Student Performance Q&A:

2014 AP® Physics B Free-Response Questions

The following comments on the 2014 free-response questions for AP® Physics B 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?

The intent of this question was to assess student understanding of kinematics, projectile motion, momentum, and mechanical energy including its transformation and conservation.

How well did students perform on this question?

The mean score was 7.91 out of a possible 15 points.

What were common student errors or omissions?

- Many students do not seem to know that "trajectory" means path. Many drew the initial velocity vector rather than the path.
- A surprising number of students who knew the meaning of trajectory were unable to predict the correct parabolic path when the person released the rope at point *B*, and very few predicted the person would drop vertically downward if they released at point *D*.
- Some students substituted a negative value for "*g*."
- Many students using energy conservation did not substitute the correct heights.
- Students often failed to correctly separate the vertical motion from the horizontal motion.
- Most students recognized that the momentum would be less at *C* than at *B* because the speed was lower at *C*, but a large percentage did not completely justify their choice with a physical explanation that described a mechanism for the reduction in speed.

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?

- "Justify" should be based on physics principles, not analogy.
- Teachers should go over the meaning of "calculate," "determine," etc. for the exam.
- Instruction should have more focus on concepts.

Question 2

What was the intent of this question?

This problem explored the topic of buoyant force and the application of Newton's second law to solve problems involving the buoyant force. The concepts stressed are: objects in a fluid experience an upward force, the ratio of densities (of object and fluid) determines the behavior of an object in a fluid, and the buoyant force is equal in magnitude to the weight of the fluid displaced by the object.

How well did students perform on this question?

The mean score was 4.20 out of a possible 10 points.

What were common student errors or omissions?

- Free body force diagrams had:
  - missing vectors
  - arrows not touching the dot
  - arrows pointing inward
  - combinations of two or more forces in one arrow
  - labels for the gravitational force of simply *g* or *G*
  - vectors labeled with quantities that aren't forces: density, pressure, etc.
  - normal forces where none are appropriate
- Newton's second law errors:
  - not understanding that at equilibrium the sum of the forces is zero
  - writing force equations that are not consistent with the free-body diagram
  - writing equations with un-like terms: i.e., a force added to a mass and then added to a density
  - cancelling a quantity out of one term but not all the other terms in an equation
- Buoyant force errors:
  - mixing up the density of the water and the density of the cube
  - mixing up pressure and force

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 learn how to correctly draw free-body diagrams, using appropriate symbols and labels.
- Algebra skills: Equations can only have like terms. You can't add forces and masses in the same equation. When canceling a quantity, you must cancel it from all terms in the equation.
- Do not skip steps. Show clearly the process used to find the answer. Always start with the equation in symbolic form, then manipulate the equation as necessary, plug in appropriate numbers, and solve. Don't just put a bunch of numbers down on a page.
- Understand the meaning of and the difference between derive, determine, calculate, and justify.

Question 3

What was the intent of this question?

The intent of this question was to assess the students' understanding of thermodynamic cycles. Part (a) tested their interpretation of a PV diagram and the ideal gas law. Part (b) tested their ability to determine whether work was done on or by a gas. Part (c) tested their understanding of the first law of thermodynamics, heat, and internal energy. Finally, part (d) tested the students' ability to find the work done on a gas using a PV diagram.

How well did students perform on this question?

The mean score was 3.19 out of a possible 10 points.

What were common student errors or omissions?

- In general, students often did not talk about the physics behind their answers in the justify portions.
- Students often left out the number of moles.
- Students would often confuse work done "on" versus "by" a gas, and would confuse when work should be positive or negative.
- Students did not derive the expression asked for, but often just stated it.

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 clearly understand the difference between internal energy, heat, and temperature.
- Students need to understand how to make a logical argument from the given information to the final conclusion, and not just restate their choice in words.
- Students need to show their work and cannot just write down their final answer.

Question 4

What was the intent of this question?

The intent of this question was to assess student understanding of electrostatics, specifically the concepts of Coulomb's law, electric fields, and voltage.

How well did students perform on this question?

The mean score was 3.23 out of a possible 10 points.

What were common student errors or omissions?

