# GEORGIA INSTITUTE OF TECHNOLOGY
## SCHOOL of ELECTRICAL & COMPUTER ENGINEERING

## ECE 6250: Advanced Topics in Digital Signal Processing
## Spring 2017

# Syllabus

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**Instructor:** Prof. David V. Anderson **office:** GTL 304
**e-mail:** anderson@gatech.edu

**Office Hours:** MW: 10:30 AM – 11:30 AM, MT 1:30 PM – 2:30 PM, W 1:30 PM – 2:00 PM

**WWW:** Course information, notes for the lectures, homework assignments, and supplemental materials will be posted on T-square as well as announcements, distributing grades, and supplemental materials with restricted distribution. `http://t-square.gatech.edu/`

**Text:** The recommended text is

- Moon and Stirling: *Mathematical Methods and Algorithms for Signal Processing* `http://tinyurl.com/kvelng`

This text is recommended but not required.

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**Summary:** ECE 6250 is a general purpose, advanced DSP course designed to follow an introductory DSP course. The central theme of the course is the application of tools from linear algebra to problems in signal processing.

**Prerequisites:** A senior-level introductory course in digital signal processing such as ECE 4270. Students should be familiar with the fundamentals of linear algebra and have had exposure to basic probability and statistics. Students should also have basic MATLAB programming skills.

**Grading:**

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|---|---|---|
| Quiz I, II, III | 50% | total |
| Homework | 25% | |
| Attendance | 5% | |
| Final | 20% | |

**Important Dates:**

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|---|---|
| Quiz 1 | mid-to-late February |
| Quiz 2 | mid March |
| Quiz 3 | mid April |
| Final Exam | not yet scheduled |

**Homework:**

Homework will be assigned weekly (approximately). Homework will be turned in at the beginning of lecture. Late homework will get zero credit.

Students are encouraged to discuss homework problems with one another, however each student must write up and turn in their own solutions.

Unauthorized use of any previous semester course materials, such as tests, quizzes, homework, projects, and any other coursework, is prohibited in this course. Using these materials will be considered a direct violation of academic policy and will be dealt with according to the GT Academic Honor Code.

The homework assignments will be hard; many of them will require significant amounts of time and effort to complete. But this is really where most of the learning takes place. You will get out of the assignments what you put into them. Students who complete all of the assignments in full will be rewarded with a deep understanding of the role that linear algebra plays in modern signal processing (among other things).

Effectively, homework is worth much more than 25% of your grade. In a class at this level, **I have yet to see a case where a student does not put effort into the homework assignments but does well on the exams**.

**Attendance:**

Lectures are Monday, Wednesday from 9:00 AM - 10:30 AM in the Brown room.
**Lecture attendance is mandatory** and will count towards your grade. Attendance will usually be taken as a simple quiz at the beginning of class.

Students are responsible for all material covered in class, including changes in schedules announced in class.

**Quizzes:**

The current plan is to have three quizzes. These will not take the whole class period and will usually take place during the last 45-60 of class.

**Text Resources:**

Below is a list of books that may be helpful for learning (and teaching) the material in this class.

- Strang: *Linear Algebra and its Applications*
  `http://tinyurl.com/my5ufk`
- Strang: *Introduction to Applied Mathematics*
  `http://tinyurl.com/nj6r5d`
- Horn and Johnson: *Matrix Analysis*
  `http://tinyurl.com/kvtxkp`
- Laub: *Matrix Analysis for Scientists and Engineers*
  `http://tinyurl.com/3ev7crf`
- Young: *An Introduction to Hilbert Space*
  `http://tinyurl.com/kt9jzu`
- Scharf: *Statistical Signal Processing*
  `http://tinyurl.com/3c9qc6p`

**Academic Honesty:**

Although students are encouraged strongly to work together to learn the course material, all students are expected to complete quizzes and exams individually, following all instructions stated in conjunction with the exam. All conduct in this course will be governed by the Georgia Tech honor code. Additionally, it is expected that students will respect their peers and the instructor such that no one takes unfair advantage of anyone else associated with the course. Any suspected cases of academic dishonesty will be reported to the Dean of Students for further action.

**Dead Week:**

As per Institute policy, I am required to inform you on the syllabus that **there will be a homework assignment due during the last week of class**.

## Outline

The outline below should be treated as an approximation; it is subject to (small) changes.

1. Signal representations in vector spaces
   (a) Introduction to discretizing signals using a basis: the Shannon-Nyquist sampling theorem
   (b) Linear vector spaces, linear independence, and basis expansions
   (c) Norms and inner products
   (d) Orthobases and the reproducing formula
   (e) Parseval's theorem and the general discretization principle
   (f) Important orthobases: Fourier, discrete cosine, lapped orthogonal, splines, wavelets
   (g) Signal approximation in an inner product space
   (h) Gram-Schmidt and the QR decomposition
2. Linear inverse problems
   (a) Introduction to linear inverse problems, examples
   (b) The singular value decomposition (SVD)
   (c) Least-squares solutions to inverse problems and the pseudo-inverse
   (d) Stable inversion and regularization
   (e) Weighted least-squares and linear estimation
   (f) Least-squares with linear constraints
3. Computing the solutions to least-squares problems
   (a) Cholesky and LU decompositions
   (b) Structured matrices: Toeplitz, diagonal+low rank, banded systems
   (c) Large-scale systems: Steepest descent
   (d) Large-scale systems: The conjugate gradient method
4. Low-rank updates for streaming solutions to least-squares problems
   (a) Recursive least-squares
   (b) The Kalman filter
5. Matrix approximation using least-squares
   (a) Low-rank approximation of matrices using the SVD
   (b) Total least-squares
   (c) Principal components analysis
6. Beyond least-squares (topics as time permits)
   (a) Gradient descent and Newton's method for unconstrained convex optimization
   (b) Constrained optimization
   (c) $\ell_1$ approximation and regularization
   (d) Independent components analysis