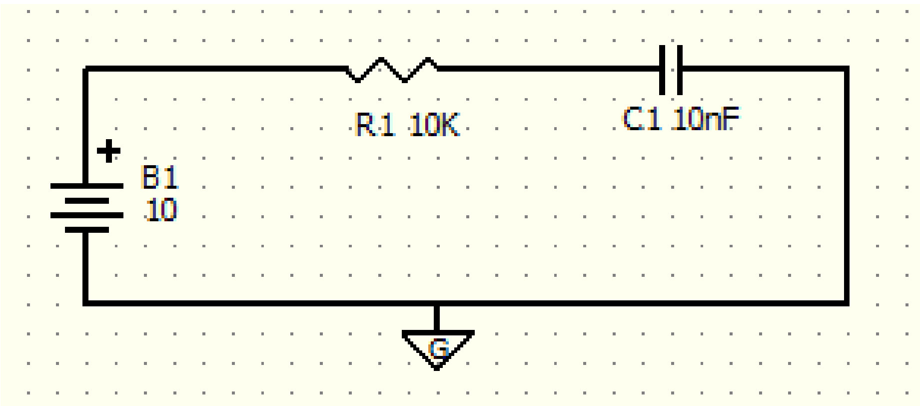
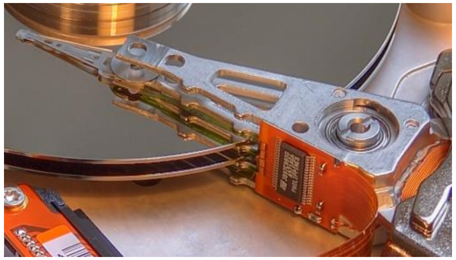
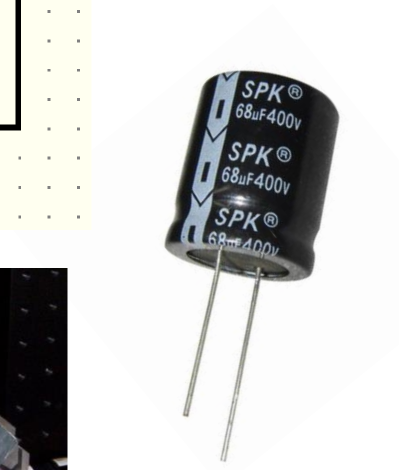
Physics 401: Electricity & Magnetism I

[i.e. electrostatics, magnetostatics, vector calculus]



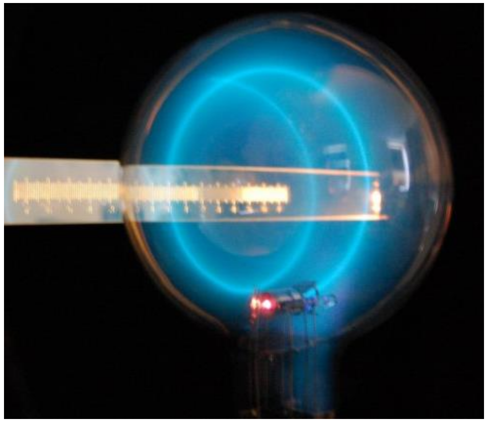


[wikipedia.org]



[nanotechetc.com]

[J-lab accelerator]



[ixnovi.people.wm.edu]

[Thywissen group, U. of Toronto]

Instructors

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Anderson: Monday 4-5 pm
Aubin: Tuesday 3-4 pm

Course Objectives

- Review & explore **vector calculus.**
- Theory of **electrostatics** and **magnetostatics**.
- Briefly introduce **electrodynamics.**

The course will cover the following topics:

- Vector calculus, divergence, curl, Laplacian.

- Boundary value problems.

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- Biot-Savart law, Ampère’s law, magnetic vector potential.
- Magnetization, bound currents, the auxiliary field.

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- Magnetization, bound currents, the auxiliary field.
- Basic electrodynamics, Faraday's law, inductance.