- Students who did poorly often could not differentiate between force, field, voltage, and potential energy. They did not know which were vector or scalar quantities.
- Students were not clear that a positive vector indicates information about direction, not about the sign of the charge or the voltage.
- When plugging into relationships, students were not clear which charges and radii to use in the equation. Students commonly tried to put all three charges in the formula together instead of as separate components.

- Many students do not understand the concept of positive/negative work. They could not clearly distinguish between work done "on" the charge or work done "by" the charge.
- Students commonly miscopied equations, changing "r^2" to "r" or dropping the constant "k" completely. Students also frequently exchanged Boltzmann's constant for the constant in Coulomb's law.
- Students often did not know the units for the various quantities

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?

- Be sure students can articulate what the various quantities, like electric field, voltage, and potential energy, mean in words, not just in equations.
- Be sure students know which equations are valid only for point charges, and not for more complex arrangements of charge.
- Be sure students can clearly articulate what the various quantities in the equations mean. For example, not just that "q" is charge, but that in Coulomb's law the expression gives the force that charge q_1 exerts on charge q_2 and vice versa, not the force these two charges exert on anything else.

Question 5

What was the intent of this question?

The intent of this question was to assess student knowledge of electromagnetism, their understanding of forces, equilibrium and dynamics, and their graphing and data analysis skills.

How well did students perform on this question?

The mean score was 4.73 out of a possible 15 points.

What were common student errors or omissions?

- Students typically did not give a full explanation of both the direction of the current and the cause.
- Students made many free-body diagram errors:
    - Vectors that did not touch the dot
    - Vectors mislabeled
    - Multiple forces combined in a single vector
    - Vectors place head to tail
    - Wrong direction for the magnetic force vector
- Many did not account for the original stretch of the springs that eliminated the weight from the equation.
- Some students confused energy and force.
- Many students did not account for both springs.
- Graphing errors included:
    - Reversed axes
    - Inconsistent/nonlinear scaling
    - Hardly any use of a straight-edge to draw the straight line
- Many students did not use the slope of the line, but used data points instead.

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?

- Focus on graphing skills, including the importance of using the slope in calculations.
- Be sure to inform students of the AP® standards for free-body diagrams and labeling of vectors.

Question 6

What was the intent of this question?

The intent of this question was to assess the students' understanding of the concepts of the photoelectric effect including the work function and the relationships between the energies of photons and the resulting emitted photoelectrons. Testing the latter concepts involve considering both increasing the intensity of light at a fixed wavelength, and decreasing the wavelengths of photons at a fixed intensity.

How well did students perform on this question?

The mean score was 1.48 out of a possible 10 points.

What were common student errors or omissions?

- Students often tried to apply improper formulas to the problem. Examples would be confusing work with the work function, and confusing wavelength and de Broglie wavelength.
- There was a good deal of symbol confusion. Some examples of this include confusing the symbol for magnetic flux and the symbol for the work function; symbols for frequency and focal length; and symbols for the constant ε_0 , the emf of a circuit, and motional EMF.
- Students confused the relationship between wavelength and frequency as well as the relationship between wavelength and energy.

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?

- Emphasize the relationship between the energy of photons and their wavelength, as well as the concept that one photon absorbed by the metal may lead to only one photoelectron emitted.
- Explain the photoelectric effect in terms of energy of the photons and the maximum kinetic energy of the photoelectrons.

Question 7

What was the intent of this question?

The intent of this question was to assess student understanding of what happens to the velocity, wavelength and frequency of light when it enters a material of a different refractive index. In particular, it assessed student understanding of the role of phase change and interference in creating a reflection maximum in thin films and the prediction, with justification, of how the color of the maximum will change as the thickness of the film increases.

How well did students perform on this question?

The mean score was 2.84 out of a possible 10 points.

What were common student errors or omissions?

- The most common mistake in the earlier parts of the question was to assume that wavelength rather than frequency was constant.
- There were many students who did not realize that long wavelength light corresponded to red light.

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?

- In "justify" questions, students need to focus on concepts rather than appealing entirely to an equation. There were many students who showed a calculation without providing text that explained the reasoning. There were also many students who essentially restated the question without explaining why this happens or specifically answering the question about what the color change is.
- Thin film interference is a topic that likely receives brief attention and in some cases was skipped entirely in the class, and the scores reflected that.