University of Victoria Department
of Physics and Astronomy

Physics 422 - Electromagnetic Theory

Spring 2026 Syllabus

General Information

Instructor: Arthur Blackburn
Email: ablackbu@uvic.ca
Office: Elliot 108
Office Hours: As arranged within course
Course Webpage: https://bright.uvic.ca/d2l/home/432651
CRN: 22649
Units: 1.5
Hours (Lecture-Lab-Tutorial): 3 - 0 - 0

Lecture Schedule:

Monday and Thursday, 1:00 - 2:20 pm
Location: TBA

Office Hours:
Tuesday 3:30 pm – 4:30 pm, Room to be confirmed: Elliott 108 / Elliott 038.

Prerequisites:

PHYS 326; MATH 301; MATH 342; MATH 346, or permission of the department.

Required Materials:

Text: Griffiths, "Introduction to Electrodynamics" (4th or 5th Edition preferred, 3rd is also acceptable). (The approximate cost in 2024 of this book is ~$CAD 80).

In addition, you should have access to a computer with either a Python, Matlab or Octave programming environment.

Accommodations:

Accommodations can be made for missed exams/assignments due to illness or other severe affliction, as well as conflicts with classes and religious observances. Accommodations will also be made for issues documented through CAL.

If you miss an exam or assignment, I expect you to contact me as soon as possible. If you anticipate missing a course requirement, you must contact me a reasonable time in advance. If an emergency occurs during a test, please talk to me. I can't help if I don't know about the problem.

Content

This one-semester upper-level undergraduate course in electromagnetic theory will cover the following topics:

- Electrodynamics
- Conservation Laws
- Electromagnetic Waves
- Potentials and Fields
- Radiation
- Electrodynamics and Relativity

These topics are discussed in chapters 7 to 12 of the textbook "Introduction to Electrodynamics: D. J. Griffiths. The lectures will provide a synopsis of these chapters, emphasize the most important concepts for each of the topics, and supplement this through working upon examples and problems using analytical and numerical approaches. A more detailed description is given later in 'Course Topics and Reading Plan'.

Course Learning Outcomes

Success in this course will be shown through students demonstrating their ability to perform the following grouped-by-topic learning outcomes:

Fundamentals of Electrodynamics

- Define and calculate Electromotive Force (EMF) in circuits.
- Apply and understand Ohm's, Faraday's and Lenz's laws.
- Apply displacement current to solve time dependent problems, and understand how it resolves the inconsistency in Ampère's law.
- Derive and apply boundary conditions for the fields in Maxwell's equation at interfaces between different media.

Conservation Laws

- Energy: Derive, interpret and apply Poynting's theorem.
- Charge: Apply the principle of charge conservation to dynamic situations.
- Momentum: Apply the conservation of momentum for electromagnetic fields to determine the electromagnetic stress tensor and use this to calculate the total electromagnetic force and force density acting on a volume.

Waves

- Utilize Maxwell's equations to derive the wave equation for electric and magnetic fields in a vacuum.
- Characterize electromagnetic (EM) plane wave solutions (using frequency, wavelength, wave number, wave vector, speed, and polarization).
- Calculate the energy density, Poynting vector (energy flux), and momentum density associated with electromagnetic waves.
- Apply electromagnetic boundary conditions at interfaces to derive Fresnel's equations for reflection and transmission at both normal and oblique incidence.
- Describe wave attenuation and the “skin depth” when waves propagate through conductors, as well as the effects of absorption and dispersion.
- Analyze the propagation of waves in rectangular confined geometries.

Potentials and Fields

- Define and work with the scalar potential and (magnetic) vector potential in time dependent situations.
- Use and understand the concepts gauge freedom and invariance, particularly employing the Coulomb and Lorenz gauges, to simplify potential and field calculations.
- Calculate the potentials and fields produced by moving point charges and distributions, accounting for the speed of light through the use of retarded time, Liénard-Wiechert potentials or Jefimenko’s Equations as appropriate.

Radiation

- Distinguish between fields that simply move with a charge (velocity fields) and radiation fields (acceleration fields) that decrease as $1/r$.
- Derive the potentials and fields for an oscillating electric and magnetic dipole and calculate their time-averaged Poynting vector and total radiated power.
- Apply the Larmor formula to calculate the total power radiated by a non-relativistic generalized accelerating point charge, or arbitrary distribution of charge.
- Understand and apply how radiated power increases significantly as a particle's velocity approaches the speed of light, following the Liénard’s relativistic generalization of the Larmor formula.

Electrodynamics and Relativity

- Understand and apply the fundamental postulates of special relativity.
- Apply mathematical tools, such as the Lorentz transform, for transforming space and time coordinates between inertial systems, to determine the consequences of time dilation, length contraction, and the relativity of simultaneity in electrodynamics.
- Utilize Minkowski space to represent physical quantities as four-vectors (such as position-time, energy-momentum, and current density) and understand the role of invariant intervals.
- Transformation of Fields: Derive and apply the transformation rules for electric and magnetic fields.

