

# ECE 244: Modern Physics & Materials for Electrical Engineering

Department of Electrical and Computer Engineering  
University of Massachusetts at Amherst

**Spring 2020**

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**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 304 (Section D01) *or*  
Th 1:00-2:15 • ELAB 304 (Section D02)

**Prerequisites:** ECE 201, Physics 152, and Math 233 (or equivalents)

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## 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.

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## Preliminary Course Outline

1. Classical Foundations
  - 1.1 Electrostatics Review: Charges, electric fields, forces, and potentials
  - 1.2 Magnetostatics Review: Currents, magnetic fields, forces, and potentials
  - 1.3 Classical Media: Dielectrics and magnetic materials
  - 1.4 Classical Conductors: Electron mobility and conductivity, origins of Ohm's Law
  - 1.5 Quantum Conductors: Qualitative survey of semiconductor electrical properties
2. Quantum Foundations
  - 2.1 The Quantum Revolution: The microworld is not the macroworld in miniature
  - 2.2 Quantum Theory: Describing the indescribable
  - 2.3 Energetics: the time-independent Schrodinger Equation
  - 2.4 Simple Quantum Systems: Free electrons, potential wells and barriers, atoms
3. Semiconductor Materials and their Electrical Properties
  - 3.1 Composition and Physical Structure of Crystalline Semiconductors
  - 3.2 Electronic Structure: Periodic potentials and energy bands
  - 3.3 Density of States, Occupation Statistics, and Carrier Concentrations
  - 3.4 Intrinsic and Extrinsic Semiconductors
  - 3.5 Electron Dynamics, Scattering, and Electrical Conductivity of Semiconductors

#### 4. Optical Properties (as time permits)

4.1 Light Propagation in Media: Refractive index and extinction coefficient

4.2 Light Absorption and Emission in Semiconductors

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### 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.
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### Course Materials

The course is based primarily on lecture notes, to be provided by the instructors, and other materials available electronically. These notes are self-contained, but large sections of the course closely follow two texts that we *highly recommend* and will refer to regularly:

- F.T. Ulaby and U. Ravaioli, *Fundamentals of Applied Electromagnetics*, 7<sup>th</sup> Edition (Pearson), 2015.
- R.F. Pierret, *Semiconductor Fundamentals (Volume 1)*, 1<sup>st</sup> (Addison Wesley) or 2<sup>nd</sup> Edition (Pearson), 1988.

Ulaby and Ravaioli is available in digital form for the semester directly from Pearson (\$46). We will draw from Chapters 3-5. Pierret is available as a hard copy, also directly from Pearson (\$59), or as a rental (\$34). Used hard copies of both are widely available and easily found on the Internet.

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### 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 will each individually 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.

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**Grading**   Exam I - 20%   •   Exam II – 20%   •   Final Exam – 20%  
                  Problem Sets and Computer Exercises - 20%  
                  Discussion – 20%

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### **Health and Wellbeing**

Success in this course and the College of Engineering depends heavily on your personal health and wellbeing. Recognize that stress is an expected part of the college experience, and it often can be compounded by unexpected setbacks or life changes outside the classroom. I strongly encourage you to reframe challenges as an unavoidable pathway to success. Reflect on your role in taking care of yourself throughout the term, before the demands of exams and projects reach their peak. Please feel free to reach out to me about any difficulty you may be having that may impact your performance in your courses or campus life as soon as it occurs and before it becomes too overwhelming. We encourage you to contact support services on campus that stand ready to assist you. Within the College, you may reach out to your academic advisor, the Office of Student Affairs (126 Marston) or the Office of Community Equity and Inclusion (128 Marcus). You can learn about the confidential mental health services available on campus by calling the Center for Counseling and Psychological Health (CCPH) at 413.545.2337 or visiting their website at [umass.edu/counseling](http://umass.edu/counseling). There are many other resources on campus for students facing personal, financial or life challenges to find support, stay in school, and graduate. See a comprehensive list at [umass.studentlife/single-stop](http://umass.studentlife/single-stop). Help is always available. Please reach out for support finding the resources you need.

