AP® Physics C—Electricity and Magnetism

Syllabus 4

AP® Physics

The three sections of AP Physics C typically begin with 80 to 90 students enrolled, and of these, 70 to 75 usually finish the course. All enrolled students are required to take the AP Physics C Exam. The course requires completion of or concurrent enrollment in integral calculus. **[C6]**

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

Texts

While I currently use Raymond A. Serway and Robert J. Beichner's *Physics for Scientists and Engineers*, 6th ed., for part of the course, *Fundamentals of Physics* by David Halliday, Robert Resnick, and Jearl Walker would also fit my style.

The primary text for Electricity and Magnetism is an eight-unit, unpublished text/workbook I have written that specifically covers the AP Physics C Electricity and Magnetism (E & M) syllabus. The workbook is definitely my style and is still in my handwriting. The school district prints a copy for each student to keep. The Serway text serves as a backup resource for E & M.

Summer Assignment

To begin the school year on a solid mathematical footing, all students enrolled for the following year are given a programmed elementary calculus book, *Quick Calculus: A Self-Teaching Guide* by Daniel Kleppner and Norman Ramsey, and assignments to be completed over the summer. The book helps students initially learn or review the basic differentiation and integration skills needed for the course. Quizzes on the material are given the first week of school. **[C6]**

Schedule

All classes meet five days a week in 53-minute periods. With our school's calendar, it is necessary to organize the course within a tight schedule that includes assignments during some holiday breaks. I find it useful to lay out a calendar by which to measure progress through the material, and to ensure completion, with extra time for sufficient review before the AP Exam. The calendar reflects the day-by-day unit assignment schedule outlined below.

Electricity and Magnetism (E & M) Outline

Electricity and Magnetism is divided into eight units, covered between mid-January and the administration of the AP Exam. Concepts and problem-solving techniques are introduced through a combination of lectures, demonstrations, lab experiments, question–answer sessions, assignments from the E & M text/workbook, and teacher-generated worksheets, with the text acting as a back-up resource. Calculus is used throughout and where appropriate. **[C6]**

Workbook Unit	Topics	Number of Days
I	Charged Particles and Electric Fields **[C1]**	**7**
	Review of the field concept and the definition of the electric field	
	Coulomb's law	
	Statics and dynamics of point charges in electric fields	
II	Electrostatic Fields and Gauss's Law **[C1]**	**10**
	By integration: electric fields of a uniformly charged rod, circular loop, disk, and sheet	
	The flux concept and Gauss's law	
	Using Gauss's law to determine the electric fields of cylindrically symmetric, spherically symmetric, and planar charge distributions	
	Using Gauss's law to determine the charge distribution on a conductor.	
III	Electric Potential **[C1]**	**9**
	The concept of electric potential	
	Calculating the electric potential of various charge distributions	
	Equipotential lines and surfaces	
	Electric fields as the derivative of the potential	
V	Ohm's Law and Direct Current Circuits **[C3]**	**11**
	Resistivity and resistance	
	Ohm's law and Kirchoff's rules applied to DC circuits	
	Equivalent resistance	
	RC circuits	
VI	Magnetic Forces and Fields **[C4]**	**7**
	The field concept applied to magnetism	
	Charged particles in magnetic fields, mass spectrometer	
	Current-carrying wires in magnetic fields	
VII	Calculating Magnetic Fields **[C4]**	**8**

C1—Electrostatics

C3—Electric circuits

C4—Magnetic fields

Workbook Unit	Topics	Number of Days
	Introduction to and applying the Biot-Savan law	
	Introduction to and applying Ampere's law	
VIII	Electromagnetic Induction **[C5]**	**10**
	Introduction to Faraday's law and Lenz's law	
	Using Faraday, Lenz, and Ohm to determine the induced *emf* and the magnitude and direction of an induced current	
	Inductance and RL circuits	
	Maxwell's Equations	

