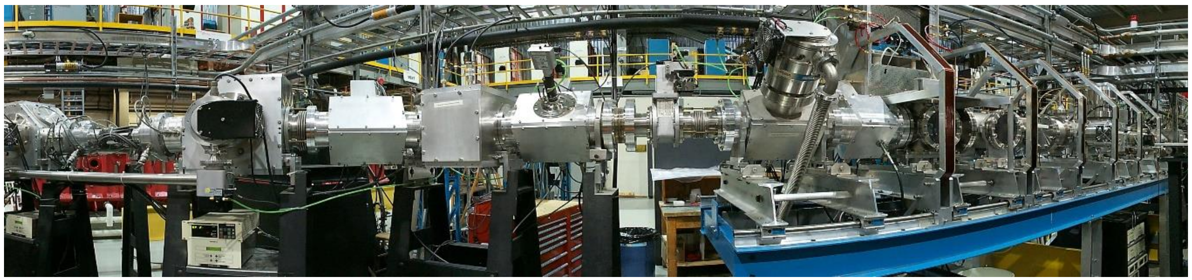
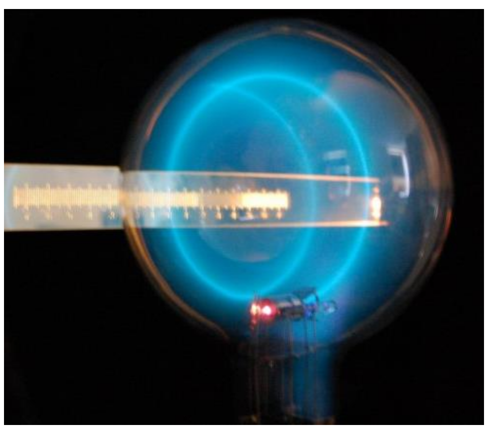
Physics 610: Electricity & Magnetism I

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



[lin12.triumph.ca]

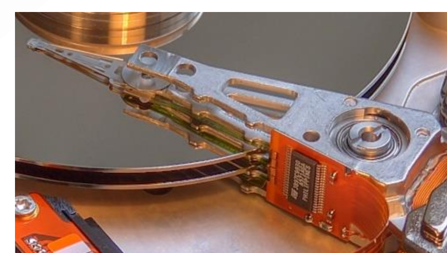
[J-lab accelerator]



[ixnovi.people.wm.edu]

[Thywissen group, U. of Toronto]

[nanotechetc.com]



[wikipedia.org]

Instructors

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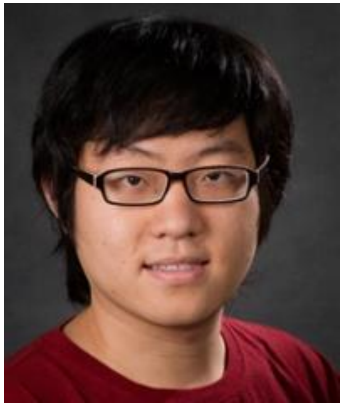

Office hours:

Aubin: Wednesday 5-6 pm
Du: TBA

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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- Method of images, Green's functions
- Multipole expansion and spherical harmonics
- Conductors and dielectric media

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- Magnetostatic boundary value problems
- Magnetic media
- Quasi-static electrodynamics

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 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 2^{nd} 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 text for the course:

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

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

Introduction to Electrodynamics by D. Griffiths.

Modern Electrodynamics by A. Zangwill.

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

The course will have a tutorial on EM simulation software (FEKO by Altair, Inc.) in the Electronics Lab.

Schedule (I)

Week 0: 1/21 **Maxwell's Equations Review**

Maxwell equations for fields and potentials, gauges.

Week 1: 1/26-28 **Relativistic Electrodynamics**

4-vectors, EM field tensor, Lorentz transformations.

Week 2: 2/2-4 **Classical Field Theory**

Least action principle for fields, Euler-Lagrange equation, Noether's theorem.

Week 3: 2/9-11 **Spin in Classical Electrodynamics**

Thomas-precession, spin-orbit coupling, EBT equation.

Week 4: 2/16-18 **Electrostatics**

Coulomb's law, Gauss's law, electric fields and potentials, capacitance.

Week 5: 2/23-25 **Electrostatics: boundary value problem**

Method of images, separation of variables, Green's functions.

Week 6: 3/1-3 **Electrostatics: Green's Function**

Green's functions for different boundary value problems.

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

Schedule (II)

Week 7: 3/15-17 **Midterm & Electrostatics: Multipole expansion**

In class mid-term. Legendre polynomials, spherical harmonics.

Week 8: 3/22-24 **Electrostatics: Dielectric media**

Polarization, linear media, bound charges, boundary conditions.

Week 9: 3/29-31 **Magnetostatics**

Bio-savart law, Ampère's law, magnetic vector potential.

Week 10: 4/5-7 **Magnetostatics: Multipole expansion**

Magnetic dipoles, multipole expansion of vector potential, anapoles.

Week 11: 4/12-14 **Magnetostatics in matter**

Magnetization, bound currents, boundary conditions, auxiliary field.

Week 12: 4/19-21 **Quasi-static Electrodynamics I**

Ohm's law, Kirchoff's laws for circuits, Faraday's law, inductance.

Week 13: 4/26-28 **Quasi-static Electrodynamics II**

Skin effect, displacement current, electromagnetic simulation software.

May 4, 2016, 9:00am-noon **Final Exam**

Quantum Accuracy

Electron's g-factor

Schrodinger: $g_e = 1.0$

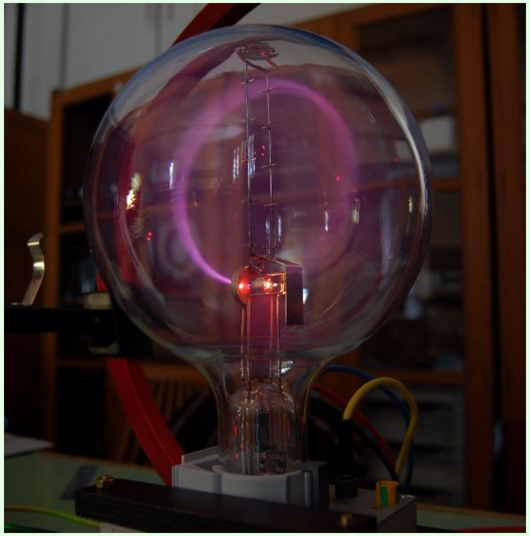
Relativistic electrodynamics + spin-1/2: $g_e = 2.0$

Dirac: $g_e = 2.0$

QED: $g_e = 2.002\ 319\ 304\ 362$

12-digits

Theory and experiment agree to 9 digits.



[Wikipedia, 2009]