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 1
Course Author * Faculty proposing/revising the course	Gu Mile
Course Author Email	gumile@ntu.edu.sg
Course Title	Linear Algebra for Scientists
Course Code	MH2802
Academic Units	3
Contact Hours	38
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	H2 maths or equivalent
Co-requisites	Nil
Pre-requisite to	
Mutually exclusive to	CE1104/CZ1104/SC1004 Linear Algebra for Computing, MH1200 Linear Algebra, MH1201 Linear Algebra , CY1602/RE1021 Mathematics II
Replacement course to	NA
Remarks (if any)	Nil

Course Aims

This course aims to support you in acquiring a wider range of mathematical concepts related to vector spaces and linear algebra, while also developing a strong set of mathematical skills for upper-level Physical, Computing and Data Science courses. Through a mathematical approach to problem-solving, you will have the opportunity to develop thinking, reasoning, communication, and modelling skills. Additionally, the course aims to help you connect ideas within mathematics and apply mathematical principles in the context of physics, computing and data science, with special emphasis on recent technological advances (e.g. machine learning, quantum computing). Ultimately, this course seeks to foster an appreciation for the rigour and abstraction in the discipline.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Basic Vector Operations (BAS) perform simple vector operations (such as vector addition, subtraction and resolving a vector to its components in a given coordinate system) to solve related problems; perform scalar, vector products whenever appropriate to solve related problems (such as determining the projection of a vector on another and calculating the torque of a system of forces); perform scalar, vector triple products whenever appropriate to solve related problems; solve basic problems in analytical geometry using vectors (such as determining distances between point and a line / plane);
ILO 2	Linear Spaces (LS) recall and use the axioms of a linear space to determine if a given set forms a linear space; apply the idea of linear independence to determine whether a given set of vectors is dependent or independent; explain the idea of the space / subspace is spanned by a given set of (basis) vectors and determine if a set of (basis) vectors span a subspace; apply the concepts of norms and inner products to compute for a given pair of vectors and to test if a given pair of vectors are orthogonal;
ILO 3	Linear Transformation and Matrices (LTM) explain the concept of linear transformation, express a linear transformation as a matrix and compute the action of a linear transformation on a vector and a matrix (including the structures of rotation, reflection, scaling, stretching and shearing matrices); perform basic operations on matrices (including basic algebraic operations, matrix multiplication, computing of inverses, determinants and traces of matrices); solve systems of linear equations using techniques such as Gaussian elimination; compute the eigenvalues, eigenvectors of a given square matrix and determine the similarity transformation that diagonalizes the given square matrix; recall the definitions and use the properties of special matrices (such as Hermitian and unitary matrices); and
ILO 4	Applications (APP) Apply the techniques from ILO 1 – 13 to solve problems in Physical, Computing and Data Science (e.g. Quantum mechanics, Principal Component Analysis), including associated mathematical techniques (e.g, Matrix Exponention)

Course Content

1. Vector Algebra & Analytical Geometry
2. Linear Spaces
3. Linear Transformations & Matrices
4. Eigenvalues and Eigenvectors
5. Applications of Linear Algebra to Problems in Physical and Computing Science

Reading and References (if applicable)

1. David C. Lay, Steven R. Lay, Judi J. McDonald, Linear Algebra and Its Applications, Global Edition (6th edition, Pearson 2021. ISBN-13: 978129351216

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Vector algebra and Vector products	1	Gu Linear Algebra Lecture Notes: Chapter 1	In-person	Learning: 1. How to add, subject and multiply vectors by a scaler. 2. How to compute the norm and normalize a vector. 3. How to write down a vector in standard notation when given its direction and magnitude. 4. Various notations for basis vectors. 5. How to cast questions about velocities or displacements in terms of vector equations.

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
2	Linear Transforms	3	Gu Linear Algebra Lecture Notes: Chapter 2	In-person	Learning: 1. Use the definition of linearity to test if a transform T is linear. 2. Work out the transformation matrix A of a transform T by examining its action on unit vectors. 3. Use the transformation matrix A to compute how it transforms a general v via matrix multiplication. 4. Work out the transformation matrices for simple geometric transformations and projections. 5. How to compute the Transpose of a matrix
3	Basic Matrix Algebra	3	Gu Linear Algebra Lecture Notes: Chapter 3	In-person	Learning: 1. How to add, subtract and multiply matrices by a scaler. 2. How to multiply two matrices and what it means in terms of transform composition. 3. The operational relationship between A inverse and A. 4. How to invert 2 × 2 matrices.

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
4	Matrix Inverse and Linear Equations	3	Gu. Linear Algebera Lecture Notes, Chapter 4	In-person	Learning: 1. How to solve systems of linear equations using row reduction. 2. How to identify if a system of equations has no or many solutions. 3. How to identify whether a matrix is in Echelon or Gauss-Jordan Reduced forms. 4. How to invert a matrix by row reduction
5	Matrix Determinants	2	Gu, Linear Algebra Lecture Notes, Chapter 5	In-person	Learning: 1. What the determinant represents in terms of volume scaling. 2. How the determinant transforms under elementary row operations and why. 3. How to express the elementary row operations as matrix multiplication. 4. How to compute the determinant through co-factor expansion and row-reduction. 5. How the determinant relates to matrix invertability.

