CollegeBoard
Advanced Placement Program

Student Performance Q&A:

2005 AP® Physics B Free-Response Questions

The following comments on the 2005 free-response questions for AP® Physics B 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 centered on the graphical representation of one-dimensional motion. The object in motion was an elevator. Students were given a graph of the position of the elevator plotted against time. In part (a) students were asked to use the position versus time graph to plot the velocity versus time. In part (b) they then used the graph drawn in (a) to determine the average acceleration of the object. Students were also asked in part (b)(ii) to draw a free-body diagram representing the direction of the acceleration that they found in part (b)(i). In the final part of the question, students were directed to find the apparent weight of a 70-kilogram passenger at a particular time.

How well did students perform on this question?

The mean score was 5.32 out of a possible 10 points. Slightly more than a quarter of the students earned scores of 8, 9, or 10; slightly less than a quarter received scores of 2 or less.

What were common student errors or omissions?

In part (a) the majority of students could draw some kind of graph, but many had problems properly sketching the transitions. The most common error was to draw the transition as a vertical line. In part (b) students had difficulty finding the slope. They made conceptual errors, such as writing $a = \Delta x/(\Delta t)^2$, as well as algebraic errors. Answers to part (b)(ii) showed that many students are Aristoteleans, as they maintained that the acceleration was directed up since the object was moving upward. In part (c) many students confused weight and mass, and many students also did not realize that the acceleration was zero.

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 7.

Question 2

What was the intent of this question?

The first two parts of this mechanics question involved drawing a free-body diagram of an object suspended by a horizontal string and a string that makes an angle of 30^{o} with respect to the vertical, then using that diagram to determine the tension in the horizontal string. The final part of the problem involved the application of the principle of conservation of energy to find the speed of the mass after the horizontal string had been cut and the mass had descended to the nadir of its trajectory.

How well did students perform on this question?

The mean score was 4.93 out of a possible 10 points. Slightly more than a quarter of the students earned scores of 8, 9, or 10; slightly less than a third earned scores of 2 or less. About 12 percent of students received no credit at all for their response.

What were common student errors or omissions?

Students often started off well. Part (a) was usually completed correctly, with the main errors being extra forces, particularly a normal force. Students were confounded in part (b) by errors in their trigonometry or in resolving the vectors into components. In part (c) students failed to use conservation of energy, instead using kinematics equations or the pendulum period equation; or they set the weight equal to the centripetal force. As is often the case, students seemed reluctant to use conservation laws when they thought kinematics would be sufficient.

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 7.

Question 3

What was the intent of this question?

This question began by examining the student’s knowledge of the electric fields and electric potentials generated by point charges. Parts (c) and (d) centered on electric forces generated by the same point charge distribution given in parts (a) and (b).

How well did students perform on this question?

The scores on this question were surprisingly low—the mean was 4.66 out of a possible 15 points. Only 13 percent of students earned a score of 11 or higher. Slightly more than a quarter of students received no credit for their response.

What were common student errors or omissions?

Performance on this question was hampered by students' confusion about the nature of the electric field and electric potential, as well as copious algebraic errors. Students did not know that the electric field is a vector and the electric potential is a scalar. Many assumed that the electric field is equal to the electric force. Another common error was assuming that $Ed = V$, where E is the electric field, d is some distance, and V is the electric potential. While this relation is true for a uniform electric field, it does not apply to point charges.

Many students seemed uncertain of the meanings of *magnitude* and *net*. Students also were careless in their use of signs for the electric field and electric potential. Many students also lost points in the final part by drawing the electric field vectors directly toward the lower charge.

The most striking thing about this problem is that students seem to be much less capable on this material than on mechanics material at a similar level.

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 7.

Question 4

What was the intent of this question?

This lab question required constructing an experiment that would allow use of optical interference to determine the spacing between a pair of narrow slits. Students were given a list of equipment and asked to choose pertinent items. In part (b) students were directed to graph the intensity of light versus position, which ought to have been a tip that physical optics was involved in the question. The final two parts of the question asked students to describe the measurements, procedures, and equations that they would use to determine the slit separation.

How well did students perform on this question?

Scores on this question were not anomalously low when compared to lab questions from previous years. The mean score was 6.43 out of a possible 15 points. One in four students earned a score of 11 or higher. Approximately one out of seven students received no credit for the question.

What were common student errors or omissions?

This question scored better than some lab questions had in the past. It was easy to see which students had lab skills, and which did not. It was also easy to see which students had been exposed to two-slit interference, and which had not. Students who had not studied two-slit interference tended to draw the diagram of intensity versus distance in part (c) as linearly decreasing or increasing. Students who had studied two-slit interference but who had minimal lab skills could draw the experimental set-up and the intensity pattern, but they had little success in describing an experimental procedure or describing the calculation that they would undertake.