Applications

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

[Wikimedia commons]

[J-lab accelerator]

[nanotechetc.com]

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[Wikimedia commons]

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

- Calculate behavior of quasi-DC **circuits**
  … and some RF circuits !!!

[Thywissen group, U. of Toronto]

… 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** (mid march).
- **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%

Textbooks

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

Introduction to Electrodynamics, by D. J. Griffiths [4th Ed., 2013]

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Some course materials will be taken from the following texts:

The Feynman Lecture on Physics, by R. Feynman, R. Leighton, M. Sands.

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

Tentative Schedule (I)

Week 0: 1/27 **Review of Vector Calculus, part 1**
Vector fields, scalar and vector products, gradient, divergence, curl, Laplacian.

Week 1: 2/1-3 **Review of Vector Calculus, part 2**
Gauss's theorem, Stokes's theorem, curvilinear coordinates, Dirac delta function.

Week 2: 2/8-10 **Electrostatics, part 1**
Coulomb's law, charge distributions, Gauss's law, electrostatic potentials.

Week 3: 2/15-17 **Electrostatics, part 2**
Electric energy, perfect conductors, capacitance, Earnshaw's theorem.

Week 4: 2/22-24 **Potentials and Solution Methods**
Laplace's equation, boundary conditions, uniqueness theorem, method of images.

Week 5: 3/1-3 **Separation of Variables, Multipole Expansion**
Symmetry, series solutions, Legendre polynomials, multipoles, dipole field.

Week 6: 3/8-10 **Electric Fields in Matter, part 1**
Induced dipoles, forces on dipoles, dielectrics, polarization, bound charges.

Week 7: 3/15 **Midterm**

Tentative Schedule (II)

Week 8: 3/22-24 **Electric Fields in Matter, part 2**
Electric displacement field, linear dielectrics, capacitors, dielectric constant.

Week 9: 3/29-31 **Magnetostatics, part 1**
Magnetic fields, Lorentz force law, Biot-Savart law.

Week 10: 4/5 **Magnetostatics, part 2**
Ampère’s law, magnetic vector potential, multipole expansion.

Week 11: 4/12-14 **Magnetic Fields in Matter, part 1**
Diamagnets, paramagnets, forces on dipoles, bound currents.

Week 12: 4/19-21 **Magnetic Fields in Matter, part 2**
Auxiliary field, magnetic susceptibility, ferromagnetism.

Week 13: 4/26-28 **Faradays’ Law**
Ohm’s law, electromotive force, induced electric field, inductance, magnetic energy.

Week 14: 5/3-5 **Maxwell’s Equations**
Ampère’s improved law, electromagnetic waves.