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
6	Vector Subspaces, Linear Independence, Null Spaces and the Invertible Matrix Theorem	2	Gu, Lecture Notes in Linear Algebra, Chapter 6	In-person	Learning: 1.How to determine if a given subset of Rn is a vector subspace. 2. How to find the Null Space of a Matrix. 3. How to determine if a set of vectors is linearly independent 4. How Linear Independence and Null Spaces relate to matrix invertibility. 5. How to use the invertible matrix theorem to find shortcuts in determining invertibility
7	Selected Applications of Matrix Algebra	4	Nil	In-person	- Conduct Mid-Term Test, including use-case study - Learning use-case study tested.

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
8	Coordinate Transforms	3	Gu, Lectures Notes in Linear Algebra Chapter 8	In-person	Learning: 1. How to convert a vector from the standard basis to a general basis and back. 2. How to determine the characteristic equation, and use it to find the eigenvalues of a matrix. 3. How to determine the eigenspace and eigenvectors associated with each eigenvalue of a matrix. 4. The geometric meaning of Eigenvalues and Eigenvectors
9	Matrix Diagonalisation, Eigenvectors and Eigenvalues	3	Gu, Lectures notes in Linear Algebra, Chapter 9	In-person	Learning: 1. How to Diagonalise the Matrix 2. Non-uniqueness of Matrix Diagonalization 3. How to deal with complex and degenerate eigenvalues. 4. How to check if a matrix is diagonalizable.

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
10	Applications of Matrix Diagonalisation	4	Gu, Lectures notes for Linear Algebra, Chapter 10	In-person	Learning: 1. How to use Diagonalisation for compute Matrix Powers and Matrix Exponentials. 2. How to use Matrix Powers to Solve Recurrence Relations. 3. How to use Matrix Exponentials to Solve Differential Equations. 4. How to analyse the long-term behaviours of Matrix Powers and Matrix Exponentials
11	Special Matrices	3	Gu, Lectures Notes in Linear Algebra, Chapter 11	In-person	Learning: 1. How to check if a basis is orthonormal 2. How to check if a matrix is orthogonal and their special properties 3. How to compute the inner product and use them to write down the form of a vector in an orthogonal/ orthornormal basis.

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
12	Abstract Vector Spaces	2	Gu, Lectures notes on Linear Algebra, Chapter 12	In-person	Learning: 1. Understand the definitions of an abstract vector spaces and functions spaces. 2. How to find the matrix form of a simple functionals with respect to some basis on a subspace of function space. 3. How to use this matrix form to identify associated eigenvalues and eigenfunctions of a functional.
13	Applications in Physics and Computer Science	4	Gu, Lectures notes in Linear Algebra, Chapter 13	In-person	Learning: Tackle in-class questions on selected topics in physics and computer science (e.g. solving Schrodinger's Equation, Principal Component Analysis)

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Derivation of formulas and demonstrating problem solving (Lecture and Tutorial)	Train students to be independent learners who are able to derive ideas/concepts from first principles and take ownership of their own learning. Help students understand the motivation behind mathematical theorems, definitions and formulas. Develop the train of thought in problem solving and presentation skills in presenting mathematical solutions.
Problem solving (Lecture and Tutorial)	Develop competence in solving linear algebra related problems.
Peer Instruction (Lecture and Tutorial)	Develop communication skills and competence in mathematics, particularly in linear algebra. The students also have an opportunity to work with their peers.

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	Summative Assessment (EXAM): Final exam(FInal Examination, assessing all aspects of course.)	All	NA	60	2.5 Hour Final exam, assessing the full content of course.	Individual	Analytic	Multistructural
2	Continuous Assessment (CA): Test/Quiz(Pre-Lesson Online Quiz)	All	NA	7	Assessed via the MyMathLab platform, with intention of giving students practice at core problems.	Individual	Analytic	Relational
3	Continuous Assessment (CA): Test/Quiz(Midterm Test)	1,2,3	NA	28	Mid-Term Test, to examine all course content covered from beginning of class to 1-week prior.	Individual	Analytic	Multistructural
4	Continuous Assessment (CA): Class Participation(Assessment on Tutorial Participation)	All	NA	5	Participation in tutorial sessons.	Individual	Holistic	Extended Abstract

Description of Assessment Components (if applicable)

NA

Formative Feedback

[Component 2] Immediate feedback is given through computer-based online homework.

[Component 3] Feedback is also given after mid-term on the common mistakes and the level of difficulty of the problems.

[Component 4] Feedback is given at tutorials for participation.

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
Creative Thinking	Intermediate
Curiosity	Intermediate
Problem Solving	Advanced
Critical Thinking	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 complete all assigned pre-class assessments before coming to lectures. They are expected to attend all computing labs, and take the mid-term test. Students are expected to take responsibility to understand the course materials, and to seek help when necessary.

Policy (Absenteeism)

Students are expected to be physically present at all tutorials, but are allowed to miss up to two tutorials without penalty.

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.

Students are expected to complete all assigned pre-class assessments before coming to lectures. They are expected to attend all computing labs, and take the mid-term test. Students are expected to take responsibility to understand the course materials, and to seek help when necessary.