ECE 398RI

Fields and Waves Virtual Reality Laboratory

Prof. Raluca Ilie
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2:00-2:50 (R1), 3:00-3:50 (R1), 4:00-4:50 (R3) 3014 ECEB www.ilie.ece.illinois.edu/ece-398-ri
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Course Description

This course is designed to be taken concurrently with ECE 329 "Fields and Waves I" (or PHY 212 "University Physics: Electricity & Magnetism") to strengthen the student's understanding of the concepts in electromagnetism and their applications through customized Virtual Reality (VR) experiences. Topics include static and quasi-static electric fields, polarization, static and quasi-static magnetic fields, dynamic fields and Maxwell's equations, wave solutions of Maxwell's equations in free space, and homogeneous media.

Student competencies around conceptual understanding of electromagnetism topics, as well as their understanding of mathematical concepts, will be measured via formative and summative assessments. Each lab period includes a multiple-choice test. Questions are designed to primarily measure conceptual understanding of the various topics, rather than measuring the ability to simply manipulate equations, and are tied to the specific contexts and topics of that lab's instruction.

Learning Objectives

Upon successful completion of this course, students will be able to:

- Explain Coulomb's Law and the generation of electric fields in point charge systems.
- Interpret Gauss' Law and the conditions under which it simplifies the calculations for the electric field.
- Use divergence and curl operators to analyze field behaviors and relate vector calculus operators to physical properties of electric and magnetic fields.
- Understand the concept of electrostatic potential and conservative electric fields; distinguish between conservative and non-conservative electric fields based on visual field patterns.
- Describe how dielectric materials affect electric fields and polarization; analyze field behavior in capacitors using VR representations of fields in media; assess the role of material properties on field distribution.
- Visualize the magnetic fields generated by various current configurations and explain Ampère's Law in the context of current loops and solenoids; compare and contrast the Earth's magnetic field with idealized systems.

- Use VR to simulate changing magnetic fields and resulting electromotive forces (EMF); Construct interpretations of motional EMF from interactive simulations; Describe Faraday's and Lenz's Laws in dynamic systems.
- Use VR to visualize the propagation of a TEM wave in guided cavities and a coaxial cable; describe the transverse nature of electromagnetic waves and their propagation in free space.
- Explain the physical meaning and implications of Maxwell's equations in different electromagnetic scenarios; describe the behavior of electric and magnetic fields in static, quasi-static, and dynamic regimes.
- Define key concepts such as polarization, electric field, magnetic field, and wave propagation in homogeneous media; distinguish between static, quasi-static, and dynamic field configurations and their applications in real-world systems.
- Use VR to investigate linear, circular, and elliptical polarization states; understand the nature of wave polarization and its physical significance; assess the impact of wave polarization in real-world applications (e.g., optics, antennas).
- Use VR to visualize and model wave propagation in transmission lines through bounce diagrams; understand wave reflection and transmission at boundaries using boundary conditions; assess how changes in boundary conditions affect wave behavior in single and multi-line bounce diagrams.
- Design and develop conceptual models or interactive simulations to illustrate key principles of electromagnetism; break down complex electromagnetic scenarios into component phenomena using conceptual and mathematical frameworks; critique the assumptions and limitations inherent in simplified electromagnetic models presented in VR simulations.

Prerequisites

Concurrent enrollment in ECE 329 or PHY 212.

Main References

The lab's instruction is aligned with that of ECE 329 and PHY 212.

Laboratory Equipment

Students enrolled in ECE 398 will be granted 24/7 access to the **ECE VR Lab located in ECEB 3014**. The VR Lab consists of 10 stations equipped with gaming-grade GPUs and Oculus Rift S headsets. All stations have Unity installed. During the instruction lab period, students will complete a quiz of the type described above while allowed to go back to the VR experience for guidance.

Schedule

Date	Topic of Instruction
Week 1	**VR:** Oculus Headset Tutorial **VR:** Coulomb's Law
Week 2	**VR:** Gauss' Law **VR:** Vector Calculus ($\nabla \times \mathbf{A}$,$\nabla \cdot \mathbf{A}$, ∇f)
Week 3	**VR:** Electrostatic Potential **MD:** Conservative Fields, Path Independence **Final Project - team forming and discussion**
Week 4	**VR:** Polarization Electric Field **VR:** Fields in Media, Capacitance
Week 5	**VR:** Ampere's Law **VR:** Current Sheet, Solenoid, Current Loops **VR:** Earth's Magnetic Field
Week 6	**VR:** Faraday's Law **VR:** Lentz's Law **VR:** Motional EMF
Week 7	**VR: TEM Wave Propagation** **MD:** Current Sheet Radiator
Week 8	**Review of Maxwell's equations**: Imagine the narrative (in-class exercise).
Week 9	**VR:** Wave Polarization
Week 10	**Final Project - Office Hours**
Week 11	**MD:** Wave Reflection and Transmission **MD:** Standing Waves **VR:** Bounce Diagram: single and multi-lines transmission line systems
Week 12	**Lab Make Up** *Sign up required*
Week 13	**Final Project Presentations**

Table 1: MD = Mathematica Demo, VR = Virtual Reality experiences
Note: New VR experiences (in addition to the ones listed here), are currently under development, and we anticipate to use them as they become available.

