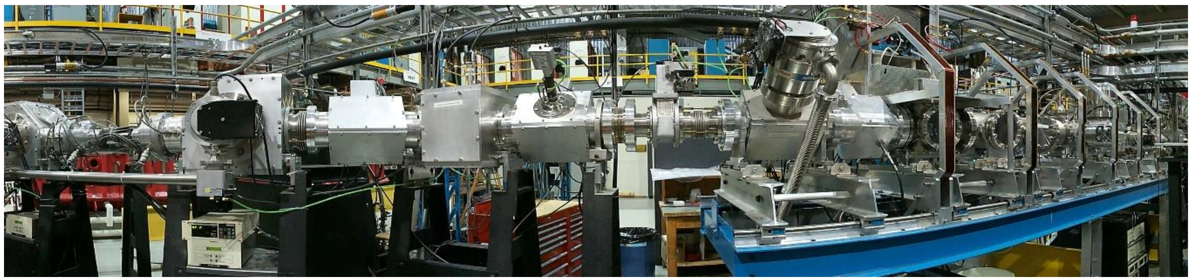
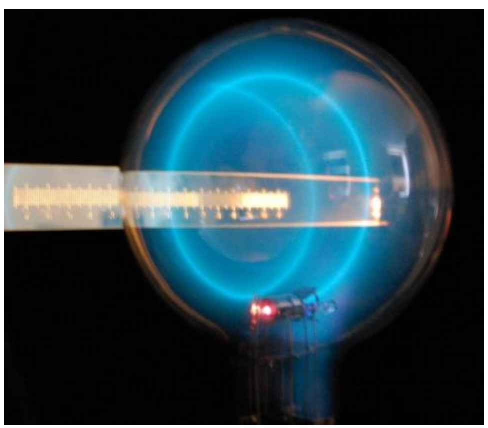
Physics 610: Electricity & Magnetism I

[i.e. relativistic EM, electro/magneto-statics]



[lin12.triumph.ca]

[J-lab accelerator]



[ixnovi.people.wm.edu]

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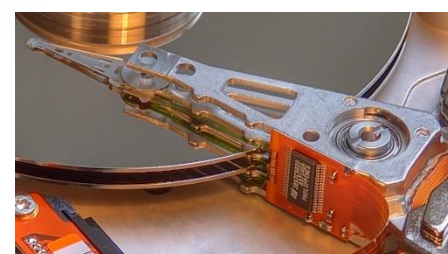

[wikipedia.org]

Instructors

Prof. Seth Aubin

Office: room 255, Small Hall, tel: 1-3545
Lab: room 069, Small Hall (new wing), tel: 1-3532

e-mail: saaubi@wm.edu
web: http://www.physics.wm.edu/~saubin/index.html

Marco Merchand

Office: room 320, cubicle #10, Small Hall
e-mail: mamerchandmedi@email.wm.edu

Office hours:

Aubin: Wednesday 4-5 pm
Merchand: Thursday 3-4 pm

Course Objectives

- Introduce **relativistic electrodynamics**.
- In-depth theory of **electrostatics** and **magnetostatics**.

The course will cover the following topics:

- Maxwell’s equations
- 4-vectors, 4-tensors, and Lorentz transformations
- Classical field theory and Noether’s theorem
- Lagrangian formulation of electrodynamics
- Conservation of electromagnetic energy, momentum, etc ...
- Thomas precession of spin in an electromagnetic field

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- Multipole expansion and spherical harmonics
- Conductors and dielectric media

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- Conductors and dielectric media
- Magnetostatic boundary value problems
- Magnetic media

Applications

Relativistic Electrodynamics:

[J-lab accelerator]

- Calculate electric and magnetic fields in any **reference frame**.

- calculate dynamics of a charged particle in an **accelerator/storage ring**.

- **Lagrangian** formalism for fields.

- **Classical field theory** description of EM field is an essential step towards **quantum field theory**.

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Electro/magneto-statics:

[Thywissen group, U. of Toronto]

[nanotechetc.com]

- Calculate electric fields of simple and **complex charge and conductor arrangements** (capacitors, electrostatic lenses, beam steerers).

- calculate magnetic fields and inductance for various current distributions (i.e. **coils**, dipoles).

- Calculate behavior of quasi-DC **circuits**.

… a few more things about E&M

- E&M is the most mathematically sophisticated theory in Physics.

  … except for quantum field theory and general relativity.

