EE 578: Computational Electromagnetics for Engineers
(30953)

Units: 4

Spring 2025—Tues/Thurs. 12:00-1:50 PM

Location: KDC 236

Instructor: Constantine Sideris

Office: EEB328

Office Hours: Tuesday, 2:00-3:00 pm (tentative) and by appointment.

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Course Description

The development of modern technologies such as 5G wireless networks, terabit silicon photonic optical interconnects, and optical computing relies on a deep understanding of the underlying electromagnetic principles governing their operation. Due to the high complexity of these modern day systems, engineers must rely on numerical simulations to predict and model their behaviors when designing these systems.

This class will give a one-semester graduate-level introduction to computational methods for solving partial differential equations describing physical phenoma which commonly arise in the real world, focusing on electromagnetics (Maxwell's equations and the wave equation), and including electro\magnetostatics (Poisson's equation), acoustive wave propagation, and the heat equation. Analytical solutions unfortunately do NOT exist for most realistic physical structures or devices and therefore numerical discretization and modeling is required for analyzing their performance. Primarily finite difference methods, in both the time and frequency domains, will be covered, although finite element methods and integral equation-based approaches will be covered as well. Numerous examples drawing from modern applications, primarily in electromagnetics, will be presented for solving relevant real-world problems, including radiating antennas for wireless communication, dielectric waveguides for nanophotonic integrated circuits, as well as acoustic and electromagnetic scattering off of arbitrary dielectric objects for applications in radar scattering and remote sensing.

Learning Objectives and Outcomes

Students who complete this class will learn how to simulate and numerically solve complicated problems which arise in physics in two and three dimensions. Emphasis will be placed on examples from electromagnetics, although there will be some examples provided from other disciplines, such as solution of acoustic propagation. Students will develop their own numerical solver codes capable of simulating relevant devices for which analytical solutions do not exist, such as antennas and nanophotonic devices. They will also develop an understanding of how commercially available solvers such as COMSOL, CST, FEKO, HFSS, and Lumerical work "under the hood" and will learn how to effectively use such commercial solvers to simulate complex electromagnetic systems for applications relevant today in both the radio-frequency (RF) and nanophotonic regimes.

Prerequisite(s): None
Co-Requisite(s): None

Recommended Preparation: Knowledge of a high-level computer programming knowledge such as C, C++, or MATLAB/Python at the levels of EE155L, EE455L, or EE301L respectively. Basic knowledge of PDE's and electromagnetics, such as as the level of EE370L, would be helpful for deeper understanding, although not required for successfully completing the course.

Course Notes

All lecture notes for this class, assignments, and any suggested additiona reading will be posted on the Blackboard site.

Technological Proficiency and Hardware/Software Required

Must have a knowledge of MATLAB or any other programming language such as Python or C/C++.

Required Readings and Supplementary Materials

There are no required textbooks for this class, although the following are recommended references:

Numerical Electromagnetics: The FDTD Method, Umran S. Inan and Robert A. Marshall, Cambridge University Press, 2011

Computational Electrodynamics: The Finite-Difference Time-Domain Method, Allen Taflove and Susan C.

Hagness, 3rd ed., Artech House, 2005

Description and Assessment of Assignments

Four problem sets will be assigned at approximately 2 week intervals. These will mostly involve implementation (in Matlab or any other programming language) and demonstration of concepts taught earlier in the class. Full code for every assignment must also be included with submission. Assignments should be handed in before lecture on the day they are due. Late assignments will not be accepted except with a medical excuse. There will be no exams; however, there will be a final project handed out during the 12^{th} week of class. The project will be worth 30% of the total grade and students may either work alone or in teams of two. Students must hand in project report, source code, and give a 10 minute presentation during the final week of class.

Final Project

Instead of a final exam, there will be a final project.

- Final project teams will be 1-2 students each.
- Topics can be suggested by the students or taken from a list of suggested topics to be provided.
- Each team will produce the following with percentage of the overall project grade shown:
    - Oral presentation: 15%, due week 15
    - Project report: 60%, due week 16
    - Commented source sode: 25%, due week 16
- Final project report has no page limit but must answer all of the questions asked in the project statement, explain the results observed, and discuss any deviations seen from the expected results.
- Final presentations will take place during the last week of classes.

Project Grading Rubrics

- PROJECT QUALITY is defined by
    - Tasks completed (e.g., correctness of results, producing code, observations noted)
    - Deviations from original project statement including things that did not work as expected.
    - Novelty & significance: How challenging was your project objective? (team size will be considered)
- PRESENTATION (15 points)
    - project quality (10) -- as defined above and conveyed by your presentation
    - presentation quality (5)
        - slide quality
        - presentation organization
        - presentation delivery
        - Q&A session
        - NOTE: one score for the entire group, but all members must present
- REPORT (60 points)
    - project quality (50) -- as defined above and conveyed by your report
    - report quality (10)
        - Clearly stating project objectives
        - Clearly stating accomplishments (see quality above)
        - Clearly describing future work (if you were to continue on this or if another team picked up from where you left off)
- SOURCE CODE (25 points)
    - Correctness and originality (20) – code must be written completely by the students and not copied from any existing or previously available source code.
    - Organization and commenting (5) – quality and readability of the code will be assessed.

- GRADING METHODOLOGY
    - All project materials will be graded by by the course instructor.

Grading Breakdown

Assignment	% of Grade
Problem Sets	70
Project	30

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Readings and Homework	Deliverable/ Due Dates
Week 1	Introduction to class. The Finite-Difference method, 1D Finite-Difference Time-Domain (FDTD) method	HW1 out	
Week 2	2D FDTD method		
Week 3	Absorbing boundary conditions and the Perfectly Matched Layer (PML)		HW1 due
Week 4	Power flux calculation and numerical dispersion	HW2 out	
Week 5	Waveguides, mode excitations, and the mode overlap integral		
Week 6	Total-Field Scattered-Field (TFSF) method	HW3 out	HW 2 due
Week 7	1D and 2D Finite-Difference Frequency Domain (FDFD) methods		
Week 8	3D FDTD method	HW 4 out	HW 3 due
Week 9	Numerical Waveguide Mode solvers		
Week 10	Digital filters and dispersive media		HW4 due
Week 11	Near-field to Far-field Transformations and Antennas	**Project Out**	
Week 12	Basic concepts behind the Finite Element Method (FEM) and Integral Equation (IE) methods		
Week 13	Pockington's Integral Equation for Wire Scatterers		

Week 14	Introduction to optimization of new electromagnetic devices		
Week 15	**Project Presentations**		
FINAL	**Project Report + Codes Due**		

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Student Health Counseling Services - (213) 740-7711 – 24/7 on call
engemannshc.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 – 24/7 on call
engemannshc.usc.edu/rsvp
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) | Title IX - (213) 740-5086
equity.usc.edu, titleix.usc.edu
Information about how to get help or help a survivor of harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following protected characteristics: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations.

Bias Assessment Response and Support - (213) 740-2421
studentaffairs.usc.edu/bias-assessment-response-support
Avenue to report incidents of bias, hate crimes, and microaggressions for appropriate investigation and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
studentaffairs.usc.edu/ssa
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.
Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.