

Syllabus for PHYSICS 6211 / Graduate Electrodynamics II

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The course provides an overview of classical electrodynamic theory, with an emphasis on dynamic (time-dependent) problems, in which the calculation of the time-dependent scalar and vector potentials, and electric and magnetic fields, can be traced to the Green function formalism. The response of a medium and gauge questions are treated in full. The multipole expansion of the radiation field, and the formalism of wave guides, and of cavity modes, complement the discussion. Advanced topics such as the interpretation of the magnetic field as an entirely relativistic effect are also discussed; indeed, one may show, via Lorentz transformation, that the magnetic field can alternatively be interpreted as an electric field generated by the Lorentz contraction of moving charges.

1 From the Maxwell Equations To Waves; 1.1 Orientation; 1.2 Time-Dependent Electromagnetic Fields; 1.3 From Dissipation and Energy Storage to the Complex Formalism.

2 Microscopic and Macroscopic Equations; 2.1 Orientation; 2.2 Averaging over Microscopic Entities and Macroscopic Equations; 2.3 Calculations Based on a Microscopic Classical Model.

3 Green Functions for the Wave Equation; 3.1 Orientation; 3.2 Green Function for the Wave Equation; 3.3 Applications of the Retarded Green Function; 3.4 Other Green Functions.

4 Electromagnetic Radiation from Oscillatory Sources; 4.1 Orientation; 4.2 Basic Formulas; 4.3 Localized Harmonically Oscillating Sources; 4.4 Potentials due to Moving Charges.

5 Electromagnetic Waves in Waveguides and Cavities; 5.1 Orientation; 5.2 Waveguides; 5.3 Resonant Cavities; 5.4 Casimir Effect and Quantum Electrodynamics.

6 Electromagnetic Waves in Media; 6.1 Orientation; 6.2 From Oscillator Strengths to Dense Materials; 6.3 Dielectric Constant for Ionic Crystals; 6.4 Propagation of Plane Waves in a Medium; 6.5 Kramers-Kronig Relationship.

7 Some Advanced Topics; 7.1 Lorentz Transformation; 7.2 Relativistic Maxwell Tensor; 7.3 Relativistic Transformations and Biot-Savart Law; 7.4 Relativity and Magnetic Force; 7.5 Potentials due to Relativistic Moving Charges.

Commensurate with the requirements of a graduate course, students are encouraged to supplement the material taught in the lecture by their own reading. Furthermore, if gaps in the mathematical background knowledge constitute an obstacle to the understanding of the course material, then the students are expected to fill these gaps independently. Some guidance is given in the lectures, and questions are always welcome, but the main responsibility for the filling of gaps in background knowledge remains with the student. The textbook for the course is [J. D. Jackson, *Classical Electrodynamics*, 3rd edition, John Wiley and Sons, New York, NY, 1998]. However, the notes for the course are fairly self-contained.

The grading schedule of the course is as follows: There are graded exercises every week. These count from 60 to 150 points, typically. Furthermore, there may be one or two so-called “directed exercises” where you work on a specific problem in class, and then you are supposed to finish the work at home and hand in the exercise during the next lecture. The directed exercises (100 to 2000 points each) may or may not be announced. The most important homework which is always due but never explicitly announced is reading the distributed notes. Actually doing this enables you to better perform in a hypothetical unannounced directed exercise as well as in an unannounced oral quiz near the start of a lecture, where we verify that basic wisdom has been learned from the distributed notes. The points from the graded weekly exercises, from the directed exercises and from the oral quizzes are added near the end of the semester, to give a joint exercise grade. The exercise percentage grade counts 60% of the final grade.

Two written exams will take place during the semester, and a final. The exams carry 150 to 200 points each and will be written during normal course hours. The percentage earned in the written exams counts 40% of the final grade. The final may replace the weakest exam, i.e., the exam percentage is calculated from the most favorable two exams out of the three: first exam, second exam, and final.

The final grading schedule follows the usual pattern. After weighted adding of the exercise and the exam grade (60% to 40%), an overall final grade is determined. From this final grade, $\geq 90\%$ gives an A, $\geq 80\%$ gives a B, $\geq 70\%$ gives a C.