

# AP<sup>®</sup> Physics C—Electricity and Magnetism

## Syllabus 1

### Overview of AP<sup>®</sup> Physics

Any student who has completed AP<sup>®</sup> Physics C: Mechanics and one term of calculus may register for the AP Physics C: Electricity and Magnetism course. While students who completed the qualitative introductory course can be at a disadvantage, there are accelerated sections in that class to better prepare students for advanced coursework.

### Schedule

We teach mechanics in the first term, electricity and some magnetism in the second. We begin review about four weeks before the exam, as we finish the last topics. Only the last week or so is spent purely reviewing. Laboratory experiments are interspersed throughout the course where they are appropriate for the subjects we are studying. On average, we spend one period per week performing an experiment. [C8] Tests come once every two to three weeks, generally covering more than one topic.

Classes meet four times a week for 50 minutes and once a week for 75 minutes. While we don't always do experiments in the long period, it is nice to have for those times when we want to do an extended experiment.

### Course Design, Objectives, and Strategies

Our goal in the Advanced Physics course is to provide an excellent first-year college-level calculus-based [C6] physics education.

Students coming out of the course should have a strong conceptual understanding of physics and well-developed skills in performing and analyzing laboratory experiments. They should also be able to apply their understanding to approach and solve problems that are essentially new to them. [C7]

### Whiteboard Problem Solving

Another technique we have used with great success is *whiteboard* problem solving. When solving problems in class, rather than having each student solve it in his or her own notebook, we send a pair of students to the board with a dry erase marker. Because they have only one marker, they must communicate effectively with each other to work through the problem. The teacher can see their work clearly and offer suggestions when appropriate. We emphasize clarity of the written work as well as the oral presentation of the result. Attention to clarity is critical in developing good problem-solving skills. [C7]

### Textbook

We use *Matter & Interactions, Volume II*, 2002 by Ruth Chabay and Bruce Sherwood. This is one of the most unusual textbooks around. It takes an unusual

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**C6**—Introductory differential and integral calculus is used throughout the course.

**C7**—The course utilizes guided inquiry and student-centered learning to foster the development of critical thinking skills.

approach to the material and follows an unusual pedagogy. The book is not meant to be “read”; instead, it actively engages the students’ minds in a process of inquiry. “Stop and Think” questions are an integral part of the strategy. These are relatively simple questions that students are supposed to answer for themselves before continuing. There are also “exercises” spread throughout each chapter that require a little more thinking and some simple calculations. These are answered at the end of each chapter. The final part in the active engagement strategy is the use of desktop experiments. Each student is provided with a kit with which they perform frequent simple at-home mini-experiments. Some of the experiments are qualitative, but many are quantitative and require students to develop their powers of estimation. [C8] I do the more interesting and challenging experiments in class, as they require additional equipment, additional hands, or additional brainpower. The kits are available through Pasco, but at a significant markup. Many of the items (tape, batteries, wires) are very easily available, while others (.5 Farad capacitors, nichrome wire) are a little more difficult to obtain. Students complete a lab notebook on all labs conducted throughout the course. The notebooks are turned in on a weekly basis for grading.

The order of topics and the emphasis given to each is also nontraditional. One of the goals of the book is to use principles of electricity and magnetism to understand the structure of matter. Hence, dipoles receive a lot of attention in the study of electric charges, forces, and fields. There is also an emphasis on the transient aspects of circuits, giving students a very thorough understanding of what goes on in a circuit. Gauss’s law and Ampere’s law aren’t introduced until near the end of the text, giving students time to familiarize themselves with the concepts of fields and the common patterns before using these more abstract laws. Modern physics examples are used throughout the text, but usually have an asterisk indicating that they are optional.

There are some fascinating problems in this book. In the second chapter, a simple experiment is performed to estimate the number of excess electrons on the surface of a charged piece of tape. The only given information is  $k$  and  $e$ . In another exercise, students estimate the polarizability of a carbon atom by observing a charged pen pick up a scrap of paper. Using only a compass, a ruler, a wire, and a magnet, they determine the magnetic moment of a magnet.

