# Electro & Magnetostatics Syllabus [PHYS 3122]

## 1. General Information

**Class Time**: Mon., Wed., & Fri. 11.00 am–11.50 am
**Online Location**: http://bluejeans.com/710377913
**Class Location**: Howey L5 (Strict schedule of in person attendance, see below)

**Instructor**: Dr. Martin Mourigal, Associate Professor
**Research**: Condensed matter physics, quantum materials, magnetism, scattering
**Email**: mourigal@gatech.edu (Please include [3122] in email title)
**Mobile**: 404-747-4969 (In case of academic or personal emergency)
**Office Hours**: Online, Wednesday 4-5 pm & Thursday 4-5 pm (Tentative).
**Slack channel**: phys3122.slack.com, to join click here.

| **TAs**: | Jason Dark | Caleb Anderson |
|---|---|---|
| **Research**: | Mesoscopic Physics | Soft Matter |
| **Contact**: | jfdark@gatech.edu | canderson313@gatech.edu |
| **Office Hours**: | Online, TBA | Online, TBA |

## 2. Course content and materials

**Textbook**: David J. Griffiths, *Introduction to Electrodynamics*, 4th Edition.
**Publisher**: Pearson (Paperback, 2015, $\leq$ \$20) or Cambridge (Hardcover, 2017, $\leq$ \$70).
**Lecture Notes**: Handwritten notes will be posted on Canvas before or just after each class.
**Course Website**: I will be using Canvas to post announcements, assignments and notes.
**Pre-Requisites**: Intro. Physics II (e.g. PHYS 2212) and Diff. Equations (e.g. MATH 2403).

**Overview**: This is an **advanced undergraduate course in electromagnetism**, one of the most beautiful and successful theory in Physics. In this course, we will work within the realm of **classical mechanics** to construct a theory of electromagnetism applicable to **vacuum and matter**. The fundamental problem we hope to solve can be formulated simply: *"I hold up a bunch of electric charges here (and maybe shake them around); what happens to some other charge, over there?"*. As we will see, the solution is best formulated in terms of a **field theory** which is the study of **Maxwell's equations** using the powerful mathematical tool of **vector analysis**. This semester in Phys 3122, we will be primarily concerned with physical situations in which charges are static or traveling at constant velocity, namely **electro and magnetostatics**. Next semester, you may choose to study the case of accelerating charges in **electrodynamics** (Phys 3123). Electromagnetism is a gateway to advanced **theoretical physics** but also an ubiquitous tool for **applied sciences** with deep ramifications in electrical & computer engineering, materials science, atmospheric sciences, aerospace engineering, and more. I hope you will find the course enjoyable, fun and useful for your future career as scientist or engineer.

**Topics from Griffiths**: This course will cover chapters 1 to 6 from Griffiths:

1. *Vector Analysis*: Differential and integral calculus, curvilinear coordinates, delta function.
2. *Electrostatics*: Electric field, electric potential, work and energy.
3. *Potentials*: Laplace's equation, method of images, multipole expansions.
4. *Electric Fields in Matter*: Polarization, dielectrics, electric displacement, linear media.
5. *Magnetostatics*: Magnetic field, magnetic force, vector potential
6. *Magnetic Fields in Matter*: Magnetization, auxiliary field, susceptibility, ferromagnetism.

**Lecture plan**: The lectures will be divided in 44 units treating in detail the following material:

1. Syllabus and course operations
2. The role of electromagnetism in physics
3. Postulates of classical electromagnetism and field theory
4. *Mathematical interlude I: vector algebra, coordinate systems*
5. Coulomb's law: theory
6. Principle of superposition: discrete and continuous charge distributions
7. Application of Coulomb's law: several examples
8. Gauss's Law: integral form
9. *Mathematical interlude II: multivariable calculus*
10. Gauss's Law: local form
11. Application of Gauss's law
12. *Mathematical interlude III: Dirac's delta*
13. The curl of E and Helmholtz theorem
14. Electric Potential
15. Poisson's and Laplace's equations
16. Boundary conditions
17. Electrostatic Energy
18. Conductors and Capacitance
19. Solving Laplace: general idea
20. Method of images: several examples
21. Separation of variables: theory
22. Application of separation of variables in cartesian coordinates
23. Application of separation variables in spherical coordinates
24. Multipole expansion: general principle
25. Discrete and continuous multipoles
26. Properties of pure dipoles and quadrupoles
27. Electrostatic fields in matter and dielectrics
28. Bound charges and polarization
29. Electric displacement
30. Linear dielectrics
31. Application to a dielectric sphere in a uniform field
32. Introduction to magnetostatics
33. Lorentzforce
34. Currents and continuity equation
35. Biot and Savart: theory and application
36. Ampere's law: theory
37. Application of Ampere's law
38. Magnetic vector potential: theory and gauge transformation
39. Application of the magnetic vector potential
40. The meaning of the vector potential: boundary conditions, Aharonov-Bohm effect
41. Multipole expansion and the vector potential of a pure magnetic dipole
42. Microscopic theory of magnetism
43. Bound and free currents
44. Linear and non-linear magnetic media

