CollegeBoard
Advanced Placement Program

Student Performance Q&A:

2007 AP® Physics C: Electricity and Magnetism Free-Response Questions

The following comments on the 2007 free-response questions for AP® Physics C: Electricity and Magnetism were written by the Chief Reader, William Ingham of James Madison University in Harrisonburg, Virginia. 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 was designed to assess students' ability to interpret and utilize information presented graphically, as well as their understanding of the charging of a simple RC circuit, including the dissipation of energy in the resistor and the consequences of changing the capacitance.

How well did students perform on this question?

Students performed very well on this 15-point question. The mean score was 9.80. About 40 percent of students earned scores of 12 or higher, while about 7 percent earned scores of 3 or below.

What were common student errors or omissions?

The majority of students did very well on parts (a) and (d). Part (e) and the check box in part (f) were largely correct. Failure to use a loop rule in part (b) was very common as was confusion about calculating charge in part (c). The justification in part (f) proved to be the most challenging. Most students who correctly checked "greater than" stated that the higher dielectric constant meant higher capacitance (thereby earning one of the justification points); very few students correctly discussed how the dielectric constant affected the time dependence.

Students were asked to *calculate* in parts (a), (b), (c), and (e); those who did not show their work did not earn points.

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A large number of students ignored the facts that the graph of current versus time had units of milliamps for the current and that the capacitance was given in microfarads. Several students flipped back and forth with units in parts (b) and (e), often dropping mA in part (e). Many students tried to use the slope of the $I(t)$ graph to determine voltage in part (a).

The most common error in part (b) was calculating the voltage across the resistor instead of that across the capacitor. Similarly, a common error in part (e) was using the voltage calculated for the capacitor rather than that for the resistor.

In part (c) many students calculated Q as $I(t = 4\text{ s})$ times 4 s, as if the current were constant for the first four seconds. A few students tried the method of estimating, or integrating, to get the area under the $I(t)$ curve for the stored charge at four seconds, but they rarely carried out this approach correctly.

In part (d) most students did reasonably well with the graph, although many neglected the fact that the time axis went to 10 s (nearly 5 time constants); their curves failed to show the charge nearing its asymptotic value by the end of the graph.

In part (e) a significant number of students calculated average power over four seconds instead of instantaneous power at four seconds.

In part (f) some students stated that the time rate increases (or decreases) with the dielectric inserted without reference to a particular dependent variable, making the statement ambiguous. Simply rephrasing the question was also a common attempt at justification.

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?

We recommend that every year teachers review (for themselves and their students) the "key words" used on the AP Physics Exams. "*Calculate*" indicates that work must be shown in order to receive credit. Note that presenting an equation, substitution, and final answer *does* satisfy the request to calculate.

It is strongly recommended that students use units in substitution and check the reasonableness of their answers. It is evident that students need practice in reading graphs and getting data from a graph. They also need practice in sketching different kinds of graphs.

When giving a justification, students should take care to avoid contradicting themselves. Often an equation can be given and successfully used to drive the discussion. Students would benefit from analyzing how changing either or both constants affect currents, voltages, and the final charge in an RC circuit in which the capacitor is being charged.

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Question 2

What was the intent of this question?

The purpose of this question was to evaluate students' ability to use Gauss's law to find the electric field that resulted from a specified spherically symmetric charge distribution, as well as their understanding of the relationship between electric field and electric potential.

How well did students perform on this question?

The mean score on this 15-point question was 6.18. About 22 percent of students earned scores of 12 or higher, while about 39 percent earned scores of 3 or below.

Most students did fairly well overall on part (a). Parts (a)(ii) and (a)(iv) were most commonly correct; (a)(iii) was a definite challenge for many students. Most students got a majority of the points available for part (b); students also generally did well on part (c).

What were common student errors or omissions?

In part (a) the question specifically asked students to *derive* their results using Gauss's law. Many students just wrote answers without showing how they got them, which did not earn points. Many students clearly did not understand how to find the charge enclosed. Surprisingly, many other students did not know that the integral of dA for a closed spherical surface is $4\pi r^2$.

In part (b) students gave the correct answer that the electric potential is zero at the outer surface of the shell, but their explanations were not always complete, resulting in the loss of a point.

In part (c) students who used an integral to answer the question had difficulty setting the correct limits with the correct sign.

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?

We recommend that every year teachers review (for themselves and their students) the "key words" used on the AP Physics Exams. "*Derive*" indicates that you must start from a fundamental equation and *show* how you got the final answer. In part (a) that meant starting with Gauss's law and determining the correct enclosed charge to find the expression for the electric field. In part (c) students were expected to derive an expression for the electric potential difference. Note that in this case students were not required to get to a final "reduced" answer; they simply had to set up the expression correctly. Knowing more specifically what sort of response was expected would have saved many students a lot of time and effort.

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Question 3

What was the intent of this question?

The intent of this question was to measure students' understanding of induced emf and induced current, as well as the magnetic force on a current-carrying wire. The question also assessed their ability to determine and qualitatively sketch the time-dependent external force required to keep a wire (carrying a varying induced current) moving at constant speed through a magnetic field. In addition, the question evaluated students' ability to analyze what would happen if the external force was removed.

How well did students perform on this question?

The mean score on this 15-point question was 5.53. About 15 percent of students earned scores of 12 or higher, while about 43 percent earned scores of 3 or below.

Almost all students (98 percent) attempted to solve this problem. They did best in parts (a) and (e). Many had the correct idea in part (a) but failed to articulate clearly what "opposing the change" means in this context.

What were common student errors or omissions?

Many students had difficulties identifying correctly which segments of the loop had to be included in the calculation of R in part (b), or the appropriate length to use in part (c).

In part (d) a significant number of students failed to sketch a graph that was consistent with their answer for part (c), even when they had a simple time dependence (such as a linear dependence) in their answer for part (c).

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 be reminded to pay careful attention to instructions. For example, in part (b) the problem asked for the *magnitude* of the induced current, yet many students included a negative sign in their answer.

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