CollegeBoard AP

Student Performance Q&A:

2010 AP® Physics C: Electricity and Magnetism Free-Response Questions

The following comments on the 2010 free-response questions for AP® Physics C: Electricity and Magnetism were written by the Chief Reader, Jiang Yu of Fitchburg State College in Massachusetts. 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 assessed students' understanding of electrostatics. In part (a) students were asked to reason qualitatively about the value of the electric potential near a quarter-circle of charge. In part (b) students were asked to derive an expression for the electric potential at the center of curvature of that quarter-circle of charge. In part (c) a charge was released from rest at the center of curvature, and students were asked to calculate the speed of the charge when it was a large distance away from the charge distribution. In parts (d) and (e) students were asked for the direction and magnitude of the electric field at the center of curvature of the charge distribution.

How well did students perform on this question?

The mean score for this question was 6.92 out of a possible 15 points. Almost all students attempted the question.

What were common student errors or omissions?

In part (b) some students tried to use the relationship between voltage and electric field ($\Delta V = \int \mathbf{E} \bullet d\mathbf{s}$), not realizing that they did not know the electric field as a function of position. In part (c) students were either able to use conservation of energy and did so well or did not know what to do at all. The latter group generally left this part blank or made a small attempt to use Newtonian mechanics, not realizing that the force was not constant as the charge moved farther away.

The majority of students were unable to correctly integrate to get the magnitude of the electric field for part (e). Some attempted to use Gauss's law, not recognizing that the electric field due to this distribution does not have the symmetry to lend itself to that analysis. Some attempted to use

$\Delta V = \int \mathbf{E} \bullet d\mathbf{s}$, not realizing that they only knew the potential at the center of curvature and not the potential as a function of position.

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?

Teachers could help students by clearly delineating which methods are appropriate for finding the electric field for different kinds of charge configurations, such as point charges, lines of charge, spheres and cylinders. Students also need practice integrating the electric field for linear charge distributions.

Question 2

What was the intent of this question?

This question assessed students' ability to apply basic circuit rules and equations to a DC circuit containing both capacitors and resistors in steady-state.

How well did students perform on this question?

The mean score for this question was 7.86 out of a possible 15 points. Few students left this question blank.

What were common student errors or omissions?

In the first part of the question, the illustration shows that a switch is open so that the two capacitors on each branch are stopping the flow of current. A very common student error was not recognizing this fact and calculating a current flowing in the circuit.

Probably the most common error occurred in the second half of the question, when the switch is closed so there is current through the resistors, which are now in parallel with the capacitors. The majority of students did not recognize that the voltage across each capacitor is equal to the voltage across the resistor it is in parallel with (which is only a portion of the battery voltage). Instead, students most often used the voltage of the battery to calculate the charge on the capacitor (part (e)).

Extremely common algebraic errors, usually using the equation $U = \frac{1}{2}CV^2$, occurred in the calculation for part (c). Although most students were able to correctly find and substitute values into this equation, they would forget to use the one-half or to square the voltage when calculating the numerical value. Students also frequently dropped the "micro" prefix out of the calculations throughout the problem.

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?

Concepts that could be reinforced include what role capacitors play in DC circuits in steady-state and how to analyze (particularly conceptually) circuits that are more complicated than simply parallel or simply series elements.

Question 3

What was the intent of this question?

This question was intended to assess students' understanding of electromagnetism. Part (a) asked students to determine the direction of the induced current in a loop of wire near a long wire. Students had to give a justification for their choice based on Lenz's law. Part (b) asked students whether the bulb brightness would increase, decrease or remain the same, and students were to justify their choice by discussing the rate of change of the flux. Part (c) asked students for the strength of the magnetic field as a function of position at time $t = 0$. Students were asked in part (d) to derive an expression for the flux through the loop as a function of time, for which they had to integrate the magnetic field over the area of the loop. In part (e) they were asked to derive an expression for the power dissipated by the lightbulb as a function of time.

How well did students perform on this question?

The mean score for this question was 5.45 out of a possible 15 points. The score distribution was skewed, with a mode of 1 and a large number of zeros, though almost all students attempted the question.

What were common student errors or omissions?

In part (a) the common error was to assume that the induced current was such as to oppose the flux through the loop, rather than opposing the change in the flux. Some students simply justified their answer using the phrase "right-hand rule" and lost all 3 points for that part.

In part (b) many students thought that because the current in the long wire was decreasing, the bulb brightness was decreasing as well. In this part and in part (e), they confused the current in the long wire with the current through the loop and thus in the bulb.

Many students were successful at part (c) and simply wrote down the standard equation derived from Ampere's law. Others unsuccessfully attempted to use the Biot–Savart law.

Many students were able to find the flux equation in the equation table and write that for part (d), but many did not know how to proceed from there. Many of them integrated with respect to time because they had the magnetic field as a function of time. There seemed to be a lot of confusion related to integrating the magnetic field with respect to area versus taking the time derivative of the flux to find the emf. Numerous students took derivatives and integrals with respect to time in part (d), and many integrated the expression for the magnetic field over r and then multiplied by the area of the loop to obtain the flux.

In part (e) many students simply wrote $P = I^2R$ and substituted the current in the long wire rather than using the emf from the change in flux to calculate the power. Students who did recognize that they needed to take the derivative of the flux were generally able to do so correctly and then use it in $P = \mathcal{E}^2/R$.

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?

Teachers could help students improve their performance by implementing the following recommendations:

- Give students more practice taking area integrals and finding the flux through loops when the magnetic field is not uniform.
- Emphasize the difference between the independently changing current and the induced current it causes.
- Emphasize that the direction of the induced field is determined by analyzing the change in external field, and it is not necessarily opposite the field itself.
- Give students more practice in recognizing the logical steps involved in reaching a conclusion, such as in part (a) of Question 3.
- Give students opportunities to practice expressing these steps in sentence form, in an organized manner.