C5—Electromagnetism

Teaching Strategies

Lecture/Question–Answer Sessions

Other than lab experiments, class time is taken up with lecture and question–answer sessions. A "lecture" consumes 20 to 30 minutes in which a concept presented in the reading is reviewed, stressing important definitions and limitations. The remainder of the period usually involves showing relevant demonstrations (toys are frequently used), and then introducing an assigned problem or set of problems related to the demonstration. The students are then guided in a discussion (whole class or small group) to develop solutions to the problem(s). During all of these activities, I encourage discussion, questions, hypotheses, and proposals to flow among the students themselves and between the students and me. Demonstrations are chosen to give the students as many different "looks" at the application of a concept as possible, so an appreciation of the universality of physical concepts is developed. Live demonstrations with simple equipment, often done by the students themselves for the rest of the class, are preferred. Computer simulations and video demonstrations have their place when real equipment is not available. Whenever possible, I use the analogies, conceptual discoveries, and problem-solving techniques that helped my understanding when I was a student. **[C7]**

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

Problem Assignments

At the beginning of each unit, I give students a list of "what you should know and be able to do" by the end of the unit, a day-to-day schedule with assignments, the experiments scheduled, and when a quiz on the material can be expected. Providing this informs the students about the work required to master the objectives of the unit.

Because of time constraints, the objectives closely parallel the AP Physics C syllabus. Demonstrations, assigned textbook and supplementary problems, worksheets, question–answer sessions, and labs are designed and chosen to aid in the "know-and-do" learning process.

The assigned problems are either from the textbook or from a supplementary problem handout. Problems are chosen to give students experience with a wide range of applications of the subject covered in the unit. When the textbook does not have a problem covering a particular application, I use one from another text or write one. These make up the supplementary problem list. I also make extensive use of worksheets that are designed to help students develop orderly, step-by-step problem-solving techniques. When working problems or in question–answer sessions, I always stress starting from a general principle and moving toward a specific application. Instead of spending class time on working a problem all the way through to the answer, we work on building a general-to-specific routine in solving problems. This is an important skill to develop for success in future course work in the long term and for success on the AP Exam in the short term, since most problems students encounter will not be of the specific type they have worked.

Lab Experiments

Approximately 20 percent of class time is taken up by lab work. Lab reports are required and are kept in a lab notebook. The experience gained by manipulating equipment, recording and organizing data, and drawing conclusions should be a vital part of any physics course. Much of the newer technology-based lab equipment does not fit my style because once it is set up, the data is taken, necessary calculations are performed, and graphs are produced at the push of a button without much thought by the students. To me, a valuable learning opportunity is lost when students are not required to work with the data and organize it into a form in which a conclusion can be drawn. In my labs, students use simple equipment with a minimum of "black boxes." [C8] My students perform all or most of the Electricity and Magnetism labs from the College Board's *AP Physics Lab Guide*, including all the calculus treatments of the data. [C6] Other lab experiments are, for the most part, written by me and chosen to provide students with experiences that reinforce concepts being covered in class. They are listed below:

C8—The course includes a laboratory component comparable to a semester-long, college-level physics laboratory. Students spend a minimum of 20 percent of instructional time engaged in laboratory work. A hands-on laboratory component is required. Each student should complete a lab notebook or portfolio of lab reports. Note: Online course providers utilizing virtual labs (simulations rather than hands-on) should submit their laboratory materials for the audit. If these lab materials are determined to develop the skills and learning objectives of hands-on labs, then courses that use these labs may receive authorization to use the "AP" designation. Online science courses authorized to use the "AP" designation will be posted on the AP Central® website.

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

Electricity and Magnetism Labs

1. **Equipotentials and Electric Fields.** Equipotential lines are mapped between electrodes of various shapes and the electric field in the region is sketched.

2. **Direct Current Circuits.** Introduces the concepts of current, potential difference, power, and resistance. Series and parallel circuits are investigated. Ohm's law is derived experimentally.

