PHYS 3400: Electrodynamics (every second winter)

Calendar description: This course is a continuation of PHYS 2400.1(.2) which focused primarily on electro- and magnetostatics, and turns to the more general theory of electrodynamics. Topics include Maxwell's equations in vacuo and matter, the Poynting vector, electromagnetic waves, wave guides, scalar and vector potentials, guage transformations, Lienardt-Wiechart potentials, radiation from moving charges, and relativistic electrodynamics.

Contents

Overview

This course is cycled with PHYS 3350 (Thermal Physics), and thus will have both third and fourth year students enrolled. This course is taught in the second semester so that all students will have had PHYS 3200 (Mathematical Methods in Physics I) and the third year students will be taking PHYS 3201 (Mathematical Methods in Physics II) concurrently.

This course is not meant to be taught at the level of Jackson, but it should prepare students who go on to graduate school to take a "Jackson-level" course.

Prerequisites

PHYS 1500 An Introduction to Modern Physics

This course provides the background in special relativity needed to support the unit on relativistic electrodynamics. In addition, both third and fourth year students will have had PHYS 3300 (Classical Dynamics) in which a more advanced treatment of special relativity (including four-vectors) ought to have been covered.

PHYS 2400 Electricity and Magnetism

PHYS 3400 is the follow-on course to PHYS 2400, and depends very heavily on its content, particularly if both courses are taught from the same text (see *Suggested texts*).

PHYS 3200 Mathematical Methods in Physics I

This course provides the mathematical background (complex numbers and analysis, second order ODEs, special functions) needed by students to solve the sophisticated problems required of them in PHYS 3400. Topics such as integral transforms and integro-differential equations are covered in PHYS 3201 (Mathematical Methods in Physics II) which is taken concurrently by the third year students. If these methods are needed in PHYS 3400, some coordination with the instructor of PHYS 3201 would be required.

Dependent courses

Student Outcomes

Students completing PHYS 3400 should have mastered the following skills:

1. deal with non-intuitive physical phenomena
2. use vector differential equations and line/surface integrals to solve real physical problems
3. prepare a complete and concise mathematical solution
4. draw out a physical understanding and explanation from a mathematical solution

Curriculum

The suggested curriculum is based on chapters 7–12 of *Introduction to Electrodynamics* by David Griffiths, the preferred text for this course. See the section *Suggested texts* for more discussion.

1. Electrodynamics
   - Maxwell's equations in vacuo and in matter
   - Poynting vector
   - Newton's Third Law
   - Maxwell Stess Tensor
   - conservation of momentum and angular momentum
2. Electromagnetic waves
   - waves in vacuum (for $\vec{E}$ and $\vec{B}$)
   - polarisation
   - plane waves

  - propagation, reflection, and transmission
  - absorption and dispersion by conductors
  - wave guides, coaxial transmission lines

3. Potentials and Fields
  - scalar and vector potentials
  - gauge transformations
  - retarded potentials
  - Lienartd-Wiechart potentials
  - fields of moving point charges

4. Radiation
  - electric and magnetic dipole radiation
  - power radiated from a point source
  - radiation reaction

5. Relativity
  - Lorentz transformations
  - magnetism is a relativistic phenomenon
  - transformation of fields; the field tensor
  - electrodynamics in tensor notation
  - relativistic potentials

Suggested texts

For the most part, the curriculum committee gives names of texts merely as suggestions. However, in this stream the committee strongly urges the instructor to use *Introduction to Electrodynamics* by Griffiths, which can serve both this course and its prerequisite, PHYS 2400 (Electricity and Magnetism). Students and instructors universally praise both of Griffiths' texts (this, and *Introduction to Quantum Mechanics*) as the most enjoyable and comprehensible treatment of both subjects; there simply is no equal. Other texts are offered as possible supplements for problems and examples, and alternative approaches.

Chapters 7–12 of *Introduction to Electrodynamics*, by David Griffiths, (ISBN 0-13-805326-X).

- universally praised by students and instructors as the best text on the market for a two-semester upper-year course in electrodynamics.
- first half of the text ideal for PHYS 2400.

- covers all the topics required
- includes many problems of varying degrees of difficulty, with many worked examples

Principles of Electricity and Magnetism by Pugh and Pugh (ISBN 0-201-06014-0)

- a possible alternative to Griffiths, as it covers both electrostatics and electrodynamics.
- includes engineering applications (wave guides, *etc.*)

Electromagnetic Fields and Waves by Lorraine and Corson (ISBN 0-7167-0331-9)

- covers a broader list of topics than Griffiths, and many in greater depth
- could be used as an alternative to Griffiths for both this course and PHYS 2400, though it is probably too high a level for second years students
- this text is often considered a viable alternative to J. D. Jackson's text "Classical Electrodynamics" for graduate level courses
- while this is an excellent text used in many advanced undergraduate curricula, the curriculum committee still strongly urges the use of Griffiths over this.

Notes to the instructor

1. This is a "terminal course" in that no other courses in the curriculum depend on it. Thus there is some latitude in which subjects are emphasised and covered by the instructor. However, it is the intent and desire of the curriculum committee and department that students finishing this course are well-prepared to take a graduate-level course out of J. D. Jackson's text *Classical Electrodynamics*.
2. Coordination with the instructor in PHYS 2400 (Electricity and Magnetism) is important so that this course may begin right where PHYS 2400 left off, and so that topics students may have had trouble with can be reviewed. This is particularly important if, for some reason, both instructors are not using the same text.
3. Coordination with the instructor in PHYS 3201 (Mathematical Methods in Physics II) is also desirable so that the third-year students can apply the math skills they may have just learned.