Physics 361: Electricity & Magnetism *Fall 2025*

Prof. Ted Allen
Eaton 108
781-3623 (Office)
http://people.hws.edu/tjallen
tjallen@hws.edu

	Room	Time
Lecture	Eaton 111	1:10-2:40 MW

Required Text
- David Griffiths, *Introduction to Electrodynamics,* 5th Edition.

Recommended Texts
- S. Lipschutz, M. Spiegel, J. Liu , *Schaum's Outline Mathematical Handbook*, 5th Edition.
- M. Nahvi & J. Edminister, *Schaum's Outline in Electromagnetics*, 5th Edition.
- M. Spiegel, *Schaum's Outline of Vector Analysis*

Graduate-level Advanced Text for Further Study Beyond This Course
- J. D. Jackson, *Classical Electrodynamics*, 3rd Edition.

Course Objective
This course is a rigorous introduction to the theory of the electromagnetic field and its interaction with charged matter. By the end of the course, students will be proficient in vector calculus and related techniques, will be able to state Maxwell's equations in differential form, and will be able to use Maxwell's equations to solve simple problems in electrodynamics.

About Physics 361
Maxwell's theory of electromagnetism is the crowning achievement of 19th century physics. It and Newton's mechanics are the two pillars of classical physics. The theory of electromagnetism was the impetus for the development of Einstein's special theory of relativity and forms the basis for understanding much of modern technology. The study of electromagnetism is the first exposure that most physics students have to a field theory, a dynamical theory with an infinite number of degrees of freedom. It is also the first exposure most physics students have to the use of many important and useful analytical techniques.

Course Requirements
Regular Homework Problems
Mid-term Exam(s)
Final Exam

Grading
Grades in this class will be based on the following elements.

- **Participation** I expect each student to do all the assigned readings and problems and to bring questions and comments to class and to participate in class discussions. Implicit in this is the expectation that all students will attend all classes. Some of the lecture material will not be in the text, so it is important that students attend lecture. The grade for participation will be assigned at my discretion at the end of the semester.

- **Homework** Homework will be assigned on a regular basis and collected. I reserve the right not to give credit for late homework assignments, based on the belief that keeping up is an essential ingredient for success in the course. You may work together on the homework. Indeed, I encourage you to work together to understand the problems. However, you must each separately write up solutions in your own words — and equations — and may not turn in something that you do not understand. That is, you may not simply paraphrase someone else's solution as your own. Paraphrasing without understanding, or outright copying, will be considered plagiarism. The correctness as well as the quality of the presentation of your work will both be graded.

- **Exams** There will be at least one mid-term exam and a final exam. The final exam period is on Friday December 19, 2025 from 8:30AM to 11:30AM. The final exam will be comprehensive.
- **Quizzes** There may be quizzes in class, mostly for your own diagnostic use. Any quizzes will be announced in advance and will count towards your participation grade.

The relative weights of each element of the grade for the course is as follows.

Element	Weight
participation	10%
homework	30%
hour exams	30%
final exam	30%

Office Hours
Initially, official office hours will be Monday from 3:00 until 4:00, Tuesday 10:30 until 11:45, and Friday from 2:30 until 4:00. Office hours also by appointment. If these hours are inconvenient for you, please tell me and I'll try to find some more convenient times.

Course Outline

I. REVIEW OF VECTOR ANALYSIS

A. Vector Differential Calculus

1. Gradient

2. Divergence

3. Curl

- *B.* Integral Vector Calculus in Euclidean $\mathbb{R}^3$ and its subspaces
  - *1.* Line integrals and $d\vec{\ell} = \frac{\partial \vec{\mathbf{r}}}{\partial u}\, du$
  - *2.* Surface integrals and $d\vec{\mathbf{a}} = \left(\frac{\partial \vec{\mathbf{r}}}{\partial u_1} \times \frac{\partial \vec{\mathbf{r}}}{\partial u_2} \right) du_1\, du_2$
  - *3.* Volume integrals and $d\tau = \frac{\partial \vec{\mathbf{r}}}{\partial u_1} \cdot \left(\frac{\partial \vec{\mathbf{r}}}{\partial u_2} \times \frac{\partial \vec{\mathbf{r}}}{\partial u_3} \right) du_1\, du_2\, du_3$
  - *4.* Fundamental Theorems: Gradient, Stokes' & Gauss' Theorems
- *C.* Cylindrical and spherical coordinate systems
- *D.* Dirac's δ function
- *E.* Topology & General Theory of Vector Fields

