COURSE SYLLABUS FORM

American University of Beirut
Faculty of Arts and Sciences
Department of Physics
Phys. 303: Advanced Electromagnetic Theory

1. Course Learning Outcomes

The main goal of this course is to have you engage in a course central to physical sciences: The attempt to model a broad range of physical phenomena using a small set of powerful fundamental principles. The specific focus of the course is an introduction to field theory, in terms of the classical theory of electricity and magnetism (E&M).
In a typical American University, the undergraduate program in E&M involves two or perhaps three semesters beyond elementary physics. As a general rule, a two-semester course in E&M theory is given to beginning graduate students. However, since our students had only one undergraduate course in E&M theory, and our Master Program offers one E&M advanced theory of E&M, We are obliged to make a specific design for the syllabus to be highly useful for students interested in theoretical physics. The student will have four general parts covering the main features generally needed as basis to more advanced field theory:

Part I:

This part covers the following materials: Electrostatics, Magnetostatic and Electromagnetism. Boundary-Value Problems, Green's functions, and Maxwell's Equations and Electromagnetic duality. We limit our selves to three different coordinates systems: Cartesian, Spherical and Cylindrical.

Part II

Electromagnetic Waves Equations: Plane Waves and Propagation, Optics.
Electromagnetic Potentials: Gauge Transformation..

Part III

Relativistic Electrodynamics and Covariant classical electrodynamics. Electromagnetic Fields and Particles: Lagrangian and Hamiltonian Formalisms.

Part IV

The Electromagnetic Fields and Matter. And finally the Radiation

Because of the increasing use of personal computers to supplement analytical work or to attack problems not amenable to analytic solution, the use of the available software such as Maple or Mathematica in the market, is required for this course.

2. Resources Available to Students

The course will use extensively, the following two main texts:

1. Electromagnetic field theory (2001), By Bo Thidé. This free course is available on the WEB , and can be downloaded from:
   http://www.plasma.uu.se/CED/book (200 pages)
   The student can also download the free online exercises book: Electromagnetic Field Theory Exercises, from the same web site.
2. Electrodynamics (3rd Edition 1999-Willey) By J.D. Jackson

Mainly the first 8 chapters will be visited during the course.

3. Links to other Electrodynamics Related Web Sites.

   The following Web sites are helpful:

   a- based on Mathematica

http://physuna.phs.uc.edu/~johnson/EM/problem.sets.index.html

   b- Interesting resources based on the use of Forms in Electromagnetism plus a number of related animations

http://emlib.jpl.nasa.gov/EMLIB/education.html

4. The following two books:

   a- "Mathematica for Physics" By Robert L. Zimmerman and Fredrick I. Olness 2d edition (2002) Addison-Wesley , can also be consulted

   b- "APhysicist's Guide To Mathematica" by Patrick T. Tam (1997) Academic Press,

   are useful and contain many Electrodynamics applications.

3. Grading Criteria

Homework for each part of the course will be given ta the end of each part, and must be returned after 72 hours. Each will be graded 10% of the total grade. The homework is supposed to be a personal activities of a student and not a team work. One midterm exam (20%) and a talk to be prepared and presented by the student on a relevant subject related to the course (10%) and A final 4 hours exam (30%).

4. Schedule

Each part of this course will be given during three weeks at a rate of three hours per week. The material will be based on the main two texts indicated above.

Part I will be given during the the first four weeks , followed by the first homework.