- The Field Tensor: Construct and manipulate the electromagnetic field tensor $\boldsymbol{F}^{\mu\nu}$.
- Express Maxwell's equations in a manifestly covariant form using tensors, demonstrating their inherent consistency with special relativity.
- Solve simple problems involving the dynamics of charged particles in electromagnetic fields within the framework of special relativity.

Methods

- Can perform the calculations and problems above using numerical methods, combined with analytical solutions as appropriate, where the numerical methods are coded using either the Python, Matlab or Octave programming languages.

Assessment and Grading

Assignments: 34%

Assignments will be given throughout the semester,

Assignments will be given throughout the semester, which will include a mix of pen-and-paper question, as well as computational questions.

Five of these assignments will be primarily pen-and-paper questions, that typically produce closed form solutions by analytical methods, though they may also have some small numerical aspects that could be assisted by numerical computational methods. These assignments in total will contribute to 25 % of the total available marks for the course, or equivalently 25/34 (≈ 73.5 %) of the marks for assignments.

There will also be three computational based assignments that require computational coding using the student's choice of either Python, Matlab or Octave programming languages. These assignments in total will contribute to 9 % of the total available marks for the course, or equivalently 9/34 (≈ 26.5 %) of the marks for assignments.

Assignment Policy: You are allowed to collaborate on assignments, so long as your work and your solutions are your own. I take a very strict stance on copying and academic infringement, but I do understand the value of collaborative work. Discussing with a friend is no different from discussing with a professor, except it will likely help your friend learn the material better! However, if you scribe their answers, I will know and there will be consequences!

Midterm Exam: 20%

The midterm will be a 1-day timed take-home assignment that covers all the material covered up to that point. Students are NOT permitted to collaborate in any way on this work, despite the similarity to an assignment.

Final Exam: 46%

The final exam will be a 1-day take-home exam with traditional problems to solve. It will be comprehensive and require knowledge of all the course material. However, the exam will focus primarily on the material after the midterm, with the pre-midterm material providing the necessary tools and techniques to solve the problems of the final exam.

Essential Requirements

The student must attempt the final exam and attempt and submit at least one computational based assignment.

If the application of this scheme would result in grades that are judged by the instructor to be inconsistent with the University's grading descriptions (as described at

https://www.uvic.ca/calendar/undergrad/index.php#/policies

under "Undergraduate Academic Regulations – Grading") then the instructor will assign percentages consistent with them.

University Regulations on Academic Integrity

These regulations are summarized https://www.uvic.ca/students/academics/academic-integrity/index.php. For full information, including procedures for dealing with academic integrity infringement, see the webpage linked above.

Academic integrity requires commitment to the values of honesty, trust, fairness, respect, and responsibility. Any action that contravenes this standard, including misrepresentation, falsification or deception, undermines the intention and worth of scholarly work and violates the fundamental academic rights of members of our community.

Several types of academic integrity violations are covered in brief below.

Plagiarism

A student commits plagiarism when he or she:

- submits the work of another person as original work
- gives inadequate attribution to an author or creator whose work is incorporated into the student's work, including failing to indicate clearly the inclusion of another individual's work
- paraphrases material from a source without sufficient acknowledgement as described above

Students who are in doubt as to what constitutes plagiarism in a particular instance should consult their course instructor.

Falsifying Material Subject to Academic Evaluation

Falsifying materials subject to academic evaluation includes, but is not limited to:

- fraudulently manipulating laboratory processes, electronic data or research data in order to achieve desired results
- using work prepared by someone else (e.g., commercially prepared essays) and submitting it as one's own
- citing a source from which material was not obtained
- using a quoted reference from a non-original source while implying reference to the original source
- submitting false records, information or data, in writing or orally

Cheating on Assignments, Tests/Quizzes and Examinations

Cheating includes, but is not limited to:

- copying the answers or other work of another person
- sharing information or answers when doing take-home assignments, tests and examinations except where the instructor has authorized collaborative work
- having in an examination or test any materials or equipment other than those authorized by the examiners impersonating a candidate on an examination or test, or being assigned the results of such impersonation
- *assisting others to engage in conduct that is considered cheating*

Opportunities for in-term feedback to instructor

Students are welcome to provide feedback on the course as it progresses, ideally in discussions during office hours.

Use of Technologies

This course involves a significant amount of calculus, involving perhaps some non-trivial integration and differentiation. Unless explicitly stated in the question, students should answer the questions posed in their work using their prior mathematics knowledge and training, along with that provided in the course, without use of a Computer Algebra System (CAS). However, students are permitted to use a CAS to check their own results. If a CAS is used in the determination or checking of an answer, and that reveals a different answer to that which the student obtained without using a CAS, the student is welcome to note the result obtained by the CAS, stating how or with what system that result was obtained. Provided the student can indicate the key steps that would need to be performed to obtain the result obtained by CAS (if it is different to that obtained without using CAS), marks will be awarded for the CAS-guided solution, provided the student demonstrates understanding of the mathematical steps required to produce their CAS based solution.

