ECE 244: Modern Physics & Materials for Electrical Engineering

Department of Electrical and Computer Engineering
University of Massachusetts at Amherst

Spring 2019

Lecture: Prof. Neal G. Anderson (210E Marcus)
MWF • 11:15-12:05 • ELAB 303
Discussion: Prof. Zlatan Aksamija (201B Marcus)
Tu 1:00-2:15 • ELAB 305 (Section D01) *or*
Th 1:00-2:15 • ELAB 305 (Section D02)
Prerequisites: ECE 201, Physics 152, and Math 233 (or equivalents)

Course Description

Introduction to the physical foundations of electronics, including classical electrostatic and magnetostatic fields and basic properties of classical dielectrics and magnetic materials; electron behavior as described by quantum theory, classical and quantum pictures of current flow in electrical conductors, and semiconductor materials (composition, structure, electronic and optical properties). Practical examples will draw from electromagnetics and contemporary materials and device applications.

Preliminary Course Outline

1. Classical Foundations

   1.1 Electrostatics Review: Charges, electric fields, and potentials
   1.2 Magnetostatics Review: Dipoles, magnetic fields, and potentials
   1.3 Classical Media Review: Permittivity and permeability
   1.4 Classical Conductors: Mobile charges, electrical conductivity, Ohm's Law
   1.5 Quantum Conductors: Introductory survey of semiconductor properties

2. Quantum Foundations

   2.1 The quantum revolution: The microworld is not the macroworld in miniature
   2.2 Duality: Light particles and electron waves
   2.3 Quantum theory: Describing the indescribable
   2.4 Energetics: the Schrodinger Equation
   2.5 Simple systems: Free electrons, potential wells, tunnel barriers, atoms

3. Semiconductor Materials

   3.1 Physical structure and composition of crystalline semiconductors
   3.2 Electronic structure: Periodic potentials and energy bands
   3.3 Charge carriers in semiconductors: Electrons and holes
   3.4 Occupation statistics
   3.5 Carrier concentrations and doping
   3.6 Carrier mobility, electrical conductivity, and drift current

3.7 Semiconductors: Ohm's Law revisited

4. Optical Properties

4.1 Light propagation in Media: Refractive index and extinction coefficient
4.2 Light absorption and emission in semiconductors

Learning Objectives

Students completing this course will be able to:

- Solve basic problems involving electrostatic and magnetostatic fields in classical dielectric and magnetic materials.
- Solve basic problems involving electrical conductors.
- Describe basic differences in electron behavior as described by classical and quantum theories of charged particles in potential fields.
- Solve basic problems involving and quantum pictures of current flow in electrical conductors, and identify the quantum origins of semiconductor material properties (composition, structure, electronic and optical properties).
- Apply the above to practical examples from electromagnetics and contemporary materials and device applications.

Course Materials

The course is based primarily on lecture notes, provided by the instructors, and materials available electronically. These notes are self-contained, but large sections of the course closely follow two texts that we highly recommend but do not require:

- F.T. Ulaby and U. Ravaioli, *Fundamentals of Applied Electromagnetics*, 7th Edition (Pearson), 2015.

- R.F. Pierret, *Semiconductor Fundamentals (Volume 1*), 1st (Addison Wesley) or 2nd Edition (Pearson), 1988.

Ulaby and Ravaioli is available in digital form for the semester directly from Pearson ($42). We will draw from Chapters 3-5. Pierret is available as a hard copy, also directly from Pearson ($55). Used hard copies of both are widely available and easily found on the Internet.

Discussion

Discussions will be held every week and attendance is mandatory. Each discussion will open with a worked example and a brief Q&A time. The remainder will be based on team-based-learning and revolve around a series of "think-pair-share" activities. You will partner with your nearest neighbor to solve conceptual or numerical problems reflecting the lecture material and report your answer(s) to the rest of the class. You and your partner will then turn in your written work at the end of each discussion; your discussion grade will be based on the work turned in as well as your participation. In computing your discussion grade, the lowest two scores will be dropped. You are strongly encouraged to come to the discussion each week prepared and ready to participate actively. There will be a roughly one week lag between lecture and discussion topics so that you can read, review your notes, and ask any questions you have before the corresponding discussion. In addition to the weekly scheduled discussions, we will maintain an active and Forum on Moodle where you will be able to ask (and answer) questions outside lectures/discussions; the Forum will be faculty-moderated.

Grading Exam I - 20% • Exam II – 20% • Final Exam – 20%
Problem Sets - 20%
Discussion – 20%

Accommodation Statement

The University of Massachusetts Amherst is committed to providing an equal educational opportunity for all students. If you have a documented physical, psychological, or learning disability on file with Disability Services (DS), you may be eligible for reasonable academic accommodations to help you succeed in this course. If you have a documented disability that requires an accommodation, please notify me within the first two weeks of the semester so that we may make appropriate arrangements.

Academic Honesty Statement

Since the integrity of the academic enterprise of any institution of higher education requires honesty in scholarship and research, academic honesty is required of all students at the University of Massachusetts Amherst. Academic dishonesty is prohibited in all programs of the University. Academic dishonesty includes but is not limited to: cheating, fabrication, plagiarism, and facilitating dishonesty. Appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Instructors should take reasonable steps to address academic misconduct. Any person who has reason to believe that a student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor as soon as possible. Instances of academic dishonesty not related to a specific course should be brought to the attention of the appropriate department Head or Chair. Since students are expected to be familiar with this policy and the commonly accepted standards of academic integrity, ignorance of such standards is not normally sufficient evidence of lack of intent (http://www.umass.edu/dean_students/codeofconduct/acadhonesty/).

Inclusivity and Diversity

The diversity of the participants in this course is a valuable source of ideas, problem solving strategies, and engineering creativity. If you feel that your contribution is not being valued for any reason, please speak with the instructor privately. If you wish to communicate anonymously, you may do so in writing or speak with Dr. Paula Rees, Director of Engineering Diversity Programs (rees@umass.edu, 413.545.6324, Marston 128). We are all members of an academic community where it is our shared responsibility to cultivate a climate where all students/individuals are valued and where both they and their ideas are treated with respect.
