Syllabus for PHYSICS 6211 / Graduate Electrodynamics II

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Overview.—Technological applications of advanced classical electrodynamics encompass radar technologies and long-range infrared sensing, over to important applications within physics, such as particle accelerators (acceleration cavities). Their importance has only increased over the last decades. 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 Green Functions for the Wave Equation;
2.1 Orientation;
2.2 Green Function for the Wave Equation;
2.3 Applications of the Retarded Green Function;
2.4 Other Green Functions.

4 Electromagnetic Radiation from Oscillatory Sources;
3.1 Orientation;
3.2 Basic Formulas;
3.3 Localized Harmonically Oscillating Sources;
3.4 Tensor Green Function.

4 Electromagnetic Waves in Waveguides and Cavities;
4.1 Orientation;
4.2 Waveguides;
4.3 Resonant Cavities;
4.4 Casimir Effect and Quantum Electrodynamics.

5 Electromagnetic Waves in Media;
5.1 Orientation;
5.2 From Oscillator Strengths to Dense Materials;
5.3 Dielectric Constant for Ionic Crystals;
5.4 Propagation of Plane Waves in a Medium;
5.5 Kramers–Kronig Relationship.

Advice and Encouragement.—Commensurate with the requirements of a graduate course, students are encouraged to supplement the material taught in the lecture by their own reading. 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 [U. D. Jentschura, Advanced Classical Electrodynamics, World Scientific, Singapore (2017)]. Further reading on the mathematical aspects of the course includes [R. Courant and D. Hilbert, Methods of Mathematical Physics—Volumes I and II, Interscience Publishers, New York (1966)], and [W. Magnus, F. Oberhettinger and R. P. Soni, Formulas and Theorems for the Special Functions of Mathematical Physics, Springer, New York (1966)], and [H. Bateman, Higher Transcendental Functions, Volumes I, II and III, McGraw–Hill, New York (1953)].

Graded Exercises.—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 200 points each) may or may not be announced. The most important homework which is always due but never explicitly announced is reading the lecture notes, and, distributed notes. Fulfillment of the most important homework can and will be checked via brief recap sessions at the start of every lecture, and may be graded. 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. Exercises will be available from qedtheory.org/resources.

Graded Exams.—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.

Final Exam.—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.

Make-up Policy.—There are no make-ups for homework assignments. Students who anticipate being away for a class for a legitimate reason, should inform the instructor by e-mail ahead of class and give the reason for absence.