## 3. Course Requirements and Grading

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|---|---|---|
| **Grading**: | Weekly Homework (11 assignments, 10 best scores: 6 points each) | 60 points |
| | Quizzes (2 assignments: 10 points each) | 20 points |
| | Final Exam (1 assignment) | 20 points |
| | Total | 100 points |
| **Letter Grades**: | A: 90 points or more, B: 80–89, C: 70–79, D: 60–69, F: 59 or less | |
| | Final score rounded to the next integer: 89.58 → 90(A), 79.42 → 79(C) | |
| **Homework**: | There will be 11 homework assignments, see schedule. | |
| | Assigned in CANVAS in a given week, usually on Friday. | |
| | Due by the end of the following week, preferably by Friday, but Sunday is fine. | |
| | No penalty if your turn the homework late (within reason), but don't fall behind! | |
| | Homework will be submitted electronically (preferably as a single file) using CANVAS. | |
| | Your 10 best scores will be kept when calculating your homework average. | |
| **Quizzes**: | There will be 2 quizzes scheduled during regular class time, see schedule. | |
| **Attendance**: | No attendance requirement. | |
| | But success requires mastering the lectures' material and working hard on homework. | |
| **Reading**: | Reading relevant parts of the textbook before and after class is extremely important. | |
| | I am only the guide, you have to actively do the learning. | |

## 4. Special measures given COVID-19

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|---|---|
| **Lectures**: | Live broadcast on Bluejeans: http://bluejeans.com/710377913 |
| | Students attending in person will be assigned a group (A/B) and follow the schedule below. |
| | Attendance groups (A/B) will have a maximum of 12 students each. |
| **Questions**: | Questions from remote participants can be asked by voice or using the chat (preferred). |
| | A student participating in person will be asked to moderate the chat, on a rolling basis. |
| **Safety** : | Face covering must be worn at all times (inside and outside the classroom). |
| | Occupy your assigned seat only, only ask questions from your assigned seat. |
| | Do not come to the white-board to talk to me before or after class. |
| | Do not congregate in the corridor, wait outside the building before I call the class in. |

## 5. Course Expectations and Guidelines

**Academic Integrity**: Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. Visit `http://www.catalog.gatech.edu/rules/18/` for information on Georgia Tech's Academic Honor Code.

**Honor Code and Homework Solutions**: Given COVID-19, it will be especially important to adhere to the honor code. You may not use sources that contain the answer to a problem that I assign in homework. In particular, do not use solution sets from previous years. Similarly, exams and their solutions from past years are not to be used in any fashion. To practice your problem solving skills, the best is to do problems in Griffiths, the solutions for which you are allowed to consult (easy to find online). Note that this is only valuable if you try to solve the problems first.

**Collaboration and symbolic computing policy**: You are strongly encouraged to discuss homework assignments with each other, but the solutions have to be executed and submitted individually. Around my and the TA's offices hours, we will form study groups to tackle the weekly assignments and discuss course content where needed. We have created a SLACK channel to centralize all the discussions about the class: use it! MATHEMATICA (or WOLFRAM ALPHA) may be used in problem sets to get past some mathematical chore (not for gaining knowledge of the physics). Make sure you simplify the result as much as possible, so that it is easy to see what the math is telling you.

**Timed quizzes and final exam**: The two quizzes and the final exam will be conducted remotely with a fixed time window during the assigned class time (or final exam time). These will be conducted with "everything closed" (no book, no notes, no internet, no chat, no text messages) but the exam cover sheet will include a lot of useful formulas. You will receive the exam through Canvas, and will have to upload pictures or a pdf (preferred) of your work by the end of the exam time (with some tolerance for technical difficulties).