Grading Policy

In class quizzes (70%), Final Project (30%)

Extra Credit: After-class Survey (5%)

In Class Quizzes

- Each lab session is followed by an in-class quiz (10 quizzes in total). These quizzes test conceptual understanding and will be administered via Gradescope or in VR during class time.
- You are allowed to work with your lab partner, but the work you submit should belong to you.
- You are allowed to go back into the VR experiment to play and work out your answer.
- Note that if you have knowledge of a violation of the Honor Code, you are obligated to report it. By submitting the quiz, you agree to the Honor Code: "I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code."

Final Project Information

SCOPE

- Devise an original experiment or interactive demonstration that illustrates one or more of Maxwell's equations. Your project may incorporate hardware (e.g., sensors, circuits), software (e.g., simulations, visualizations), theoretical analysis (e.g., analytical modeling), or a combination of these components.
- The goal is to make abstract electromagnetic principles concrete and intuitive, especially through visual, interactive, or immersive elements. Your design should clearly identify the specific Maxwell equation(s) being addressed and provide a means (either qualitative or quantitative) for observing or testing the associated electromagnetic behavior.

GUIDELINES

- The project must clearly identify the Maxwell equation(s) being demonstrated and include a description of the physical or simulated setup.
- The project must integrate data, visualization, or interactivity to enhance conceptual understanding and be presented in a format that is understandable to peers (e.g., VR, lab kit, digital applet).
- Students will work in teams of two or three students.

EVALUATION

- Each team will have an oral presentation of their projects.
- Each team will submit a write-up of their project; the page limit is 10. A template will be provided to you, and you are **required** to use it. The written portion of the project should be submitted via Gradescope no later than **DATE**.
- You will be evaluated on creativity (40 points), oral presentation (30 points), and written presentation (30 points). Late written reports will be penalized 10% of the grade per day from the due date.

Extra Credit: After-class Survey

We need your feedback to improve the development of the VR labs; therefore, you will be invited to complete an anonymous survey after the class is completed. To receive the extra credit, you will need to save the confirmation emails and submit the top portion as a document via Gradescope. You will be instructed on how to proceed in class.

Class Philosophy

- Research has demonstrated that the best learning occurs when the learner is actively involved. Thus, the students are expected to come to class prepared to **think, participate in active learning activities, and learn.**

Class Policy

- The classroom is a learning environment. Please avoid distractions for yourself and others.
- Please turn off your cell phone during class. Do not keep your cell phone on your desk. NO TEXTING during class.

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: https://studentcode.illinois.edu/article1/part4/1-401/. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Health Safety

Following University policy, all students are required to engage in appropriate behavior to protect the health and safety of the community.

Students who feel ill must not come to class. Students who fail to abide by these rules will first be asked to comply; if they refuse, they will be required to leave the classroom immediately. If a student is asked to leave the classroom, the non-compliant student will be judged to have an unexcused absence and reported to the Office for Student Conflict Resolution for disciplinary action. Accumulation of non-compliance complaints against a student may result in dismissal from the University.

Students with Disabilities

To ensure equity for each student's educational experience, those with a documented disability and required accommodations should contact me early in the semester so that all learning needs may be appropriately met. If you have not yet contacted DRES, please do so as soon as possible.

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnose a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Anti-Racism and Inclusivity Statement

This classroom is a place where you will be treated with respect. I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, national origins, religious affiliations, sexual orientations, abilities - and other visible or non-visible differences. All members of this class are expected to contribute to a respectful, welcoming, and inclusive environment for every other member of the class.

The intent is to raise student and instructor awareness of the ongoing threat of bias and racism and of the need to take personal responsibility for creating an inclusive learning environment. The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity, national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality can be found here: https://wecare.illinois.edu/resources/students/confidential. Other information about resources and reporting is available here: https://wecare.illinois.edu.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to the Family Educational Rights and Privacy Act (FERPA) should self-identify with the instructor to ensure the protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.