Student Performance Q&A:

2014 AP® Physics C: E&M Free-Response Questions

The following comments on the 2014 free-response questions for AP® Physics C: E&M were written by the Chief Reader, Peter Sheldon of Randolph College in Lynchburg, Va. 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 involved an experiment where voltage was varied and current was measured. In addition to assessing data analysis, the question was intended to assess student understanding of *RC* circuits, especially the loop rule. It required students to use data to make a graph of current versus voltage to determine resistance, to solve a few simple loop rule questions, and then to answer and justify questions about capacitor charging behavior.

How well did students perform on this question?

The mean score was 9.78 out of a possible 15 points.

What were common student errors or omissions?

- Most student errors came from not using the graph appropriately to determine the effective resistance. Because the question asked explicitly for current versus voltage rather than the more usual voltage versus current, many students made the inverse graph, and did not recognize that.
- Students did not use the slope of the best-fit line, but rather used the data points provided to calculate slope.
- Students were not able to "justify" their responses by explaining the underlying physics.

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 understand the purpose of a best-fit line, and need to understand that the slope of the line is the meaningful quantity (rather than slope between two arbitrary data points).
- Students should be able to graph correctly, including labeling and scaling axes, and understand how to make theoretical predictions from graphs.

- Students need significant practice constructing airtight justifications that include skillfully worded connections to the basic physics. Too many students seemed to feel that restating the fact already provided in the question using other words was equivalent to a justification.

Question 2

What was the intent of this question?

This question was a standard loop moving into a constant magnetic field. The students are expected to know that there will be an induced emf, resulting current, and force on the moving loop. The question gives the student multiple opportunities to demonstrate this knowledge first by just making correct selections from choices, then using equations, then describing in words what is happening.

How well did students perform on this question?

The mean score was 5.28 out of a possible 15 points.

What were common student errors or omissions?

- Students tried to (incorrectly) use Ampere's law.
- Students commonly related the quantity BLv to current rather than emf.
- Students often used the area of the loop instead of the rate of change of the area.
- Students often justify result by restating the result rather than using correct reasoning.

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 more practice with justifications.

Question 3

What was the intent of this question?

This question dealt with Gauss' law. It was not at all like a standard problem with an insulating or conducting sphere. Instead the students were told that they had a nucleus with a positive charge surrounded by a negative charge distributed non-uniformly. Students had to sketch graphs of positive and negative charge and electric field as a function of r. Then they were told to use Gauss' law to solve for the electric field outside and inside the boundary of the charge at $r = \alpha$.

How well did students perform on this question?

The mean score was 4.99 out of a possible 15 points.

What were common student errors or omissions?

- Students could not qualitatively reproduce the correct trend on the graph.
- Students did not show each step of the derivation (substitution) for Gauss' law. The most common missed step was stating that the charge enclosed was zero.
- Students did not recognize the need to integrate with respect to volume to calculate charge enclosed by the Gaussian surface.

- Students used the area of a circle or the volume of a sphere instead of the area of the Gaussian surface.
- Students forgot to include $+Q$ when calculating total charge enclosed.
- Students had difficulty explaining the "physical meaning" of alpha.

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?

- This problem required that students "think outside the box." They had studied Gauss' law but never had to apply it like this. Teachers should look for ways to challenge their students to apply the theoretical concepts they teach to real world situations.
- Problems involving non-uniform charge density are not common but should be a part of the instruction in the CE class.