PHYS 8202: Advanced Electromagnetic Theory II

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Topics: The course extends the classical description of electrodynamics, as discussed in part I, toward a quantum field theoretical generalization. This will include the relativistically covariant formulation and its incorporation into Lagrange's and Hamilton's theory of the motion of charged particles and their interaction with electromagnetic waves. Field quantization concepts, such as the canonical operator approach and symmetry properties, will be discussed and applied to describe field propagation and scattering processes of matter and light.


Class: Tuesday and Thursday, 2:00–3:15pm, room 254 Physics Bldg.

Office Hours: You can contact me at any time.

Exams: Midterm (March) and Final (May); style and dates to be announced at short notice. In case of written in-class exams, own hand-written lecture notes and homework solutions are admitted, but no books or printed scripts. Excused midterm exam absence causes the grade of the final exam to be substituted for the midterm exam; unexcused absence entails grade F. Missing the final exam without documented reason results in failing the course. If the instructor decides that final exam absence was excusable, an oral make-up exam will be set up.

Homework: There will be graded assignments on a regular basis (probably bi-weekly) with deadlines. No late homework is accepted. No submission via email. Teamwork is acceptable, even encouraged, but each student must hand in an own copy of homework solutions with all names of team members indicated.

Grade: Total Grade = (2xHomework + Midterm + Final)/4

Grading: [100,85]: A; (85,82.5]: A−; (82.5,80]: B+; (80,70]: B; (70,67.5]: B−; (67.5,65]: C+; (65,55]: C; (55,52.5]: C−; (52.5,40]: D; (40,0]: F

Academic Honesty: All members of the academic community are committed to honesty. The academic honesty policy statement of the UGA can be viewed online at www.uga.edu/honesty.
Outline of Courses PHYS 8201/8202 (changes possible)

I. Electrostatics
   - Electric charge; force; field concept; potentials
   - Gauss’s Law; Stokes’s Theorem
   - Charged interfaces; Poisson and Laplace equations
   - Potential energy
   - Multipole expansion
   - Boundary conditions; solution methods for boundary-value problems; Green functions
   - Macroscopic media; dielectrics

II. Magnetostatics
   - Magnetic induction; Biot-Savart Law; Maxwell equations
   - Vector potential; gauge transformation
   - Macroscopic boundary-value problems
   - Thermodynamic magnetic order/disorder phase transition; \( \varphi^4 \) theory; mean-field theory

III. Electromagnetism and Electrodynamics
   - Faraday’s law of induction
   - Maxwell’s field equations
   - Vector and scalar potentials; gauge transformations
   - Wave equations; Green functions; causality
   - Wave propagation in conductors and at dielectric interfaces; optics; plane-wave solutions
   - Polarization effects; radiation characteristics
   - Charges in motion; Liénard-Wiechert potentials

IV. Theory of Special Relativity and Covariant Formulation of Electromagnetism
   - Einstein’s postulates; Lorentz transformation
   - Consequences of Lorentz invariance
   - Covariant formulations of classical mechanics and electrodynamics
   - Lorentz transformation of electromagnetic fields
   - Generalized covariant Lagrange formalism

V. Conceptual Approach to Field Theory
   - Functional variation; Lagrange density; Euler-Lagrange field equations
   - Symmetries; conservation laws
   - Noether’s theorem
VI. Canonical Field Quantization
- Second quantization; spin statistics; Bose and Fermi fields
- Bosonic and fermionic (anti)commutation relations
- Neutral and charged Klein-Gordon theory; particles and antiparticles
- Normal ordering; charge operator; charge conservation
- Time-ordering; Feynman propagator

VII. Fermions and Vector Bosons
- Dirac equation; quantization of Dirac fields
- Feynman propagator for electrons and positrons
- Lagrange density of electromagnetic fields
- Canonical vector field quantization in Lorentz gauge
- Polarizations of massless photons; Gupta-Bleuler method
- Feynman photon propagator

VIII. Quantum Electrodynamics (QED)
- Lagrange density of QED; local gauge transformations; minimal coupling
- Interaction picture; time evolution operator
- Scattering; S-matrix; cross section
- Perturbation series; Wick’s theorem; Wick contractions
- Feynman rules and diagrams of QED
- Scattering processes
- Comments on higher collision energies; standard model of elementary particle physics