**Cheating and Plagiarizing**: Any student suspected of cheating or plagiarizing on a homework assignment, quiz or final exam, will be reported to the Office of Student Integrity, who will investigate the incident. This being said, you will not be policed by me or by the TAs. For instance we will not use intrusive software such as Honorlock during quizzes and final exam. This is your responsibility to adhere to the guidelines above. If you betray the Honor code, cheat, and do not get caught, you will have to live with the resulting disturbance in the electromagnetic field for the rest of your life. If you get caught, you will have to face severe consequences. So why taking the risk? Also, remember that it is infinitely better to fail honorably than to succeed dishonestly (although this principle seem to be currently unpopular in the United States).

**Missed Exams**: If you anticipate missing a quiz, contact me in advance.

**Students with Disabilities**: If you are a student with learning needs that require special accommodation, contact me and the Office of Disability Services at `http://disabilityservices.gatech.edu/` or (404)894-2563, as soon as possible, to make an appointment to discuss your needs.

**6. Course Schedule** Please visit CANVAS for an up-to-date schedule during the semester.

| Week | Day | Date | Lecture | Attendance Group | Homework Assigned | Homework Due |
|---|---|---|---|---|---|---|
| 1 | M | 08/17 | Course Operations | Online | | |
| 1 | W | 08/19 | L01 | A | | |
| 1 | F | 08/21 | L02 | B | HW1 | **No** |
| 2 | M | 08/24 | L03 | A | | |
| 2 | W | 08/26 | L04 | B | | |
| 2 | F | 08/28 | L05 | A | HW2 | HW1 |
| 3 | M | 08/31 | L06 | B | | |
| 3 | W | 09/02 | L07 | A | | |
| 3 | F | 09/04 | L08 | B | HW3 | HW2 |
| 4 | M | 09/07 | *Labor Day* | – | | |
| 4 | W | 09/09 | L09 | A | | |
| 4 | F | 09/11 | L10 | B | **No** | HW3 |
| 5 | M | 09/14 | L11 | A | | |
| 5 | W | 09/16 | L12 | B | | |
| 5 | F | 09/18 | **Quiz 1** | Online | HW4 | **No** |
| 6 | M | 09/21 | L13 | A | | |
| 6 | W | 09/23 | L14 | B | | |
| 6 | F | 09/25 | L15 | A | HW5 | HW4 |
| 7 | M | 09/28 | L16 | B | | |
| 7 | W | 09/30 | L17 | A | | |
| 7 | F | 10/02 | L18 | B | HW6 | HW5 |
| 8 | M | 10/05 | L19 | A | | |
| 8 | W | 10/07 | L20 | B | | |
| 8 | F | 10/09 | L21 | A | HW7 | HW6 |
| 9 | M | 10/12 | L22 | B | | |
| 9 | W | 10/14 | L23 | A | | |
| 9 | F | 10/16 | L24 | B | **No** | HW7 |
| 10 | M | 10/19 | L25 | A | | |
| 10 | W | 10/21 | L26 | B | | |
| 10 | F | 10/23 | **Quiz 2** | Online | HW8 | **No** |
| 11 | M | 10/26 | L27 | A | | |
| 11 | W | 10/28 | L28 | B | | |
| 11 | F | 10/30 | L29 | A | HW9 | HW8 |
| 12 | M | 11/02 | L30 | B | | |
| 12 | W | 11/04 | L31 | A | | |
| 12 | F | 11/06 | L32 | B | HW10 | HW9 |
| 13 | M | 11/09 | L33 | A | | |
| 13 | W | 11/11 | L34 | B | | |
| 13 | F | 11/13 | L35 | A | HW11 | HW10 |
| 14 | M | 11/16 | L36 | B | | |
| 14 | W | 11/18 | L37 | A | | |
| 14 | F | 11/20 | L38 | B | **No** | HW11 |
| 15 | M | 11/23 | L39 | A | | |
| 15 | W | 11/25 | *Thanksgiving* | – | | |
| 15 | F | 11/27 | *Thanksgiving* | – | **No** | **No** |
| 16 | M | 12/02 | **Final Exam** | Online | | |