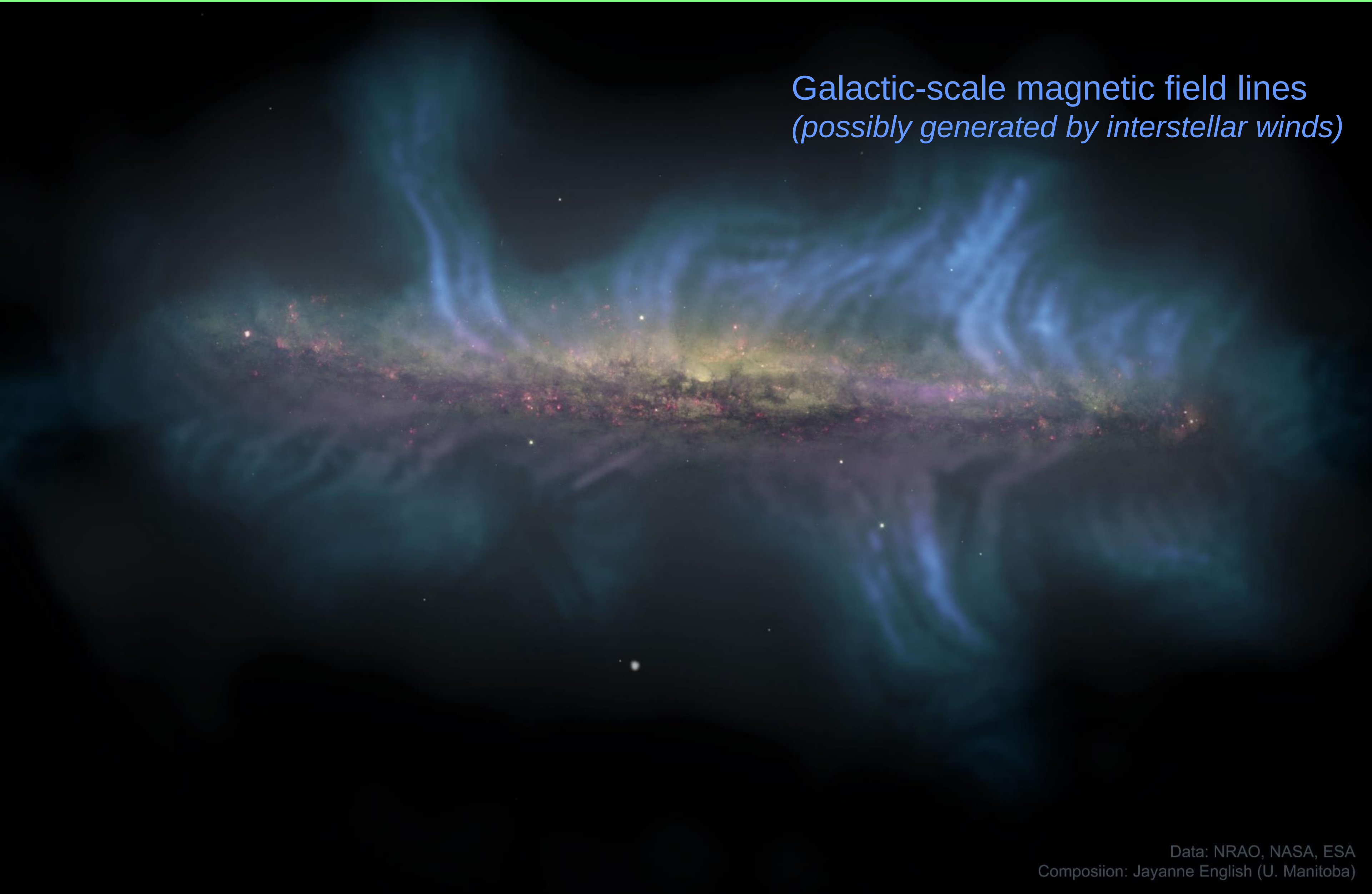
May 11, 2021, 7-10 pm **Final Exam**

Macro E&M: Galactic Magnetism

NGC 5775 galaxy, Virgo cluster

[Source: NASA/Hubble/ESA]

Macro E&M: Galactic Magnetism



Micro E&M: Electron's Magnetism

Electron's g-factor (relates spin to magnetic moment)

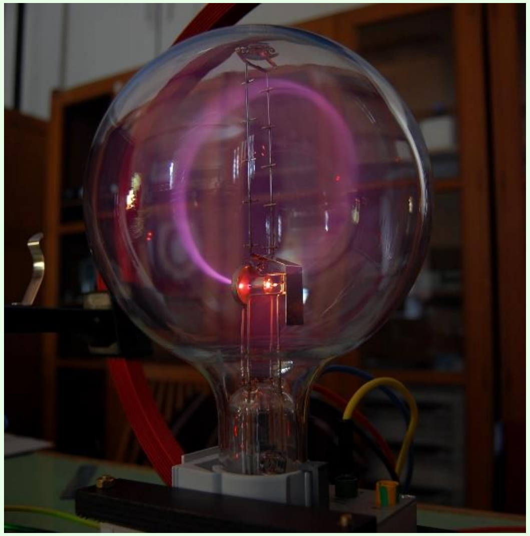
Classical EM / Schrodinger: $g_e = 1.0$

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]