Math 218: Matrices and Vector Spaces
An Introduction to Computational and Applied Linear Algebra

Class Times:	MWF Noon-12:50pm	**Instructor:**	Rann Bar-On
Email:	rann@math.duke.edu	**Office Hours:**	
HW Web Page:	`https://math.duke.edu/~rann/218materials/`		
Textbook:	Introduction to Linear Algebra (5th Ed) by Gilbert Strang, Wellesley-Cambridge Press/SIAM (2016).		

This is an introductory course on linear algebra that will focus on concepts, methods and applications. Gaussian elimination is presented as the fundamental process for solving systems of linear equations. Deeper understanding is developed by examination of matrix factorizations, orthogonality, and associated vector subspaces. Least squares problems, eigenvalue problems, the singular value decomposition and principal component analysis will also be studied as fundamental tools for solving data-driven applications.

This course will be more applied and computational than **Math 221** (for students heading to a math major2), which goes into much more depth on theory and develops skills in writing rigorous mathematical proofs. **Math 218** is also significantly different from **Math 216** – less differential equations will be covered, instead, we will cover more advanced topics from linear algebra.

Grading: Based 50% on three in-class tests, 30% final exam, 20% homeworks (more or less weekly).

Homework: Homework will be assigned weekly and posted on the web page mentioned at the top of the page. All homework will be submitted and graded on Gradescope. You will be required to take photos of your homework or scan it in. Use Scannable on iOS or Genius Scan on Android.

Tests: There will be three one hours tests in class. Each test will cover all classes after the previous test, but will require knowledge of previous material covered in this class. Calculators may be used on tests for arithmetic purposes only.

Final: The final examination will cover all course materials, unless otherwise indicated in class. Calculators may be used on the final for arithmetic purposes only.

Attendance: Attendance is mandatory and vital for success in this class. Absences from assessed work will only be accepted with official excuses. Makeups may or may not be allowed.

The final will be Saturday, 2nd May, 2pm-5pm. Keep this date in mind when making travel plans.

Math 218L: Math 218 has an optional 0.5 credit lab component, **Math 218L**. In this lab, which meets twice a week, we will cover programming techniques and implement a wide variety of linear algebra algorithms. Later, we will apply them to varied concepts such as machine learning, handwriting recognition, image compression, and others. We will end the semester by implementing a facial recognition algorithm. Code will be developed in Python using the NumPy package. We will explore algorithms, numerical implementations and their difficulties, and develop a substantial code base to use in applications. The workload won't be too large, especially as most work will be carried out in pairs. If you are planning to work in the field of data-based research or data science, the labs will give you a very strong introduction to ideas commonly used in those fields, as well as providing a gateway to more advanced courses.

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Course Outline

The following is an approximate outline of topics covered, their order, and their approximate timing, plus the releavant chapters in Strang. All these are subject to modification as the semester proceeds.

1. **Introduction - Matrices, Vectors, and Equations** — **Chapters 1,2**

   Algebra with vectors — **Weeks 1-3**

   Algebra with matrices

   Row- and column-based descriptions of systems of equations

   Gaussian elimination

   Inverse matrices

   The LU matrix factorization

2. **Vector spaces defined by matrices** — **Chapters 3, 4**

   Column-spaces and null-spaces of matrices and relations on dimensions — **Weeks 4-7**

   Orthogonality and projections onto subspaces, orthogonal bases

   Least squares problems

   The Gram-Schmidt process and the QR matrix factorization

3. **Eigenvalues and eigenvectors of matrices** — **Chapters 5,6**

   Determinants — **Weeks 8-11**

   Calculating eigenvalues and eigenvectors

   The eigenvalue/eigenvector matrix factorization and diagonalizable matrices

   Symmetric and positive definite matrices

4. **The Singular Value Decomposition** — **Chapter 7**

   Relation to eigenvalues — **Weeks 12-14**

   Calculating the SVD matrix factorization

   Principal Component Analysis: a brief introduction