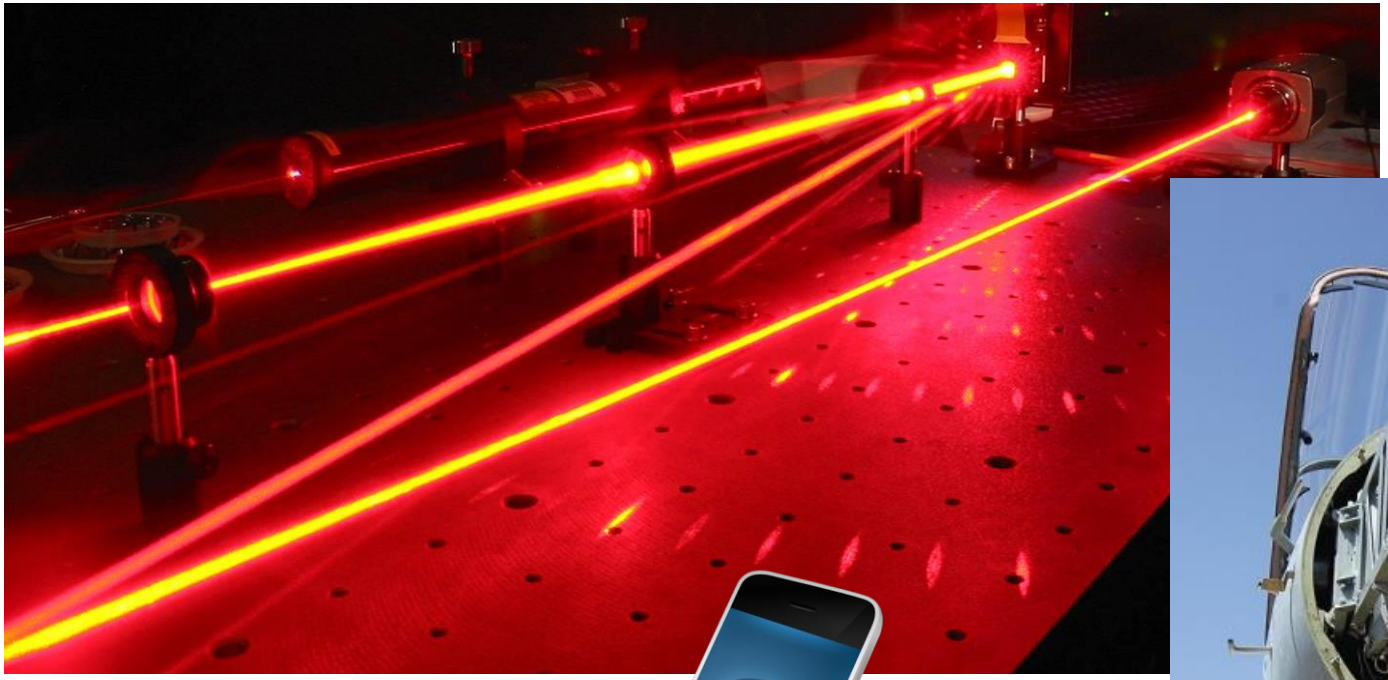
Physics 402: Electricity & Magnetism II

(i.e. time-dependent electromagnetism)



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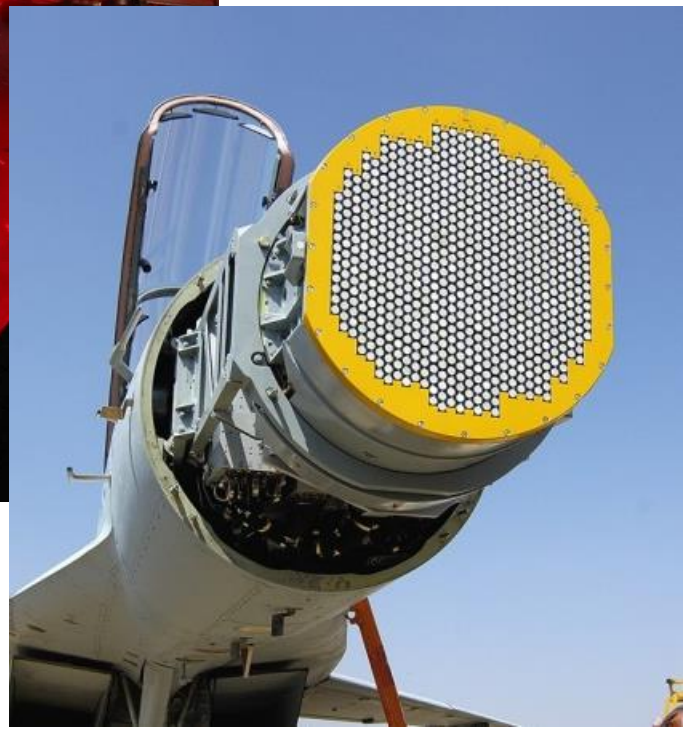

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Instructors

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Aubin: Wednesday 4-5pm
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Course Objectives

Introduce the basic ***physics*** and ***applications*** of **time-dependent electromagnetic fields**.

