E 231 Mathematical Methods for Engineers Fall 2017

Instructor:	Kameshwar Poolla, 5141 Etcheverry Hall Tel. 520-1150, *poolla@berkeley.edu*
Website:	`https://bspace.berkeley.edu/`
Prerequisites:	Math 1A, 1B, 53, 54 or equivalent. Some previous exposure to Matrix Algebra will be valuable. If you have already taken ME 232 or EE 221A, you should *not* take this course.
Office Hours:	Thursdays 3-5pm, 5102 Etcheverry
Grading:	3 midterms + homework (weights TBD)
Text:	None is required. *Notes will be provided for most of the topics covered.*
Homework	Issued Wednesdays, due in box outside my office by 5pm Fridays

Primary References:

- G. Strang. *Linear Algebra and its Applications*. Brooks Cole, 4th edition, 2005.
- D. P. Bertsekas and J. N. Tsitsiklis. *Introduction to Probability*. Athena Scientific, 2002.
- S. Boyd and L. Vandenberghe. *Convex Optimization*. Cambridge University Press, 2004.
  Also available for download on the web at *http://www.stanford.edu/ boyd/cvxbook.html*

Other References:

- P. R. Halmos. *Finite-dimensional Vector spaces*. Springer Verlag, 1958.
- B. Noble and J. Daniel. *Applied Linear Algebra*. Prentice-Hall, 2nd edition, 1977.
- G. Golub and C. Van Loan. *Matrix Computations*. Johns Hopkins Press, 1989.
- M. Gantmacher. *Theory of Matrices, Vol 1 & 2*. Chelsea, 1959.
- G. R. Grimmett, D. R. Stirzaker. *Probability and Random Processes*. Oxford Univ. Press, 2001.
- S. Karlin. *A First Course in Stochastic Processes*. Academic Press, 1975.
- E. Wong. *Stochastic processes in information and dynamical systems*. Springer Verlag, 1971.
- K. L. Chung. *A first course in Probability Theory*. Academic Press, 1974.
- D. G. Luenberger. *Optimization by vector-space Methods*. Wiley-Interscience, 1997.
- J.E. Dennis, Jr. and R. B. Schnabel, *Numerical methods for unconstrained optimization and nonlinear equations*. Prentice-Hall, 1983.
- P. E. Gill, W. Murray, and M. H. Wright. *Practical optimization*. Academic Press, 1981.
- D. G. Luenberger, *Introduction to linear and nonlinear programming*. Addison-Wesley, 1973.

Course Objectives:

This course is aimed at first-year engineering graduate students in Engineering. Our goal is to consolidate the mathematical preliminaries required from our graduate students into a single course.

Several of the core graduate courses in Mechanical Engineering (for example: ME 232, 233, 234, 180, 185), especially those in dynamics, control, mechanics and systems, require a thorough knowledge of Linear Algebra, Random Processes, and Optimization. Teaching these courses is made challenging by the significant diversity of the mathematical background of incoming students. As a result, we are compelled to teach to the lowest common denominator and review the background mathematics. This is done is several courses, and we therefore lose significant lecture time that could be otherwise dedicated to the core Engineering content of these courses.

One solution (which a large number of the students with weaker mathematical preparation choose) is to take a series of elementary courses such as Math 110, 104, EE 126. This is the material that is "assumed known" but nonetheless reviewed in our first-year graduate engineering courses. This solution is unsatisfactory because it significantly delays the students' entry into research. In the event these students *concurrently* take our first-year graduate engineering courses, historical evidence suggests that they learn and retain less that their better prepared peers.

It is for these reasons that we propose this new course to address our curricular needs.

Target Audience:

We expect that graduate students in control, dynamics, solid mechanics, fluids, and robotics would enroll in this course. It would be offered once per year in the Fall semester. The expected enrollment in 50 students.

Pre-requisites:

Math 1A, 1B, 53 and 54 or equivalent.

Course Catalog Description:

This course offers an integrated treatment of three topics essential to modern engineering: Linear Algebra, Random Processes, and Optimization. These topics will be covered more rapidly than in separate undergraduate courses covering the same material, and will draw on engineering examples for motivation. The stress will be on proofs and computational aspects will also be highlighted. It is intended for engineering students whose research focus has a significant mathematical component, but who have not previously had a thorough exposure to these topics.

Instructors in Charge:

- ◇ Professor Andrew Packard. 5117 Etcheverry Hall.
  Office Telephone: 643-7959. *pack@me.berkeley.edu*
- ◇ Professor Kameshwar Poolla. 6191 Etcheverry Hall.
  Office Telephone: 642-4642. *poolla@me.berkeley.edu*

Course Outline:

A. Linear Algebra: 5 weeks

(Faster paced and more directed than Math 110)

Vector Spaces. The direct sum decomposition. Linear Operators. Matrix algebra. Determinant. Trace. Rank. Inverses. Eigenvalues, eigenvectors, invariant subspaces. Matrix transformations. Functions of a matrix. Spectral mapping theorem. The Schur decomposition. Hermitian, Normal, Unitary matrices. Factorization Theorem for Hermitian matrices. Positive definiteness. Matrix square-roots. Induced norms of operators. Adjoint operators. Least squares problems. The Singular Value Decomposition.

B. Probability and stochastic processes: 5 weeks

(More elementary than EECS 226A)

Probability spaces. Random variables. Density, Distribution. Expectation. Conditioning. Bayes' theorem. Conditional density. Gaussian random variables. Random sequences. Convergence Aspects. Large number laws. Central Limit Theorem. Autocorrelation. Power spectral density. Filtering of Random Sequences. Random Processes.

C. Optimization: 5 weeks

(More specific and elementary than EE227A, IEOR 162, Math 171)

Convex sets and functions. Separating hyper-planes. Linear programming. Semi-definite programming, sum-of-squares programming. Non-convex quadratically constrained quadratic programming. Nonlinear programming.