The CAS may be the use of free online tools such Wolfram Alpha https://www.wolframalpha.com/, SymPy within Python, or the symbolic math toolbox in Matlab. Use of other CAS like tools, including those which are integrated with AI based tools such ChatGPT are permitted, provided their use is clearly stated in submitted materials and described as above. If students use such tools they may, at the instructor's discretion, be asked to discuss their use of the tool with the instructor.

Course Topics and Reading Plan

Students are expected to read through the recommended text, to supplement their understanding of the material. Ideally, a cursory quick reading of the chapter related to the topic description should be carried out before the class as below, even though it is unlikely that the student will gain a full understanding of the material in that first reading. The content will of course be reviewed in class, though a significant portion of the class may be spent going over examples. In some cases, which will be pointed out in class, the expectation is that some steps of detailed theoretical proofs may be left for the student to work over in their own time though the instructor will describe the key steps required to make such proofs. A second reading of the relevant section of the text book, as may be required to complete assignments and fully grasp the material, after the class should be performed.

Week	Date (notes)	'Pen-and-Paper' Assignment # Set	Due	Compuational Assignment # Set	Due	Book Chapter	Topics
1	January 5, 2026	1					**Review and Background**:
	January 8, 2026					2 -6	Gauss's Law, Faraday's Law, Poission's Equation,
							Multipoles, Polarization, Magentization,
2	January 12, 2026			A			Magnetostatics, Magnetization
	January 15, 2026						**Electrodynamics**: Motional EMF,
						7	Induction & Maxwell's Equations
3	January 19, 2026	2	1				**Conservation Laws**:
	January 22, 2026					8	Charge,
							Energy,
4	January 26, 2026						Momentum - Stress Tensor
	January 29, 2026						
		3	2	B	A		
5	February 2, 2026						**Waves**
	February 5, 2026						General Properties, Key Equations
							Energy and Momentum
6	February 9, 2026					9	EM Wave in Matter
	February 12, 2026						In Polarizable Matter
			3				In Conductive Media
Reading Break	February 16, 2026 (a)						Wave Guides
	February 19, 2026 (b)	[Possible Mid-Term Date]					
	Feb 20 / Feb 21, 2026 (c)	[Possible Mid-Term Date]					
7	February 23, 2026						
	February 26, 2026 (d)	4					**Potentials and Fields**
				C	B		Magnetic Potential
8	March 2, 2026					10	Coulomb Gauge and Lorenz Gauge
	March 5, 2026						Lorenz Gauge Solutions
							Jefimenko Equations
9	March 9, 2026						Lienard-Wiechert Potentials
	March 12, 2026	5					
			4				**Radiation**
10	March 16, 2026					11	Fields of Point Charges
	March 19, 2026						Radiation
							Generalized Radiation
11	March 23, 2026						
	March 26, 2026 (e)	6*(e)					**Electrodynamics and Relativity:**
			5		C		Relativistic Electrodynamics
12	March 30, 2026					12	
	April 2, 2026						
							Revision

Notes on the above are on the next page.

a - No Class - Reading Break & Family Day (Holiday)

b - No Class - Reading Break, and also a possible date for the Mid-term.

c - Possible Dates for Mid-Term (to be discussed in class)

d - Honours Fest immediately follows this session. For those of you attending there is time to join this

class and honours fest, but if necessary I'll do my best to accommodate those who must leave early.
*e - This 'assignment' will include sample questions. I will I go over some questions in last the lecture and I will also post solutions online after classes finish for you to self-evaluate, as part of your revision.

Resources

a. UVic Learn Anywhere. UVic Learn Anywhere is the primary learning resource for students that offers many learning workshops and resources to help students with academics and learning strategies.
b. Library resources (https://www.uvic.ca/library/index.php)
c. Indigenous student services (ISS)
d. Centre for Academic Communication (CAC)
e. Math & Stats Assistance Centre (MSAC)
f. Learning Strategies Program (LSP)
g. Academic Concession Regulations
h. Academic Concession and Accommodation
i. Academic Accommodation – Policy AC1205

Further resources and policies

University statements and policies

a. University Calendar - Section "Information for all students"
b. Creating a respectful, inclusive and productive learning environment
c. Accommodation of Religious Observance
d. Student Conduct
e. Non-academic Student Misconduct
f. Accessibility
g. Diversity / EDI
h. Equity statement
i. Sexualized Violence Prevention and Response
j. Discrimination and Harassment Policy

Student groups and resources

a. Student wellness
b. Ombudsperson