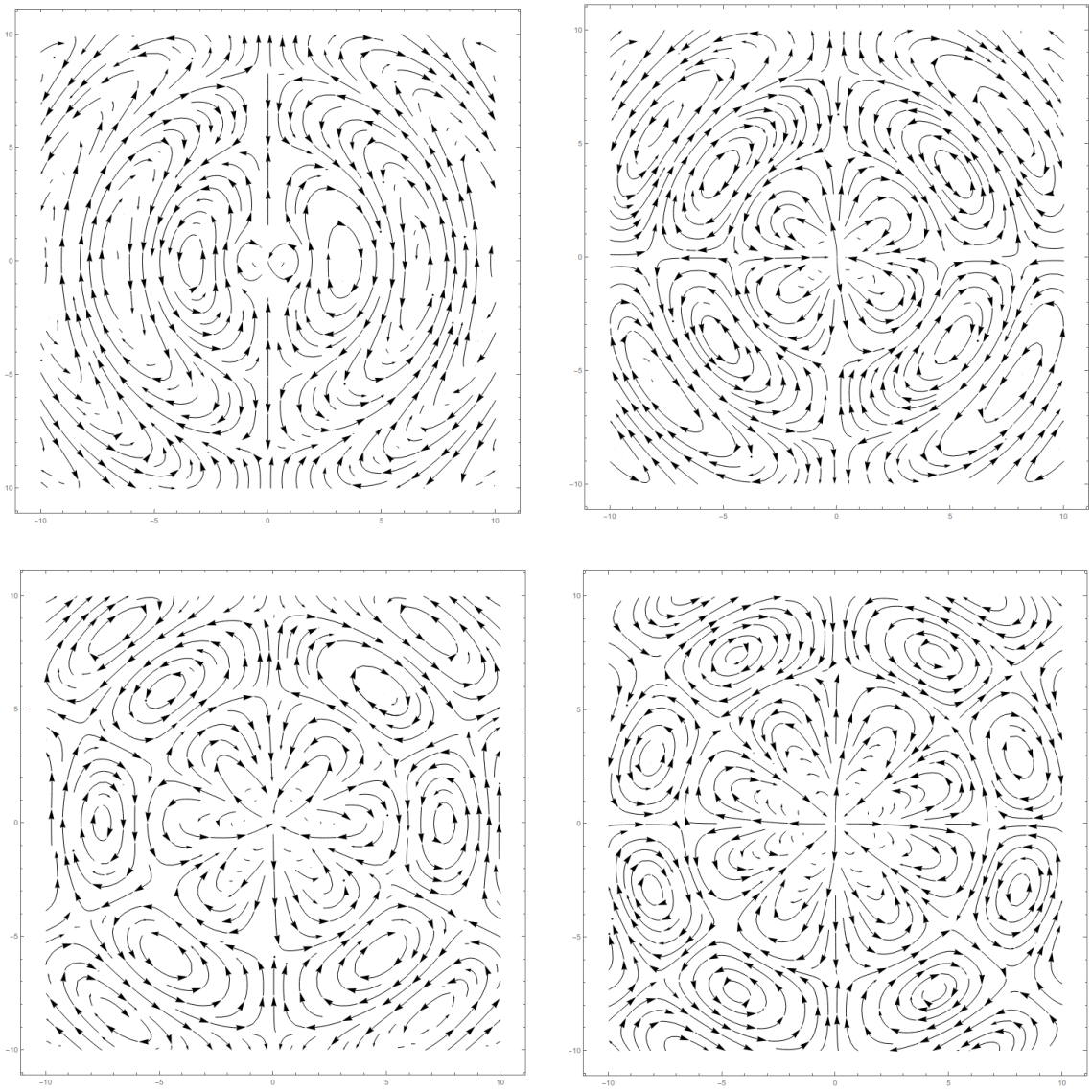
Appeals.—If you believe an exception to a course rule should be made, you may file a written appeal. Appeals must be filed within one week of the occurrence of the circumstance that causes your appeal. Minor illness, lack of preparation, "I did poorly on two exams," non-emergency family events, oversleeping, "I forgot about it," etc., are not reasons for filing an appeal.

Unresolved Complaints about the Course.—It is hoped that any complaints about the course can be resolved in a collegial manner through discussions with the instructor. However, if there are any complaints that cannot be resolved, you may take them up to Dr. Marco Cavagla, Physics Department Chairman.

Accessibility and Accommodations.—It is the university's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please contact Student Disability Services at (573) 341-6655, dss@mst.edu, visit http://dss.mst.edu/ for information and to initiate the accommodation process.

Academic Dishonesty.—Academic dishonesty, including cheating, plagiarism or sabotage, will be dealt with severely, and disruptive talking and other distractions will not be tolerated. See Student Academic Regulations at http://registrar.mst.edu/academicregs.

ChatGPT and AI, Internet Search Engines.—The use of any Artificial Intelligence (AI) tools in the course is highly discouraged, and exercise solutions must be prepared without the use of AI. By contrast, the use of internet search tools, to improve background knowledge and look up concepts, and to get inspiration for exercise solutions, is highly encouraged. This includes WikiPedia articles.

Title IX.—The title IX policies, resources and reporting options are available online at http://titleix.mst.edu.

Snapshots of the Fields of Multipole Radiation