ENG EC 456 A1 Electromagnetic Systems II SPRING 2023

Location: EMB-105
Class meeting times: Tues, Thurs, 1:20-3:15 PM
Credits: 4
Prerequisites: ENG EC 455.
Note that prerequisites for EC 455 are:
Physics PY 212 General Physics 2 (covers circuits, optics and basic electromagnetics.)
Math MA 225 Multivariable Calculus (covers integral theorems of Gauss and Stokes.)
(Please tell me if you have *not* had ENG EK 307 (ECT) or MA 226 (Differential equations.)

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Course description:
Electric field, energy, and force. Lorenz force. Dielectric materials. Steady electric currents. Magnetic field, energy, and force. Magnetic materials. Applications of electrostatics, magnetostatics, and electrodynamics. Electromagnetic waves in dielectric and conducting materials. Solution techniques for electromagnetic fields and waves.

Informal course objective: To make friends with Maxwell's equations, realizing that this is facilitated by using the math that you (should) know, even if you're a bit rusty. Since this is a small class, if there is a particular application of electromagnetic theory which interests you, but you find the details technically challenging, please let me know and I'll try touch upon it at the appropriate point in the course. Since this course leads to a final paper or project related to your evolving professional interests, it is useful to try articulate your interests as well as you can.

Also, since this class is too small to warrant a discussion section, feel free to make your difficulties know at the beginning or end of lecture, and don't feel shy about taking full advantage of office hours.

A note about e-mail: Please make a clear distinction between e-mails and texts; I consider e-mails to be like letters which should be edited and read on a screen that can display the contents of a written page. On the other hand, texts can be read on a narrow screen; please don't respond to lengthy e-mails containing multiple threads using a phone if it reformats the message to fit a narrow screen.

Evaluation scheme:

Homework & questionnaire responses	15
Attendence/Participation in both lecture and discussion sections	10
Two Midterms (20 points each; there may be an oral component)	40
Formal proposal for, and presentation on individual final paper or project	10
Final exam, paper or project	25
Total	100

Textbook for the course:
There is no required textbook for the course; I will make every effort to have the lecture notes self-contained. A quick survey revealed that all of the enrolled students used Sadiku in EC 455, and so I urge you to hang on to this as a reference and, if you are having trouble with any background material, bring in your copy of Sadiku and I will point you to the Chapter and subsection that can help you out.

There is another reference I find useful for a mix of theory, applications and historical context:

Author:	Notaros, Branislav
Title:	Electromagnetics
Publisher:	Prentice-Hall
ISBN:	9780132433846
Edition:	11

The text is very student friendly, but I'll take some freedom to lecture in a slightly more concise style and touch on a few more sophisticated applications. For this reason, I will update the syllabus with pointers to other books that you might find particularly useful.

A Reminder and 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.

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

Be sure to ask: Am I having fun? Will the course material help change the world?

Here's the basic outline of the Spring 2023 offering:
- The Integral form of Maxwell's equations in the context of "the fundamental theorem of multivariable calculus".
- The Lorentz force law and some quasi-static limits of Maxwells equations. The basic variables of circuit theory and some applications.
- Vector calculus in Cartesian coordinates and the differential version of Maxwell's equations.
- Orthogonal curvilinear coordinates and vector calculus in cylindrical and spherical coordinates.
- Separation of variables in rectangular and cylindrical coordinates; the impedance of a round wire.
- Use of circuit models in quasi-statics.
- Wave equations in odd vs even spatial dimensions.
- The potentials for the electromagnetic field and the wave equations for the electromagnetic field; superposition integrals. The problem of defining a self-consistent field.
- Power, energy and Poynting's theorem.
- Applications of the electric scalar potential and subtleties in defining and using a magnetic scalar potential.
- The rationale for complex variable methods in 2-d potential problems.
- Transmission line models

- Waves on transmission lines. (There will be relatively little time spent on the loaded line since this is covered in EC 455.)
- Electromagnetic waves in the context of optics.
- An analysis of optical fibers
- The basics of magnetic materials and micromagnetics; a diversion on MRI and fMRI.

Depending on student interests, and opportunities to “connect dots”, we’ll cover some more advanced topics in the above contexts:

1. Orthogonal Curvilinear Coordinates beyond cylindrical and spherical coordinates. For the most part, they are either translationally or rotationally invariant, and the coordinate surfaces are given by polynomial equations of degree at most four. (This makes most integral solvable inn closed form.) These coordinate systems are typically interpreted in terms of conic sections, and the associated functions have uses in electrical engineering beyond wave propagation; they play a special role in the context of Fourier analysis, analog signal processing, and the analysis of quantum devices.

2. Direct and inverse problems; the relationship between impedance tomography and Inverse scattering, applications to environmental remediation and medical imaging.
MRAM and nanoscale magnetic devices.