CollegeBoard
Advanced Placement Program

Student Performance Q&A:

2005 AP® Physics C: Electricity and Magnetism Free-Response Questions

The following comments on the 2005 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 explored students' understanding of electric fields, the motion of charged particles in electric fields, and the relation between electric field and electric potential. In part (a) students were asked to interpret a map of electric field lines in order to determine at which of three points the electric field was greatest and at which of three points the electric potential was greatest. In part (b) they were to discuss the motion of an electron after it is released in a nonuniform electric field. In part (c) students were asked to estimate the magnitude of an electric field between two points (the two points had a 20-volt potential difference between them). The final part of the question required that students draw an equipotential line on the field-line map. The equipotential had to pass through a given point and intercept at least three electric field lines.

How well did students perform on this question?

Student performance was about average for an electrostatics question. The mean score was 7.29 out of a possible 15 points. The question provided good discrimination among students of all abilities throughout the scoring range. Approximately a quarter of students earned scores of 11 or more. Slightly less than 20 percent of students earned scores of 3 or less.

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What were common student errors or omissions?

This question probed students' conceptual understanding of a variety of topics, and the errors were scattered throughout each part of the question.

In part (a) students often conflated the notion of electric field strength and potential. They knew that point A in the diagram was at a higher potential, but they could not explain why, often using the same explanation that they used to justify their answer regarding electric field strength.

In part (b) students had difficulty giving a complete and succinct description of the motion of an electron after it is released from rest. A common error in part (b)(ii) was to use the expression $QV/2$ for the electric potential energy.

Part (c) provided some difficulties for students, particularly in their statement of assumptions. Many students failed to realize that the expression $Ed = V$ is a version of the equation $E = -(\Delta V/\Delta x)$. This means that d is a distance between two points, not a point in space. Also, the failure to supply an answer with units cost about half the students a point.

The final difficulties centered on drawing the equipotential lines in part (d). Some students explicitly stated that they could not do the problem since a field line was the same as an equipotential line. Many students failed to properly draw the equipotential line perpendicular to the field lines at the point where they intersected.

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?

See general comments at the end of question 3.

Question 2

What was the intent of this question?

This question tested the students' understanding of LR circuits at long and short time scales. Students needed to understand that at short time scales, inductors resist changes in the current flowing through them. In the dc circuit shown, when the switch S was closed, the current flowing through the inductor was zero, and all of the current flowing through R_1 had to flow through R_2. After a long time, the inductor acted like a short circuit, so that all of the current flowing through R_1 flowed through L. When the switch S was opened again, the current continued to flow through L, and the voltage drop across R_2 could be calculated by Ohm's Law. The remaining concept, which is that the voltage drop across an inductor is given by $L(dI/dt)$, was tested in part (b). Part (d) was designed to test students' ability to graph the time-dependent behavior of the current supplied by the battery.

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How well did students perform on this question?

Student scores were lower than expected on this LR circuit problem. The mean score was 4.5 out of a possible 15 points. Approximately 11 percent of students earned scores of 11 or better. Slightly more than half of students earned scores of 3 or less.

What were common student errors or omissions?

The most common error was students' failure to recognize what an inductor was. This meant they were also in the dark concerning how the inductor affected the flow of current. Students did not know that the current through the inductor immediately after the switch was closed was zero, or that at long periods after the switch was closed the inductor would act as a wire. Some students lost a few points to algebra errors, but the most serious error was ignorance of the inductor.

For those students who did know what the inductor was, the graph presented little difficulty. It was not clear in part (e) if students were correctly applying the loop rule or Ohm's Law, but they received credit in either case.

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?

See general comments at the end of question 3.

Question 3

What was the intent of this question?

The question required that students do numerical and graphical analysis on a set of data presented in the exam booklet. In the course of this analysis they were to use the equation for the magnetic field in a long solenoid ($B = \mu_0 nI$). The data consisted of the current flowing through the solenoid, the magnetic field within the solenoid, and the length of a coil whose number of turns was fixed but whose length could be varied. Students were asked to graph the data in such a way as to be able to determine a value for μ_0 from the graph. If B were graphed on the vertical axis and n on the horizontal axis, the slope of the resulting line was equal to $\mu_0 I$. Students were also asked to calculate the percent error between the value of μ_0 that they found from their graph and the theoretical value of that constant.

How well did students perform on this question?

Students did much better than usual on this magnetism-based lab problem. The mean score was 9.39 out of a possible 15 points. Slightly less than half the students earned scores of 11 or more. Slightly more than 12 percent of students earned scores of 3 or less.

What were common student errors or omissions?

Students who did not read all parts of this question got off to a rocky start by using the solenoid formula for a magnetic field to calculate n instead of simply dividing the 100 turns of the coil by its length. Those who did the latter (roughly half of those taking the exam) received full credit for their work.

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Students had difficulty using the graph to obtain a value for μ_0. Some assumed that the slope, which is equal to $\mu_0 I$, was equal to μ_0. Others eschewed the help given to them by the labels and scale on the graph and relabeled and rescaled it. The final place where errors occurred was due to students' inability to calculate a percent error.

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?

Performance was good overall, and the comments made above point out the areas in which students could use additional work. The most glaring shortcoming was in the inductor-resistor problem in question 2, where many students had no idea of how an inductor functions in a circuit. The graph in question 3 also gave problems, even with the rather large hint given by the labeling and scaling of the graph. Graphing skills among all the Physics C students, both in Mechanics and Electricity and Magnetism, seem to be weaker than in the past.

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