

ECE 244: Modern Physics & Materials for Electrical Engineering

Department of Electrical and Computer Engineering
University of Massachusetts at Amherst

Spring 2022

Lecture:	Prof. Neal G. Anderson MWF • 11:15-12:05 ELAB 303
Discussion:	Prof. Rama Janaswamy Tu 2:30-3:45 (Section D01) <i>or</i> Tu 4:00-5:15 (Section D02) Marston 220
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, 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 Fundamentals
 - 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

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*, 7th Edition (Pearson), 2015.
- R.F. Pierret, *Semiconductor Fundamentals (Volume 1)*, 1st (Addison Wesley) or 2nd Edition (Pearson), 1988.

Ulaby and Ravaioli is available from Pearson, including in digital form for the semester (\$46). We will draw from Chapters 3-5. Pierret is available from Pearson in hard copy form (\$73/\$53 new/used) or as a semester rental (\$26). Both textbooks can be purchased through eCampus (see SPIRE), and used hard copies of both are widely available.

Discussion

Discussions are an integral part of the course and will meet every week. Attendance is considered essential for your success in the course and will factor into your final grade. The purpose of the discussions is to give you additional insight into the course material by way of working out relevant examples for gaining mastery of the subject and by considering potential applications of the theory. Examples considered during the discussion hour should also aid you with working out homework problems. Periodic homeworks will be assigned throughout the course and you will have one-week to complete and submit it on Gradescope. Solutions will be provided within two days of the submission deadline. No homeworks will be accepted for grade after the solutions have been posted. You can expect at least 8 homework sets distributed over the semester. Some homework problems will involve MATLAB coding and graphing.

There will be a 15-minute quiz during every discussion class and it will be graded. You are expected to take the quiz in class. You will be scanning and posting your quiz solutions directly on Gradescope upon completion. As determined by the discussion instructor, you may also have a pre-exam quiz lasting the whole period to help you prepare for an upcoming exam. Makeup of quizzes will not be offered unless you have a sporadic, excusable conflict for missing discussion class or if you fall ill.

Grading

Exam I - 20% • Exam II – 20% • Final Exam – 20%
Problem Sets - 25% • Discussion – 15%

Policies and Statements

Classroom Safety • For the health and safety of all members of our campus community, students are expected to follow all [COVID-related policies on campus](#). In particular, students must follow the masking policy. Your instructor will remind you, but it is your responsibility to wear a (preferably high quality) mask that securely covers your mouth and nose. If you are unwilling to mask, you will be asked to leave the class. If you do not leave the class, the instructor will end the class, and the Dean of Students office will be informed that you have disrupted class and violated the [Guidelines for Classroom Civility and Respect](#). Anyone with a mask exemption must provide prior written notice to the instructor and must maintain at least six feet of distance from faculty and other students at all times.

Inclusivity • Everyone should feel that they are an integral part of the community and that all individuals and their perspectives are respected. A diversity of perspective and experience provides 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 me privately. If you wish to communicate with someone else in the College or University, there are several ways to do so anonymously or to provide contact information if you so choose:

1. Notify the University Diversity, Equity, and Inclusion Office through the “Report a Climate Incident” form: <https://www.umass.edu/diversity/incident-report-form>
Note that this form requires sharing name and contact information.
2. Speak with Assistant Dean Dr. Paula Rees (rees@umass.edu).
3. Report an incident anonymously to the College of Engineering Diversity, Equity, and Inclusion Office
 - Climate Concerns and Suggestions - <https://tinyurl.com/UMassEngineerClimate>
 - Classroom Experience - <https://tinyurl.com/UMassEngineerClassroom>
4. Reach out to the departmental DEI Committee. You can find the anonymous ECE feedback form on <https://ece.umass.edu/ece-diversity-equity-inclusion> (scroll down for feedback link)

We are all members of an academic community with a shared responsibility to cultivate a climate where all individuals are valued and where both they and their ideas are treated with respect.

Accessibility Support Services • Your success in this class is important to me. 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 all students 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 me in a timely manner. If you have a disability but are not yet affiliated with Disability Services, please register with Disability Services (<https://www.umass.edu/disability/students>). Information on services and materials for registering are also available on their website 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 being fully included in the class, please let me know as soon as possible. Together we'll develop strategies to meet both your needs and the requirements of the course.

Academic Honesty Statement • Maintaining the integrity of scholarship and research within institutions of higher education requires a cultural commitment. All members of the UMass Amherst community are expected to be knowledgeable of and uphold our academic honesty policies (<https://www.umass.edu/honesty/>). Academic dishonesty includes but is not limited to cheating, fabrication, plagiarism, and *abetting or facilitating* dishonesty. Instructors are requested to take reasonable steps to address academic misconduct, and appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Any person who has reason to believe that a fellow student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor or an alternate, trusted member of the faculty or College administration 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. Community members may fill out the College's classroom experience form (<https://tinyurl.com/UMassEngineerClassroom>) to report academic dishonesty anonymously. 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.

Cheating and Plagiarism Policy • The University Academic Honesty Policy Applies in this and all courses. This policy can be found on the University Web Page (<https://www.umass.edu/honesty/>). Appendix B covers plagiarism, cheating, fabrication, and facilitating dishonesty. Students are expected to be familiar with the definitions and examples provided.

Health and Wellbeing • You are not alone at UMass – many people care about your wellbeing and many resources are available to help you thrive and succeed. The College recognizes that coursework is challenging and that classes are not the only demand in your life. Success in this course and the College of Engineering depends heavily on your personal health and wellbeing. Recognize that while stress is an expected part of the college experience, it can be compounded by unexpected setbacks or life changes outside the classroom. Strive 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 as soon as it occurs and before it becomes too overwhelming.

You can learn about the confidential mental health services available on campus by calling the Center for Counseling and Psychological Health (CCPH) by visiting their website at 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 (<https://www.umass.edu/studentlife/single-stop>). Within the College, you may reach out to myself, your academic advisor, the Office of Student Affairs (<http://engineering.umass.edu/current-students/academics-advising>) or the Office of Community Equity and Inclusion (rees@umass.edu). I encourage you to contact support services on campus that stand ready to assist you. Remember that I am here to help you find the resources you need.

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, please see this resource: https://www.umass.edu/stonewall/sites/default/files/pronouns_intro.pdf

Gender Respect and Title IX • The University of Massachusetts Amherst aspires to be a university environment that is free of discrimination, sexual harassment, and sexual violence. Faculty have the responsibility to inform students of resources and reporting options. If you or someone you know has experienced sexual assault, sexual misconduct, or sexual discrimination please see <https://www.umass.edu/titleix/what-to-do> for information about resources and reporting options. A report to the Title IX Coordinator may be made at any time (including during non-business hours) by using the Title IX Coordinator's email (TitleXCoordinator@umass.edu), telephone number (413.545.6124) or mail. UMass Amherst is committed to supporting community members who report concerns of prohibited conduct. Please reach out to me if you would like assistance connecting with any of these resources/options.