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### **Disability, Accommodation, and Inclusive Learning Statement**

Your success in this class is important to us. We all learn differently and bring different strengths and needs to the class. The University of Massachusetts Amherst is committed to making reasonable, effective and appropriate accommodations to meet the needs of students with disabilities and help create a barrier-free campus. If you have a qualifying disability and require accommodations while participating in this course, please work with Disability Services to have an accommodation letter sent to us in a timely manner. If you have a disability but are not yet affiliated with Disability Services, please register with Disability Services (161 Whitmore Administration building; phone 413-545-0892). Information on services and materials for registering are also available on their website [www.umass.edu/disability](http://www.umass.edu/disability). If you are eligible for exam accommodations, your exams will be administered by the exam proctoring center. Contact Disability Services immediately, and comply with their exam scheduling policies, including the requirement that you book your exams at least seven days in advance of the exam date. *It is incumbent upon you contact me during the first few weeks of the semester, or shortly following registration with Disability Services, to ensure that your accommodations are being sufficiently met, including extra time and note-taking access, as applicable.* Finally, beyond disability accommodations, if there are aspects of the course that prevent you from learning or make you feel excluded, please let us know as soon as possible. Together we'll develop strategies to meet both your needs and the requirements of the course.

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### **Integrity and Academic Honesty**

There is no place for a dishonest engineer! Please read and be aware of the academic honesty policy: [http://www.umass.edu/dean\\_students/academic\\_policy](http://www.umass.edu/dean_students/academic_policy). While this isn't something that should arise, it is something we should be aware of and discuss as a class, as integrity is a core value of the engineering profession.

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## Inclusivity

The diversity of the participants of this course is a valuable source of ideas, problem solving strategies, and engineering creativity. If you feel that your contribution is not being valued or respected for any reason, please speak with us privately. If you wish to communicate with someone else in the College, speak with Assistant Dean Dr. Paula Rees ([rees@umass.edu](mailto:rees@umass.edu), 413.545.6324, 128b Marcus Hall). You may also submit anonymously through the College of Engineering Climate Concerns and Suggestions on-line form (<https://tinyurl.com/UMassEngineerClimate>) and/or the Positive and Negative Classroom Experience online form (<https://tinyurl.com/UMassEngineerClassroom>). We are all members of an academic community with a shared responsibility to cultivate a climate where all students/individuals are valued and where both they and their ideas are treated with respect..

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## Pronouns and Names

Everyone has the right to be addressed by the name and pronouns that they use for themselves. Students can indicate their preferred/chosen first name and pronouns on SPIRE, which appear on class rosters. Please let me know what name and pronouns I should use for you if they are not on the roster. A student's chosen name and pronouns are to be respected at all times in the classroom. To learn more, read the Intro Handout on Pronouns: [https://www.umass.edu/stonewall/sites/default/files/pronouns\\_intro.pdf](https://www.umass.edu/stonewall/sites/default/files/pronouns_intro.pdf)

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## Title IX

Any conduct that has the purpose or effect of unreasonably interfering with an individual's performance by creating an intimidating, hostile, or sexually offensive educational, academic, residential, or working environment is considered sexual harassment. Faculty have the responsibility to inform students of the resources and reporting options relevant to reporting an incident of sexual assault, sexual harassment, relationship violence or stalking for all genders. You may go to the Title IX webpage at <http://www.umass.edu/titleix/> and the Sexual & Relationship Violence Resource Guide at ([https://www.umass.edu/titleix/sites/default/files/documents/sexual\\_violence\\_resource\\_guide-fall2019.pdf](https://www.umass.edu/titleix/sites/default/files/documents/sexual_violence_resource_guide-fall2019.pdf)) to find more information about resources and reporting options. Please reach out to us if you would like assistance connecting with any of these resources/options. You may also contact William Brady, the Interim Title IX Coordinator by email at [wbrady@umass.edu](mailto:wbrady@umass.edu) or by phone at (413) 545-6204 if they have any questions or want to make a report, file a complaint, find out about resources and/or academic support.

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