Student Performance Q&A:

2003 AP® Physics C: Electricity and Magnetism Free-Response Questions

The following comments on the 2003 free-response questions for AP® Physics C: Electricity and Magnetism were written by the Chief Reader, Patrick Polley of Beloit College in Beloit, Wisconsin. They give an overview of each free-response question and of how students performed on the question, including typical student errors. General comments regarding the skills and content that students frequently have the most problems with are included. Some suggestions for improving student performance in these areas are also provided. Teachers are encouraged to attend a College Board workshop, to learn strategies for improving student performance in specific areas.

Question 1

What was the intent of this question?

This question in electrostatics asked students to calculate the electric field and potential outside and inside a spherically symmetric charge distribution. Students were also asked to calculate or explain the motion of a proton or electron when those particles were placed near the distribution. Students needed to use Gauss' law in the fourth part of the question.

How well did students perform on this question?

The mean score for this question was 4.81 out of a possible 15 points. The scores were surprisingly low, with less than 8 percent of the students earning a score of 10 or higher and more than a quarter of the students earning a score of 2 or less.

What were common student errors or omissions?

Most students earned a few points on Parts (a) and (b), which dealt with situations outside of the charge distribution. The trouble began in Part (c), where many students had difficulty synthesizing the concept of the conservation of mechanical energy with the change in the electric potential energy of an electron as it neared the distribution.

The real problems came in Parts (d) and (e). The great majority of the students were unable to correctly integrate the charge density over the volume of the distribution in order to obtain the total charge Q. Many students decided to eschew the calculus altogether and write ρ_0 as a function of r. This garnered them no points. The application of Gauss' Law in Part (e) stumped most students as well.

Based on your experience of student responses at the AP Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

The relation between the surface integral in Gauss' law and the charge within the volume enclosed by that surface is one that students did not grasp. It is clear that most students have a poor understanding of this relationship, except for the simplest charge distributions.

Question 2

What was the intent of this question?

This question involved the analysis of the time-dependent behavior of an *RC* circuit. The final part of the problem had a lab component, which required students to design a circuit. The circuit was to allow a capacitor to charge and discharge through the same resistor by adding a single-pole, double-throw switch to the original circuit.

How well did students perform on this question?

The mean score was 9.68 out of a possible 15 points. Student performance was good, with 20 percent of the students earning a score of 14 or 15 and slightly over a quarter of all students earning a score of less than 8.

What were common student errors or omissions?

The construction of the circuit in Part (a) gave students little problem, but the circuit in Part (d) was more difficult. Readers had the feeling that students had seen the circuit for Part (a) before or built it during a lab, particularly as most students used a voltmeter in parallel with the resistor *R* to measure the current in the circuit.

Many students decided to do Part (b) the hard way. The easy way to get *R* is to divide the current at $t = 0$ into the emf in the circuit ($R = V/I$). A substantial number of students picked another point on the graph and calculated $e^{-t/4}$ and then used that to find *R*. From there it was pretty smooth sailing to find *C* in Part (c) by using $RC = 4$

Based on your experience of student responses at the AP Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

Students need to think about these circuits, and the equations that describe their behavior, in the simplest terms possible. Many students made more work for themselves by using inappropriate equations in their answers to the question. There were also a significant number of students who did not understand how to hook up a voltmeter or ammeter in order to measure voltages or currents in a circuit.

Question 3

What was the intent of this question?

This question involved the Lorentz force and electromagnetic induction. The application was a little unusual, as it involved the calculation of forces on charges in a wire attached to an airplane that was flying through a constant and uniform magnetic field.

How well did students perform on this question?

The mean score for this question was 6.02 out of a possible 15 points, which is low but to be expected on a problem involving magnetism. Exactly a quarter of the students earned a score of 10 or better, while slightly more than a quarter earned a score of 2 or less.

What were common student errors or omissions?

Part (a) gave students little difficulty, as it required a straightforward application of the right-hand rule. The calculation of the electric field in the antenna in Part (b), and the potential difference along the antenna in Part (c), were tractable for many students. Algebraic errors, more than a lack of understanding, cost students some points in those sections. In Part (e) students generated many different acceptable answers. As long as the flux changed, students earned full credit on this part of the question.

Based on your experience of student responses at the AP Reading, what message would you like to send to teachers that might help them to improve the performance of their students on the exam?

Electromagnetic induction always gives students more trouble than the Lorentz force, probably because induction is more closely tied to the interplay of the electric and magnetic fields, and the Lorentz force is just an application of mechanics to a point particle.

Overview of the AP Physics C: Electricity and Magnetism Exam

Performance on this year's exam was lower than we would like to see, but it was in line with other years. The biggest surprise was the poor showing on Question 1. Students' inability to apply the integral calculus successfully was an eye opener. Clearly students lacked both the conceptual understanding and the problem-solving skills that are necessary to apply the calculus to a problem that was slightly different from one they might have seen.

The good news is that many students were comfortable with the circuit problem (Question 2) and showed some familiarity with designing simple circuits. Here they demonstrated some lab skills and conceptual understanding of the behavior of *RC* circuits as well.

Magnetism problems continue to be difficult for students. This year's problem was no harder than in previous years, as indicated by student scores. No specific weaknesses were seen here, except for a general weakness in applying concepts beyond the Lorentz force in problems involving magnetism.