The course will cover the following topics:

- Electromotive force, Faraday's law
- Ohm's law, inductance
- Maxwell's equations, Maxwell stress tensor
- EM field momentum, energy, and Poynting vector
- EM waves in vacuum and matter
- EM potentials, gauges, retarded potentials
- Waveguides and transmission lines
- Optics and diffraction theory
- Dipole radiation, radiation reaction
- EM simulation software
- Relativistic electrodynamics, $F\mu\nu$, covariance

Statics vs. Dynamics: Applications

Time-independent E&M (PHYS 401):

- understand magnets.

- calculate electrical circuits.
(… at low frequencies)

- understand static electricity on a balloon … free charges are rare !!!

- low energy ion beams.

Statics vs. Dynamics: Applications

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Time-dependent E&M (PHYS 402):

- antennas, radio, radar …
… wireless, microwave ovens …

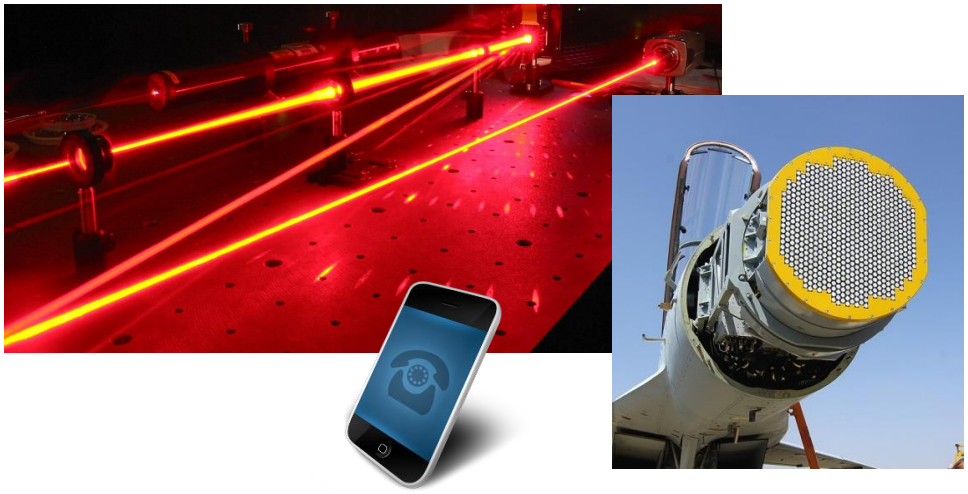
- all of optics.

- relativity, speed of light.

- first unification of forces/fields.

$$\vec{E} \leftrightarrow \vec{B}$$

- modern particle accelerators.



… a few more things about E&M

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

  … except for quantum field theory … general relativity.

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

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

- Electrodynamics is an important part of the GRE.

Course Work

- **Problem sets:** weekly.
- **Participation:** class attendance, classroom discussion, occasional quiz.
- **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 text for the course:

Introduction to Electrodynamics by D. Griffiths [Prentice-Hall (3^{rd}/4^{th} ed., 2013)]

EM simulation software: FEKO in the Electronics Lab.

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

Classical Electrodynamics, by J. D. Jackson.

Modern Electrodynamics, by A. Zangwill.

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

Schedule (I)

Week 0: 8/31 **Review of Electrostatics & Magnetostatics**
Brief review of time independent electric & magnetic fields in vacuum and matter.

Week 1: 9/5-9/7 **Introduction to Electrodynamics**
Faraday's law, Lenz's law, electromotive force, inductance.

Week 2: 9/12-14 **Maxwell's Equations**
The unification of electricity & magnetism, displacement currents.

Week 3: 9/19-21 **Electromagnetic Momentum**
Momentum of EM fields, Maxwell's stress tensor, Poynting vector.

Week 4: 9/26-28 **Electromagnetic Waves in Vacuum**
Wave solutions to Maxwell's equations, light, and polarization.

Week 5: 10/3-5 **Introduction to Optics: EM waves in matter**
Reflection and refraction at a dielectric interface.

Week 6: 10/10-12 **Optics continued**
Brewster's angle, total internal reflection, EM waves in conductors.

---------- *Fall Break* ----------

Week 7: 10/19 **Midterm**

Schedule (II)

Week 8: 10/24-26 **Transmission Lines and EM Resonators**
TEM transmission lines, coaxial cables, and Fabry-Perot cavities.

Week 9: 10/31-11/2 **Potentials, Gauges, and Fields**
Coulomb and Lorentz gauges, retarded potentials, Liénard-Wiechert potentials.

Week 10: 11/7-9 **Radiation Fields**
Radiation from accelerating charges, synchrotron radiation.

Week 11: 11/14-16 **Dipole Radiation**
Dipole radiation, basic antenna theory, radiation reaction, synchrotron radiation.

Week 12: 11/21 **Diffraction Theory & EM Simulation**
Fraunhoffer & Fresnel diffraction. EM simulation.

---------- Thanksgiving Break ----------

Week 13: 11/28-30 **Lorentz Transformations**
EM simulation (cont.), Lorentz invariance, relativistic mechanics, 4-vectors

Week 14: 12/5-7 **Relativistic Electrodynamics**
$F\mu\nu$, Lorentz invariance, covariant formulation of Electromagnetism.

Dec 11, 2017, 9am-noon **Final Exam**