- Standard E&M theory can solve very hard/complex problems.

- E&M is generally the hardest part of graduate qualifying exams.

Course Work

- **Problem sets:** weekly.
- **Participation:** class attendance, classroom discussion, quizzes.
- **Midterm** (after fall break).
- **Final** covers all course material with emphasis on 2nd half of course.

Weighting:

Problem sets:	45%
Participation:	10%
Midterm:	15%
Final Exam:	30%
Total =	100%

References

Text: Almost all of the course materials and problem sets will be taken from the following required texts for the course:

Classical Electrodynamics, by J. D. Jackson [3rd Ed., 1999]

Modern Electrodynamics, by A. Zangwill [1st Ed., 2013]

The rest of the course materials will be taken from the following texts:

Introduction to Electrodynamics by D. Griffiths.

The Classical Theory of Fields by L. D. Landau and E. M. Lifshitz.

Schedule (I)

Week 0: 1/18 **Maxwell's Equations Review**
Maxwell equations for fields and potentials, gauges.

Week 1: 1/23-25 **Special Relativity**
Lorentz transformations, Minkowski space, 4-vectors.

Week 2: 1/30-2/1 **Relativistic Electrodynamics**
EM field tensor, EM field of a relativistic point charge, Lorentz 4-force law.

Week 3: 2/6-8 **Classical Field Theory**
Least action principle for fields, Lagrangian for EM systems, Euler-Lagrange equation.

Week 4: 2/13-15 **Noether's Theorem**
Continuous symmetries and conservation laws, EM stress-energy tensor.

Week 5: 2/20-22 **Lorentz Group and Classical Spin**
Lorentz boosts, rotations, group generators, Thomas precession … Thomas-BMT equation.

Week 6: 2/27-3/1 **Intro to Electrostatics**
Discrete symmetries, vector calculus theorems, Coulomb's law, conductors. (midterm?)

------------------------------ Spring Break ------------------------------

Schedule (II)

Week 7: 3/13-15 **Midterm & Electrostatics**
In class mid-term. Conductors, boundary conditions, electrostatic energy, capacitance.

Week 8: 3/20-22 **Electrostatics: Method of Images and Green's Functions**
Conducting planes and spheres, von Neuman and Dirichlet boundary conditions.

Week 9: 3/27-29 **Electrostatics: Separation of Variables**
Cartesian symmetry, cylindrical symmetry, spherical symmetry, Bessel functions.

Week 10: 4/3-5 **Electrostatics: Spherical Harmonics and Multipoles**
Legendre polynomials, spherical harmonics and identities, dipoles, quadrupoles.

Week 11: 4/10-12 **Electrostatics in Matter: Dielectrics**
Polarization, linear media, electric displacement, bound charges, boundary conditions.

Week 12: 4/17-18?-19 **Magnetostatics I**
Biot-Savart law, Ampère's law, magnetic vector potential.

Week 13: 4/24-26-27? **Magnetostatics II**
Magnetization, bound currents, auxillary field, multipole expansion … anapoles.

May 3, 2018, 9:00am-noon **Final Exam**

Quantum Accuracy

Electron's g-factor

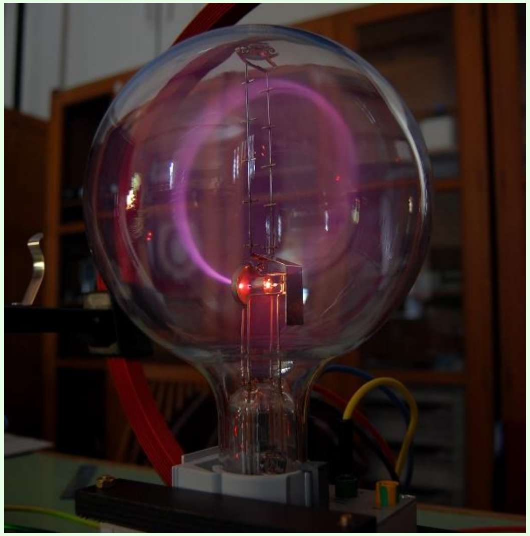
Schrodinger: $g_e = 1.0$

Relativistic electrodynamics + spin-1/2: $g_e = 2.0$

Dirac: $g_e = 2.0$

QED: $g_e = 2.\underbrace{002\ 319\ 304\ 362}_{\text{12-digits}}$

Theory and experiment agree to 9 digits.



[Wikipedia, 2009]