3. **RC Circuits.** Using a simple RC series circuit, the voltages across R and C and the current in the circuit are measured and plotted as functions of time as the capacitor is charged and discharged.

4. **Forces on Currents.** Students determine the relationship between the magnetic force between two wires and each of three factors: current moving through the wires, the wires' separation, and the length of the parallel segments. Also, they determine the relationship between the magnetic field of a straight wire and each of two factors: the distance from the wire, and the current flowing through the wire.

Evaluation

Quizzes are given approximately every two units. The quizzes are purposely similar in construction to the AP Exam. Each consists of 8 to 12 multiple-choice questions and a multipart free-response question. A teacher-constructed "anti-memorization" sheet is permitted on all quizzes. While going through the course material, the stress is on developing concepts and problem-solving strategies, not on memorization.

The multiple-choice questions come from many sources, such as AP Released Exams, New York Regents Exam review books, and questions I have written. The free-response questions have the same format as those on the AP Exam, and most are modified AP Exam questions. All are constructed to test current material and material previously covered. For example, an energy free-response question might require a free-body diagram and have a part involving a trajectory.

The day after the quizzes are given, students score each other's papers using a rubric similar to those used to score the free-response questions on the AP Exam. The solution is projected on a screen, showing where points are to be given. Before students begin scoring papers, each section of the solution is carefully explained. This requires them to go through the solution carefully, perhaps recognizing their own mistakes and perhaps learning a little from the mistakes of others.

Homework

Homework is assigned through a day-by-day assignment sheet, which students are given at the beginning of each unit. After they have had the chance to ask about a group of assigned problems or worksheet, two to five problems and/or a worksheet are handed in at random intervals during the unit. Homework is accepted only when asked for. This encourages students to stay current in their assignments. Since students have had the chance to ask questions, the homework they hand in is expected to be correct.

Grading

Lab reports are graded on the basis of 10 points, with the formal reports worth 20 points. Quizzes are worth 25 to 30 points, with the multiple-choice questions worth one point apiece and the free-response questions worth the remainder of the points. The homework collected in each unit is worth roughly half a quiz grade. The semester final and review exams are worth 35 points each. Extra credit—which can include helping to set up labs, building a car within stated design parameters, or working out amusement park problems—is liberally sprinkled throughout the course. All points are added and the percentage of points possible is determined. Grades are assigned according to the following schedule:

A = 85–100%; B = 70–84%; C = 55–69%; D = 45–54%; E = below 45%

Having taught the course for more than 20 years, I calibrate the points available to result in half to two-thirds of the students earning grades of A or B.

AP Exam Review

Formal review begins two weeks before the AP Exam is administered. Each student is given an exam review booklet consisting of the multiple-choice sections from two AP Physics C Released Exams and the free-response questions from the last five exams. In the booklet is a listing of the multiple-choice questions sorted by subject (i.e., electrostatics, circuits, etc.). During the early part of the review, several of these subject areas are assigned as homework. The first part of each class period is used to answer questions on the previous day's assignment. The rest of the period is divided up into 15-minute intervals, and one free-response question is assigned during each interval. Students may work alone or in groups of no more than three. Solution notebooks are available in the classroom for students to check their work. At the end of the first week of review, the Mechanics multiple-choice questions from an AP Physics C Released Exam are given for credit. After the end of the second week, the multiple-choice questions from the E & M exam are given.

Resources

Primary Texts

McGehee, John. *AP Physics C Electricity and Magnetism Workbook*. Unpublished.

Kleppner, Daniel, and Norman Ramsey. *Quick Calculus: A Self-Teaching Guide*. 2nd ed. New York: John Wiley, 1985.

Serway, Raymond A., and Robert J. Beichner. *Physics: for Scientists and Engineers*. 5th ed. Fort Worth: Saunders, 2000.