II. ELECTROSTATICS

- *A.* Electric Fields & Field Lines
  - *1.* Electric Flux
  - *2.* Integral & Differential forms of Gauss' Law
  - *3.* $\nabla \times \vec{\mathbf{E}} = \vec{\mathbf{0}}$
- *B.* Electric Potentials
  - *1.* Poisson's Equation
- *C.* Boundary Conditions
- *D.* Work and Energy
  - *1.* Energy of Assembly
  - *2.* Energy Density of Electric Fields
- *E.* Conductors
  - *1.* Induced Charge Density
  - *2.* Electrostatic Stress
  - *3.* Capacitors
- *F.* Mathematical Techniques
  - *1.* Potential Theory: Laplace's Equation
  - *2.* Green's Theorem
  - *3.* Uniqueness Theorems
  - *4.* Method of Images
  - *5.* Separation of Variables
    - *a.* Euclidean Coordinates
    - *b.* Spherical Coordinates & Legendre Polynomials
  - *6.* Multipole expansions

III. ELECTRIC FIELDS IN MATTER: DIELECTRICS

- *A.* Dielectric Polarization & Induced Dipole Moments
  - *1.* Bound Charge Densities: Surface & Volume
- *B.* Electric Displacement $\vec{\mathbf{D}}$
- *C.* Dielectric Constitutive Relations
- *D.* Dielectric Shielding
- *E.* Energy in Dielectrics
- *F.* Dielectrics & Capacitors

IV. MAGNETOSTATICS

- *A.* Steady Currents & Magnetostatic Field $\vec{\mathbf{B}}$
  - *1.* Ampère's Force Law
  - *2.* Magnetic Field Lines
  - *3.* Lorentz Force Law
- *B.* Charged Particle Motion in Magnetostatic Fields
- *C.* Current Density & Continuity Equation
- *D.* Biot-Savart Law
- *E.* Divergence & Curl of Magnetostatic Fields
  - *1.* No Magnetic Monopoles
  - *2.* Ampère's Law
- *F.* Maxwell's Equations for Static Fields
- *G.* Vector Potential $\vec{\mathbf{A}}$
- *H.* Multipole Expansion of $\vec{\mathbf{A}}$

V. MAGNETIC FIELDS IN MATTER

- *A.* Induced Magnetic Dipole Moment: Magnetization
- *B.* Field of a Magnetized Object
- *C.* Bound Currents
- *D.* Magnetic Field $\vec{\mathbf{H}}$
- *E.* Paramagnetic and Diamagnetic Constitutive Relations
- *F.* Ferromagnetism

VI. ELECTRODYNAMICS

- *A.* EM Fields in Matter: Conductors
- *B.* Ohm's Law: $\vec{\mathbf{J}} = \sigma\vec{\mathbf{E}}$
- *C.* Electromotive Force & Faraday's Law
- *D.* Inductance & Mutual Inductance
- *E.* Work & Energy in Magnetic Fields
- *F.* Maxwell's Consistency Fix for Electrodynamics
- *G.* Magnetic Charge & Electric-Magnetic Duality
- *H.* Maxwell's Equations in Matter
- *I.* Transformations of Static Fields in Changing Reference Frame ($v \ll c$)

VII. ELECTROMAGETIC WAVES

- *A.* In Vacuum
  - *1.* Plane Waves
- *B.* In Matter
  - *1.* Boundary Conditions
- *C.* Intensity

- *D.* Reflection & Refraction
  - *1.* Normal Incidence
    - *a.* Reflected & Transmitted Intensities
  - *2.* Oblique Incidence
    - *a.* Law of Reflection
    - *b.* Snell's Law of Refraction
- *E.* Wave Guides
  - *1.* TE, TM, & TEM modes

VIII. CONSERVATION LAWS

- *A.* Poynting's Theorem
- *B.* Maxwell Stress Tensor
- *C.* Example of Force on a Hemisphere

IX. RELATIVISTIC FORMULATION & SYMMETRIES

- *A.* Electromagnetic Field Tensor $F_{\mu\nu}$ and 4-vector Potential A_μ
- *B.* Lorentz Transformations of $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$
- *C.* Action Principle
- *D.* Charged Point Particle Action
- *E.* Noether's Theorem
- *F.* Gauge Transformations & Spacetime Translations

X. FIELDS AND POTENTIALS

- *A.* Full Solution of Maxwell's Equations in terms of Sources
- *B.* Green's Function & Retarded Potentials
- *C.* Liénard-Weichert Potentials for a Point Charge