** A = PDP^-1. **Diagonalization:** Conditions for diagonalizability. **Symmetric Matrices:** Spectral Theorem for symmetric matrices.	Lecture Slides and Worked Examples	Quiz
W10	2	Students will be able to compute the Singular Value Decomposition for rectangular matrices and interpret its use in data compression and recommender systems	**Matrix Decomposition II (SVD)** **Singular Value Decomposition (SVD):** Concept and calculation. **Applications of SVD:** Low-rank approximation and data compression. **Relationship to Eigenvalues:** A^TA and AA^T.		
W11	2	Students will be able to formulate the Normal Equations to solve Least Squares problems using Orthogonal	**Projections and Approximations** **Orthogonal Projections:** Projecting vectors onto subspaces. **The Normal Equations:**	Lecture Slides and Worked Examples	Oral Questions

Week	Hours	Required Learning Outcomes	Unit or subject name	Learning method	Evaluation method
		Projections	Structure and derivation (A^TAx = A^Tb). **Least Squares:** Solving unsolvable systems.		
W12	2	Students will be able to evaluate system sensitivity using matrix norms and extend vector concepts to infinite-dimensional Hilbert spaces.	**Sensitivity Analysis** - Matrix & Vector Norms Infinite Dimensional Spaces **Function Spaces:** Inner products of functions. **Hilbert Space:** Introduction to complete inner product spaces. **Orthogonality in Function Spaces:** Orthogonal polynomials.	Lecture Slides and Worked Examples	Oral Questions
W13+14	4	Students will be able to apply Fourier Series and Transforms to convert functions between the time/space domain and the frequency domain.	**The Laplacian Operator:** Definition in R^n (Divergence of Gradient). **Eigenfunctions** **Fourier Analysis** **Fourier Series:** Decomposition of periodic functions. **Fourier Transform:** Transformation from time/space domain to frequency domain.	Lecture Slides and Worked Examples	Oral Questions
W15	2		Seminars		

11.Course Evaluation

Assessment Type	Marks
Homework	5
Attendance	5
Mid Exam	20
Final Exam	70
Total	100

12.Learning and Teaching Resources

Required textbooks (curricular books, if any)	Linear Algebra for Computer Vision, Robotics, and Machine Learning. University of Pennsylvania. Gallier, J., & Quaintance, J. (2025). *Mathematics for Machine Learning*. Cambridge University Press. Deisenroth, M. P., Faisal, A. A., & Ong, C. S. (2020). Numerical Algorithms Methods for Computer Vision, Machine Learning, and Graphics. Justin Solomon. CRC Press Taylor and Francis Group. Solomon, J. (2015). *Mathematical Methods: Lecture Notes*. Department of Computing, Imperial College London. Deisenroth, M., & Cheraghchi, M. (2016).

Main references (sources)	
Recommended books and references (scientific journals, reports...)	
Electronic References, Websites	