Student Performance Q&A:

2011 AP® Physics C: Electricity and Magnetism Free-Response Questions

The following comments on the 2011 free-response questions for AP® Physics C: Electricity and Magnetism were written by the Chief Reader, Jiang Yu of Fitchburg State University in Fitchburg, Mass. 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 Gauss's law, the concept of electric flux, and the nature of electric fields due to charge distributions. A large part of the question concerned the idea of flux and the fact that the total flux through a closed surface is proportional to the charge enclosed by the surface.

How well did students perform on this question?

The mean score was 5.76 out of a possible 15 points. Almost all (99 percent) students attempted to answer at least one part of the question; 94 percent earned a nonzero score. A majority of the students attempted parts (a) through (e).

What were common student errors or omissions?

In part (a) many students considered the charged shell itself to be the required Gaussian surface.

In part (b) many students attempted to apply Gauss's law where it could not be used.

In part (c) many students displayed partial understanding of the concept of electric flux as a scalar product of the electric field vector and the area vector, and that the area vector is normal to the surface in question. Many students could not differentiate the dot product from the cross product.

In part (f) the most common error was to calculate the flux using $\oint \mathbf{E} \cdot d\mathbf{A}$ by taking the electric field out of the integral as if it were a constant field through the surfaces in 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?

- Push students to a fuller conceptualization of Gauss's law, including all its subtleties.
- Provide students with experiences that involve conceptual questions about flux, such as the typical linear, 2-D sheet, cube, cylindrical and spherical problems found in popular textbooks.
- Provide experiences where Gauss's law is not useful or cannot be used and then ask students to consider other approaches, which require deeper understanding of the law.

Question 2

What was the intent of this question?

This question assessed students' understanding of RC and LC circuits in two related hypothetical experiments where simple circuit analysis, conservation of energy and Kirchhoff's loop rule were used.

How well did students perform on this question?

The mean score was 6.66 out of a possible 15 points. Some 98 percent of students attempted to answer at least one part of the question, and 93 percent earned a nonzero score. Most students attempted parts (a) through (b) i.

What were common student errors or omissions?

In part (a) i many students misunderstood the charge on one plate of the capacitor as one-half of the total charge it holds. They divided the correct magnitude by 2 to find the value on the bottom plate.

In parts (a) ii and (a) iii there were all kinds of incorrect curves. For example, many students did not know that the charge on the capacitor increased asymptotically to the $Q_{\max}$ that they calculated or drew the curve reversed (concave up instead of concave down). Similarly, the current curve was incorrectly drawn straight or curved. Some took the current as zero throughout. Many had a nonzero constant value of current between $t = 0$ and t_1, or a nonzero value occurring before t_1. And many had incorrect or missing labels on both drawings.

In part (b) i many students misused 9 V for the voltage in $U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$. Some students substituted the energy found in part (b) i for the emf in $\mathcal{E} = -L\frac{dI}{dt}$ and solved for the current in (b) ii. Many students substituted incorrect values of voltage in (b) iii when using the loop rule.

In general many students incorrectly substituted 10^{-6} (or other incorrect powers of ten) for “milli” in the given values, and algebraic errors were common. The common student omission of appropriate units for physical quantities persisted.

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?

- Help students develop a good understanding of capacitors, inductors and their functions in RC, RL and RLC circuits.
- Remind students to show their understanding by drawing appropriate graphs.
- Help students to understand the meaning of dI/dt and the essence of Kirchhoff’s rules as practical applications of conservation of energy and conservation of charge.

Question 3

What was the intent of this question?

This lab question assessed student understanding of Ampere’s law with a long-conducting, hollow, current-carrying cylinder. It also assessed students’ ability to graph a set of experimental data and then extrapolate information from the graph to obtain values of physical quantities.

How well did students perform on this question?

The mean score was 8.30 out of a possible 15 points. Some 98 percent of students attempted to answer at least one part of the question, and 97 percent earned a nonzero score. Most students attempted all parts.

What were common student errors or omissions?

In part (a) many students seemed unfamiliar with how to calculate the current enclosed in the Amperian loop. Many were also unable to evaluate the integral for the closed loop.

In part (b), when students were asked to draw the field on the point P labeled in the diagram, many drew a curved line to represent the magnetic field at the distance $2b$ rather than the direction of the magnetic field at that particular point as a tangent vector.

In part (c), when asked to describe the electromagnetic forces acting on an electron at point P, most students omitted a discussion of an electric field (which was not present), and roughly 30 percent incorrectly described a magnetic force on the charge due to the magnetic field when the charge was stationary.

In part (d), when asked to calculate μ_0 using the slope of the best-fit line, students used data points that were not on the straight line. Many students did not make the connection between the given function for the magnetic field given and the line drawn on the graph.

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?

- Push students to a fuller conceptualization of Ampere's law. Help students to apply the law in conceptual as well as computational questions regarding the resulting fields around the typical configurations of electric current found in most textbooks.
- Help students to master data analysis techniques, practice scaling graphs properly, and draw best-fit straight lines using a straightedge. Students need to understand the use of properties of the best-fit line and not use data points that are not on that line. Students need to gain a good understanding of the connections between the experimental data and the physics for which they apply.
- Teach at the appropriate level — calculus must be employed in thinking and in problem solving.