Boston University College of Engineering,
Department of Electrical and Computer Engineering

ENG EK 501
Fall 2009
Mathematical Methods I

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Course Description: Mathematical methods I and II (501 & 502) present mathematical methods and concepts which are widely used in science and engineering. Unifying and/or geometric concepts are emphasized while stressing representative applications. The first course emphasizes calculus, linear algebra and ordinary differential equations (see course content below), while the second course emphasizes partial differential equations and numerical methods. For official "boilerplate", see http://www.bu.edu/dbin/ece/web/grad/courses.html .

Where and when: T, R, 2-4, SOC B65

Office hours: Most likely Friday mornings; to. In general, if you want to find me outside of office hours, you can call office number above, send an e-mail, or leave a note in my ECE mailbox. (e-mail is probably the best route.)

Prerequisites: Previous exposure to univariable calculus, linear algebra, vector calculus, ordinary differential equations, complex variable methods, and transform methods. (Don't panic!) The course will review all of these topics, but will not develop them from scratch. The emphasis will be on unifying themes that appear through application.

Goals:
- Present linear algebra in a manner consistent with practices in scientific computing.
- Develop vector calculus and complex variables in a conceptually coherent manner.
- Develop a broader appreciation of the research that goes on in their department, and the college.

Textbooks:

"All the Mathematics You Missed- But need to Know for Grad School", Thomas A. Garrity, Cambridge University Press, 2001- Available in the BU bookstore. (9th printing was in 2005, and so ISBN numbers can be hard to follow).

The following books were once required for the course, and now serve as references. Note that the first five books are well known books in their respective fields, yet the price of all five is less than some textbooks. Besides being a great value, each is small enough to carry around, to read, and to refer to!

- M. R. Spiegel, Schaum's Outline of Complex Variables, McGraw-Hill Book Companies, (ISBN 0070602301).
- C.H. Edwards, Advanced Calculus of Several Variables, Dover, 1973,ISBN: 0-486-68336-2
- K. Yoshida, Lectures on Differential and Integral Equations, Dover, 1991, ISBN: 0-486-66679-4
- Golub & VanLoan, Matrix Computations, Johns Hopkins, 3rd ed., 1996, ISBN: 0801854148
- N. Young, An Introduction to Hilbert Space, Camb. U. P., 1998, ISBN: 0-521-337178
- The Mathworks, MATLAB-Student ed., documentation.

A wonderful book that recently caught my eye, which I was tempted to adopt on account of its orientation, but which would have been overwhelming in terms of detail, is:

- Z. A. Melzak, Companion to Concrete Mathematics, Dover Publications Inc., 2007. (Two volumes bound as one).ISBN-13: 978-0-486-45781-9.

References to other books and web resources will be given as the need arises, or as particular interests are identified. This typically happens if in-class examinations are replaced with projects.

Course Content:

At least two weeks will be spent on each of the first four sections below. Emphasis on remaining three sections will be dictated by the needs of the class:

- A development of the notions of numbers and polynomials which sets the stage for many involved results and applications of the course material. Some algorithmic themes will be developed in this context.
- Univariable calculus: review of basic techniques with an emphasis on algebraic and computational aspects such as rational functions and Pade approximations.
- Linear algebra: basic properties of linear systems, solution of linear systems by both direct and iterative methods, sparse matrices, inner product spaces, condition numbers, Krylov subspaces, eigenvalue and singular value decompositions, normal matrices, functions of matrices, structured (circulant, Hankel and Toeplitz) matrices.
- Multivariable calculus: multivariable Taylor approximations and critical point theory, implicit and inverse function theorems, fundamental theorem of multivariable (vector) calculus.

- Complex variable methods: Cauchy-Riemann equations, analytic functions, conformal mapping, positive real functions, analytic extension, Cauchy's theorem, the principle of the argument, special functions.
- Ordinary differential equations: Emphasis will be on aspects which reinforce concepts from linear algebra; systems of linear differential equations and Sturm-Liouville theory.
- Fourier, Hilbert and Laplace transform methods: Emphasis will be on complex inversion formulas and applications to systems theory (causality, passivity, Nyquist stability), Poisson resummation (sampling theorem), and integral equations.

Evaluation: There are two choices; the class makes a final decision after the first midterm. In the past the first scheme has been the preferred one. Suggestions for modifying the evaluation scheme are welcome but will have no impact on the current semester if they do not come in the first week of class.

	Scheme 1	Scheme 2
Homework	10	10
First Midterm exam	20	25
Second Midterm exam	20	25
Final Exam	-	40
Final project written report	40	-
Final project class presentation	5	-
Attendance during class presentations	5	-
Total	100 %	100 %

A Reminder of an Expectation:

Students are expected to attend class regularly and develop their own interests in the context of the course. If this seems difficult or unreasonable, be sure to engage the instructor.

Resources for exploration and project ideas:

For inspiration, have a peek at:
http://www.google.com/Top/Science/Math/

Eventually, I would like to compile a list of books which students found inspiring in the course of their project work. What you find below is a feeble start based on feedback from students.

David Benson, "Music: A Mathematical Offering". Cambrige University Press 2007. Info. and an online .pdf version can be found at:
http://www.maths.abdn.ac.uk/~bensondj/html/maths-music.html
Do not be intimidated by this book; file it. Although many of the chapters contain mathematical material, most chapters can be read independently and the author has a wonderful way of introducing mathematical concepts in an easily accessible context. ECE students should note that the author maintains the web page for Yamaha synthesizers, and that the Book is a real gem for Musical EEs.

Manfred Schroeder, "Number Theory in Science and Communication", Springer-Verlag (various editions).
Again, don't try read this book in a night. The math is nontrivial but the author is quite a master of introducing seemingly advanced topics in a very practical context. If you get into concert hall or recording studio acoustics, this book is a must. The author is a very well known engineer who, amongst other things, has fixed the acoustics of various concert halls (after they were built!).

Jeffrey Hoffstein, Jill Pipher, and Joseph H. Silverman, "An Introduction to Mathematical Cryptography", Undergraduate texts in mathematics, Springer, 2008.
This book is remarkably accessible given the nature of the material. Joe Silverman is a local area mathematician who grew his cryptography start-up into a respectable company.

Google's PageRank and Beyond: The Science of Search Engine Rankings by **Amy N. Langville and Carl D. Meyer**, Princeton University Press, 2006. This book is a self-contained account of Google's page rank algorithm and an account of all the underlying numerical linear algebra. A related book is: A Course on the Web Graph (Graduate Studies in Mathematics) by **Anthony Bonato,** American Mathematical Society, 2008.

The following are "timeless classics" written by truly exceptional people, and aimed at the non-specialist:

Mark Kac and Stanislaw M. Ulam, "Mathematics and Logic", Dover Publications Inc., Mineola, N.Y., 1992. This book was originally published in 1968 as part of the celebration of the 200th anniversary of the Encyclopedia Britannica. It takes a very concrete approach to getting the reader to think about the nature of mathematics, how it is created and practiced, how it developed alongside science.

There are also two books written in the first half of the last century, intended for people with little more than a high school education, and intended to be relatively elementary:

Richard Courant and Herbert Robbins, “What is Mathematics”.
The latest edition is edited by Ian Stewart**:** What Is Mathematics? An Elementary Approach to Ideas and Methods **by Courant and Robbins; edited by Ian Stewart**.

Rademacher and Otto Toeplitz, “The Enjoyment of Mathematics”, Published at various times by both Princeton University Press and Dover Publications, Inc..

The Bottom line:
If you are having difficulty relating the course material or your interests to this course, it is time to talk to engage the instructor!