Each chapter ends with some easy “Review Questions” and some more challenging homework problems. I frequently find myself wishing there were more homework problems. I end up supplementing with my own problems, frequently based on AP problems. While the book teaches all the topics necessary to prepare for the AP Exam (and more), the emphasis is different and the types of questions asked are different, so it is necessary (but not difficult) to intermingle AP-type questions.

I find this book to be a refreshing change from a traditional textbook. The ideas are fascinating, and the pedagogy is sound. It does take a full commitment from the teacher and the students. The students must do their part and be active in class and out of class. For homework, they must do the experiments and answer the questions. They absolutely cannot try to read this as they frequently read other texts—by looking for the formula that will help them answer a specific problem.

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The commitment from the teacher is that this isn't a "pick and choose" book; you have to follow the book in order, and there are few sections that can be skipped.

## Winter Term

1. Electric Fields, Electric Potential, and Coulomb's Law—This is most of electrostatics, [C1] with the exception of Gauss's Law.
2. The emphasis is placed on the structure of matter, including insulators and conductors as well as permanent and induced dipoles. This leads to the ideas of polarizability and dielectrics. Emphasis is also placed on fields and potential of distributed charges. [C2] In addition to frequent simple experiments with charged tape and other objects, some of the more interesting experiments include:
  - i. Measure/estimate charge on a piece of tape.
  - ii. Measure/estimate polarizability of carbon
  - iii. Measure/estimate atomic mass of aluminum
3. Magnetic Fields [C4] — This early introduction to magnetism stresses the concept of a field. It introduces the Biot-Savart Law and bar magnets, including microscopic view of magnets. Students use compasses to explore fields produced by currents and permanent magnets. One of the interesting experiments is to measure/estimate the dipole moment of a bar magnet.
4. Microscopic and macroscopic view of electric circuits [C3] —Students build simple circuits using batteries, bulbs, wires, and capacitors to gain a deep understanding of how circuits work. An emphasis is placed on the initial transient behavior of circuits, providing an understanding of how and why electrons move within circuits. This microscopic description then leads to a macroscopic description including Ohm's Law, parallel and series behavior, and RC circuits. In addition to the daily circuit experiments, students perform a full circuit lab using DMMs. They investigate the internal resistance of batteries, resistivity of nichrome wire, and RC discharge.

**C1**— The course covers electricity and magnetism in depth and provides instruction in each of the five content areas outlined in the AP Physics Course Description: Electrostatics

**C2**— The course covers electricity and magnetism in depth and provides instruction in each of the five content areas outlined in the AP Physics Course Description: Conductors, capacitors, and dielectrics

**C4**— The course covers electricity and magnetism in depth and provides instruction in each of the five content areas outlined in the AP Physics Course Description: Magnetic fields

**C3**— The course covers electricity and magnetism in depth and provides instruction in each of the five content areas outlined in the AP Physics Course Description: Electric circuits

## Spring Term

1. Magnetic Force—Students begin with the force on moving charges and then move to the more observable force on current-carrying wires. They solve problems on mass spectrometers and cyclotrons. Two full laboratory experiments are performed:
  - i. Charge to mass ratio of the electron
  - ii. Magnetic force on a dipole using Helmholtz coils and measurement of dipole moment
2. Patterns of Fields in Space—Having developed a high level of comfort with electric and magnetic fields, students are finally introduced to Gauss's Law and Ampere's Law. [C1]

**C1**— The course covers electricity and magnetism in depth and provides instruction in each of the five content areas outlined in the AP Physics Course Description: Electrostatics

3. Faraday's Law, Inductors, Maxwell's equations, and Electromagnetic Radiation [C5] – Faraday's law and Lenz's law are studied using several desktop experiments. While not full labs, the class does two experimental investigations:
  - i. Measurement of EMF generated by loop rotating in a magnetic field
  - ii. Measurement of  $c$  using resonant frequency of a wound toroid
4. Oscillating Circuits – RC, RL, LC, and RLC circuits are studied along with mechanical oscillations and motion with air resistance. This puts all of the differential equations within the course together. At this point in the term, we are also into review for the AP exams. We do a large lab investigating RC, RL, LC, and RLC circuits using oscilloscopes and function generators after the exam.

**C5**— The course covers electricity and magnetism in depth and provides instruction in each of the five content areas outlined in the AP Physics Course Description: Electromagnetism