ENS 525 - Fall 2011

Mathematical Methods for Scientists and Engineers I

(December 27, 2011)

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Lectures: M 13:40-15:30 FENS L055
W 15:40-16:30 FENS L058

Recitation: W 16:40-17:30 FENS L058

Course Description: This is the first in a series of two courses that aim to equip students in engineering and natural sciences with abstract concepts for approaching as well as practical tools for solving a diverse range of mathematical problems that they will encounter throughout their post-graduate education. The presentation will start with a review of real-number calculus in one and two dimensions. Then, we will turn to the complex plane, where our main goal will be to introduce the calculus of residues and use it to evaluate integrals that are difficult to approach by other means. The skills developed in the process will prove useful in the discussion of Fourier and Laplace transforms, widely used in engineering applications. The utility of the Laplace transform for solving linear differential equations will be illustrated. Our subsequent review of matrix algebra aims to highlight the role of eigenvalues and eigenvectors as means for characterizing and solving linear problems. The case of chemical exchange in magnetic resonance will be used to illustrate the use of Markov chain models in applications. The section on ordinary differential equations aims to introduce Green's functions as a tool for solving nonhomogeneous linear differential equations. In addition, power series expansion will be employed to obtain solutions of homogeneous linear differential equations.

Who can take this course: The course is catered to starting graduate students in engineering and natural sciences who feel the need to refresh their knowledge of complex calculus, linear algebra, and ordinary differential equations. Alternatively, the course can serve as a streamlined overview of these fields for students who have taken only two semesters of undergraduate Calculus. Therefore, it should be attractive to motivated, advanced undergraduate students as well.

Evaluation:

Quizzes and homework	15 %
Exam I (Nov 2)	25 %
Exam II (Dec 21)	25 %
Comprehensive final exam	35 %

Detailed Course Content:

I. Review of real-number calculus in one and two dimensions

   A. Elementary functions

   B. Differentiation and integration

C. Power series

D. The Dirac delta function

E. Differential and integral calculus in two variables

II. Complex-number calculus

A. Complex numbers and complex functions

B. Differentiation and the Cauchy-Riemann conditions

C. Contour integration and the Cauchy formula

D. Taylor and Laurent series

E. Calculus of residues

III. Transforms

A. Fourier transform

B. Laplace transform

IV. Matrix algebra

A. Matrix operations and functions of matrices

B. Linear equations and least squares

C. The eigenvalue problem and (bi)orthogonal systems

D. Application of Markov chains in magnetic resonance

V. Ordinary differential equations

A. First order linear DEs and Green's function solutions

B. Second order linear DEs and Green's function solutions

C. Power series solutions of homogeneous, linear DEs (method of Frobenius)

D. Solutions of hypergeometric and confluent hypergeometric DEs

Reference Books:

- Haluk Beker, *Fen ve Mühendislikte Matematiksel Metotlar*, Boğaziçi Üniversitesi Yayınevi, Istanbul, 2006.
- Bruce R. Kusse and Eric A. Westwig, *Mathematical Physics: Applied Mathematics for Scientists and Engineers*, 2nd edition, Wiley-VCH, Weinheim, 2006.
- Cornelius Lanczos, *Applied Analysis*, Prentice-Hall Inc., Englewood Cliffs, N.J., 1956. (Dover edition, 1988.)
- Roger Penrose, *The Road to Reality: A Complete Guide to the Laws of the Universe*, Alfred A. Knopf, New York, 2005.