1 Classical Electrodynamics 1

1.1 Electrostatics

1.1.1 Coulomb's

1.1.2 The electrostatic field

1.2 Magnetostatics

1.2.1 Ampère's law

1.2.2 The magnetostatic field

1.3 Electrodynamics

1.3.1 Equation of continuity for electric charge

1.3.2 Maxwell's displacement current

1.3.3 Electromotive force

1.3.4 Faraday's law of induction

1.3.5 Maxwell's microscopic equations

1.3.6 Maxwell's macroscopic equations

1.4 Electromagnetic Duality

Example 1.1 Faraday's law as a consequence of conservation of magnetic charge

Example 1.2 Duality of the electromagnetodynamic equations

Example 1.3 Dirac's symmetrised Maxwell equations for a fixed mixing angle

Example 1.4 The complex field six-vector
Example 1.5 Duality expressed in the complex field six-vector

The Two Chapters 2 and 3 of Jackson Book will be covered during the next three weeks

Part II cover the following materials during three consecutive weeks:

ElectromagneticWaves
2.1 The Wave Equations
2.1.1 The wave equation for **E**
2.1.2 The wave equation for **B**
2.1.3 The time-independent wave equation for **E**
Example 2.1 Wave equations in electromagnetodynamics
2.2 Plane Waves .
2.2.1 Telegrapher's equation
2.2.2 Waves in conductive media
2.3 Observables and Averages
Electromagnetic Potentials
3.1 The Electrostatic Scalar Potential
3.2 The Magnetostatic Vector Potential
3.3 The Electrodynamic Potentials
3.3.1 Electrodynamic gauges
Lorentz equations for the electrodynamic potentials Gauge transformations
3.3.2 Solution of the Lorentz equations for the electromagnetic potentials
The retarded potentials
Example 3.1 Electromagnetodynamic potentials
Part of chapters 5, 6 and 7 of Jackson contains relevant discussions of these materials

Part III cover the following materials during three consecutive weeks:

Relativistic Electrodynamics
4.1 The Special Theory of Relativity
4.1.1 The Lorentz transformation
4.1.2 Lorentz space
Radius four-vector in contravariant and covariant form
Scalar product and norm
Metric tensor
Invariant line element and proper time
Four-vector fields
The Lorentz transformation matrix
The Lorentz group
4.1.3 Minkowski space
4.2 Covariant Classical Mechanics
4.3 Covariant Classical Electrodynamics
4.3.1 The four-potential
4.3.2 The Liénard-Wiechert potentials
4.3.3 The electromagnetic field tensor
Electromagnetic Fields and Particles
5.1 Charged Particles in an Electromagnetic Field
5.1.1 Covariant equations of motion
Lagrange formalism

Hamiltonian formalism
5.2 Covariant Field Theory
5.2.1 Lagrange-Hamilton formalism for fields and interactions
The electromagnetic field
Example 5.1 Field energy difference expressed in the field tensor
Other fields

Part of Chapter 12 of Jackson book will be visited

Part III cover the following materials during four consecutive weeks:

Electromagnetic Fields and Matter
6.1 Electric Polarisation and Displacement
6.1.1 Electric multipole moments
6.2 Magnetisation and the Magnetising Field
6.3 Energy and Momentum
6.3.1 The energy theorem in Maxwell's theory
6.3.2 The momentum theorem in Maxwell's theory

Electromagnetic Fields from Arbitrary Source Distributions
7.1 The Magnetic Field
7.2 The Electric Field
7.3 The Radiation Fields
7.4 Radiated Energy
7.4.1 Monochromatic signals
7.4.2 Finite bandwidth signals

Electromagnetic Radiation and Radiating Systems
8.1 Radiation from Extended Sources
8.1.1 Radiation from a one-dimensional current distribution
8.1.2 Radiation from a two-dimensional current distribution
8.2 Multipole Radiation
8.2.1 The Hertz potential
8.2.2 Electric dipole radiation
8.2.3 Magnetic dipole radiation
8.2.4 Electric quadrupole radiation
8.3 Radiation from a Localised Charge in Arbitrary Motion
8.3.1 The Liénard-Wiechert potentials
8.3.2 Radiation from an accelerated point charge
The differential operator method
Example 8.1 The fields from a uniformly moving charge

Parts of Chapter 4, 5,14 of Jackson books will be visited.

The course will take minimum 4+3+3+4 = 14 weeks