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 7.

Question 5

What was the intent of this question?

This question in fluid statics centered on a rectangular raft floating in fresh (as opposed to salt) water. Students were given the surface area, density, and volume of the raft and asked to find the freeboard of the raft, or how high the top of the raft was above the surface of the water. In part (b) students were asked to find the buoyant force acting on the raft and to state the direction of this buoyant force. In the final part of the question, students were instructed to find how many 75-kilogram people could stand on the raft before it sank below the surface of the water.

How well did students perform on this question?

The average score on this problem was low, but problems on fluid mechanics have not generated high scores since the topic was introduced to the Physics B curriculum in 2002. The mean score was 3.59 out of 10 possible points, with only 12 percent of students scoring 8 or higher. Approximately 19 percent of students received no credit for this question.

What were common student errors or omissions?

The most common error in part (a) was to assume that the volume given in the problem referred only to that part of the raft above the water. Many of the students who made this assumption then ignored the assumption later and treated the volume given as referring to the entire raft volume. Many students missed possible points by writing down, in any of the first three parts, the equation $F = \rho V g$, without indicating which density ρ or which volume V they were referencing. Students also had difficulty with the direction of the buoyant force, as north, south, east, or west were not acceptable answers. Students who were grasping at straws sometimes used Bernoulli's equation, which led them to make the velocity-squared term in that equation a volume-squared term.

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 7.

Question 6

What was the intent of this question?

This question on thermodynamics concerned the ideal gas law. Students were given the description of a cylinder with a movable piston. Gas within the cylinder was heated, and the gas expanded against constant atmospheric pressure. Students were given a data table listing the height H of the piston and the temperature T of the gas and asked to find a relationship between those quantities that would allow them to find the number of moles of gas contained within the cylinder. In part (b) students were asked to plot the data given in the H-T table in such a manner as to be able to find the number of moles of the gas. In the final part of the question, students were asked to use the graph to find the number of moles after being given the cross-sectional area of the piston.

How well did students perform on this question?

The mean score on this problem was a surprisingly high 5.13 out of 10 possible points. About one out of five students earned a score of 8 or higher. However, slightly more than 17 percent of students received scores of 2 or less.

What were common student errors or omissions?

Many students did not seem to know that in part (a) they were supposed to develop an equation that related H to T. In part (b) students showed poor graphing technique when they scaled the graph, so the data were all compressed into a small region of the grid. Students also did a poor job of scaling the axes by including the origin. Many students did not correctly convert the pressure from atmospheres to pascals. In part (c) many students did not use the slope of the graph to obtain a value for n and instead simply pulled a single point from the graph or the data table.

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 7.

Question 7

What was the intent of this question?

In this modern physics question, students were given a set of energy levels that occur in an atom (actually singly ionized helium). The levels were the ground state and first three excited states. In part (a) students were given the energies in eV of the first two excited states and the ground state. They were asked to find the energy in eV of the third excited state if the $n = 4$ to $n = 2$ transition yielded a photon with a wavelength of 121.9 nm. In part (b) they were asked to find the momentum of that photon. In parts (c) and (d) the problem switched focus to the photoelectric effect. The 121.9 nm photon struck a silver surface whose work function was 4.7 eV, and students were asked to find the kinetic energy of the emitted photoelectrons and the stopping potential for those electrons.

How well did students perform on this question?

This modern physics question fared about as well as most questions on this topic, which is to say not very. The mean score was 2.84 out of 10 possible points. While 12 percent of students earned a score of 8 or higher, 40 percent received no credit for this question. These numbers are in line with those generated by other recent modern physics questions.

What were common student errors or omissions?

This problem scored low for most students who attempted it. In part (a) students confused the energy level with the photon energy. They also appeared to confuse frequency and wavelength, multiplying the wavelength by Planck's constant to try to obtain the energy of the photon. Many students were confused by the term *nanometer*, not knowing that it meant 10^{-9}. Responses to part (b) were full of errors involving units, where students would use a value for *hc* instead of *h*. Students who decided that $p = m\upsilon$ for a photon ran into difficulty with the zero mass of the photon, a difficulty they neatly sidestepped by inserting the mass of an electron or proton. Part (c) responses included more unit errors involving joules and electron volts. In part (d) students set the stopping potential equal to the kinetic energy of the photoelectrons, forgetting to divide by the electron charge to obtain a potential.

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?

Overall, performance on the Physics B exam was as expected. The areas in which students need work are experimental technique in general and graphical analysis in particular. Students had a great deal of trouble with a straightforward point-charge problem in question 3, indicating that this material needs more thorough coverage. It does not seem to be the case that electricity and magnetism is getting so much more time that teachers are forced to shortchange thermodynamics, fluid mechanics, and modern physics.