Student Performance Q&A:

2015 AP® Physics C-Electricity & Magnetism Free-Response Questions

The following comments on the 2015 free-response questions for AP® Physics C-Electricity & Magnetism were written by the Chief Reader, Peter Sheldon of Randolph College. 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, dielectrics, and energy storage in capacitors. The dielectric constant varied with height, and calculus was required. While relatively straightforward, the problem challenged students in an unfamiliar way.

How well did students perform on this question?

The mean score was 4.70 out of a possible 15 points.

What were common student errors or omissions?

The biggest discriminant was whether students treated the electric field as constant in the variable dielectric, thus allowing them to avoid calculus altogether by using $V = Ed$. Students often struggled with the notion of a non-constant dielectric constant and its implications for the capacitance and potential difference.

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 think more broadly about non-traditional contexts and focus on the learning and application of physics, and not so much on the exam, which will take care of itself. This problem was perhaps more straightforward than it appeared, but the unfamiliar idea of a dielectric that is not constant throughout was problematic for students.

Question 2

What was the intent of this question?

This problem explored the relationship between resistance and voltage in a basic circuit, and explored how to experimentally verify the relationship with measurement, graphing, and straight-line fitting. The concepts stressed are: the relationship between voltage and resistance, the effect of an internal resistance in a battery, the effect of a voltmeter in a circuit, and the experimental means to find the values of the emf and internal resistance of the battery.

How well did students perform on this question?

The mean score was 5.94 out of a possible 15 points.

What were common student errors or omissions?

Graphs:

- missing units
- missing axis labels
- scale not consistent along the axis
- scale too short or too long to display the data well
- connecting the data points with lines
- not understanding that the statement "graph A as a function of B" means that A is on the vertical axis

Algebra:

- errors solving for a variable
- errors inverting equations
- misunderstanding what a function is
- inability to express a relationship as a straight line

Circuits:

- not understanding the loop rule
- not understanding Ohm's Law
- mixing up the resistance in the battery, the resistance of the voltmeter, and the load resistance
- switching the sign of the potential drop across the internal resistance of the battery
- not understanding the concept of current (e.g., thinking current is used up in a resistor)

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 Kirchhoff's rules and Ohm's Law and know when each is appropriate to use.
- Students need to review the basics of making graphs: appropriate scales, labels, drawing data points, best-fit line, etc.
- Algebra skills: review the equation for a line and discuss the meaning of slope and y-intercept.
- Students need to be able to solve an equation for other quantities.
- Do not skip steps in solving problems. Show clearly the process used to find the answer. Always start with the equation in symbolic form and solve, only plugging in numbers at the end.
- Understand the meaning of and the difference between *derive*, *determine*, *calculate*, and *justify* as used on the AP Physics Exams.

Question 3

What was the intent of this question?

The question tests concepts of flux and induced current in a loop in a variable magnetic field. Students demonstrate their understanding of flux, voltage, current, energy, net force, and net torque on the loop.

How well did students perform on this question?

The mean score was 5.83 out of a possible 15 points.

What were common student errors or omissions?

- The most common mistakes were in generating the correct expression for magnetic flux. Many students integrated magnetic field with respect to an incorrect variable (time). Students commonly used the incorrect angle for the component of the magnetic field perpendicular to the loop.
- When calculating induced emf, students were not able to take the derivative of flux correctly.
- When justifying direction, students often wrote things such as "Right Hand Rule" and "Lenz's Law" without demonstrating an understanding of how these justify the direction.
- Students confused power with energy dissipated.
- Students often did not explain why the forces would cancel and the torques would not.
- Many students did not use units on all of their answers.

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?

- It is important to clearly define for students when and why integrals and derivatives are used in Physics.
- It is important that students have a better understanding of Lenz's Law and be able to explain how it applies to a situation such as this problem.
- This question shows that students struggle with the difference between power and energy.
- Students should be instructed to explain laws and rules and not just write down the name of the rule with no explanation.