Student Performance Q&A:

2003 AP® Physics B Free-Response Questions

The following comments on the 2003 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 asked students to demonstrate their understanding of kinematics and Newton's Second Law by analyzing the motion of a modified Atwood machine.

How well did students perform on this question?

The mean score for this question was 9.06 out of a possible 15 points. Slightly more than half of the students had a score of 10 or better, and approximately a quarter of the students earned a score of 6 or less. Fewer than 3 percent of all students earned a score of 0.

What were common student errors or omissions?

The most common error in attacking the question was to assume that the object pictured was a *simple* Atwood machine. As a result, the most common error in Part (a) was to leave off the normal force acting on Student A. What was more surprising was that some of the students who left the normal force off in Part (a) correctly calculated the value of the normal force in Part (b). A common error in Part (b) was to set the normal force equal to the weight of Student A. In Parts (d) and (e) students had a difficult time explaining under what conditions Student A would move.

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 clear that students need to spend more time on questions that involve conceptual explanations. A purely algorithmic approach to solving problems has limited success on the exam.

Question 2

What was the intent of this question?

This question involved a dc circuit containing a battery, two resistors, and two capacitors. Students needed to understand how to find the effective capacitance of two capacitors in series and how to apply Kirchoff's loop role.

How well did students perform on this question?

The mean score for this question was 6.19 out of a possible 15 points. With over a quarter of the students earning a score of 3 or less and 6.5 percent earning a score of 0, it is clear that most of the students who attempted this problem received little credit for their efforts. Only 7 percent earned a score of 13 or better.

What were common student errors or omissions?

Most students had trouble with the entire problem. A common error in Part (b) was to misuse Ohm's law, with the entire emf appearing across the 10-ohm resistor. It was clear that most students had difficulty in determining the effective capacitance of two capacitors in series. This made it impossible for them to calculate the charge on one of the capacitors, as they were asked to do in Part (d). In Part (e), when students were asked to calculate the potential difference between Points A and B, their answers made it evident that they had little understanding of 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?

While student performance on this question was low, it was about what one would expect based on how students usually do on the electricity and magnetism part of the AP Physics B Exam. Most students can handle straightforward circuits involving resistors in series or parallel, but they seem to do it by memorizing examples rather than solving the problems through the application of fundamental principles.

Question 3

What was the intent of this question?

This question required the application of concepts from kinematics and Newton's Second Law in Parts (a), (b), and (c), and electricity and magnetism, specifically the Lorentz Force, in Parts (d) and (e).

How well did students perform on this question?

The mean score for this question was 4.82 out of a possible 15 points. Student performance on this question was low; 28 percent of all students earned a score of 0, indicating they had no idea of how to tackle this problem. Yet 20 percent earned a score of 11 or better.

What were common student errors or omissions?

Most students were unable to see that the first three parts of the problem could be solved without recourse to the concepts of electricity and magnetism. Many students immediately applied the equation $F = I\,DB$ in Part (a) rather than simply solving for the position and speed of the object in terms of F.

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?

The low student performance on this question indicates that many students had no idea they could apply the principles of one-dimensional kinematics and Newton's Second Law to garner the majority of the points on the question. One source of difficulty is that students were unprepared to deal with problems that involved more than one area of physics. This problem, involving mechanics and electricity and magnetism, seemed to throw off many students right at the start. Unfamiliarity with synthesizing material from different areas of physics was the main problem here.

Question 4

What was the intent of this question?

This year's laboratory-based question dealt with geometrical optics. Students had to describe a procedure for finding an image formed by a concave mirror that was four times the size of the object. In addition to a description of laboratory technique, students were asked to draw a ray diagram and understand the characteristics of the image formed by the mirror.

How well did students perform on this question?

The mean score for this question was 5.38 out of a possible 15 points. Few students did well on this question, with less than 15 percent earning a score of 11 or higher and 17 percent earning a score of 0.

What were common student errors or omissions?

There were two common errors involved in this question. Students committed the first error when they decided to make it a lens problem instead of a mirror problem. While in physics we often restate a difficult problem in simpler terms so that we may solve it, that was not a winning strategy here. The second error occurred when students approached the question as a problem in algebra rather than a problem involving laboratory technique.

Despite the clear instructions that the problem involved finding the position of an image formed by a *concave mirror,* many students drew ray diagrams that clearly showed an image formed by a *convex lens*. This earned them few points. The other major problem was that many students only performed a calculation of the image and object distances, without any indication of the procedure to be followed to locate the image on the optical bench.

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?

As has been the case in the past, many students have a great deal of difficulty with any problem involving laboratory technique. This indicates that laboratory technique is being neglected throughout the B curriculum.

Question 5

What was the intent of this question?

This question asked students to analyze the thermodynamic properties of an ideal gas that is carried around various cycles on a *PV* diagram. This tested students' familiarity with the First Law of Thermodynamics and with the difference between state variables, such as energy, and path-dependent variables, such as heat and work.

How well did students perform on this question?

The mean score for this question was 2.62 out of a possible 10 points. Four percent of the students earned a score better than 6. The fact that fewer than 20 percent of the students earned a score of 0 on this problem indicates that most students attempted the problem but had a great deal of difficulty with this kind of question.

What were common student errors or omissions?

Some of the difficulty was the result of the students' confusion over the idea of work done *by the gas* or heat *added to the gas*. But a more fundamental problem, one that indicated a lack of deep conceptual understanding, was the students' failure to understand the first law and how it applies to thermodynamic cycles. Most students did not understand that the change in internal energy, after the gas undergoes a complete cycle, is zero. They also did not understand that the work and heat added to or extracted from a gas during a thermodynamic process does depend on the path taken between the end points of the process, but that the change in internal energy does not depend on the path taken.

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?

Most students did not understand how to apply the First Law of Thermodynamics or the nature of the internal energy in thermodynamic processes. These ideas are central to thermodynamics, and students' inability to deploy them in this problem is a troubling indication of their failure to grasp these fundamental ideas.

Question 6

What was the intent of this question?

This question investigated students' understanding of absolute and gauge pressure, Archimedes' principle, and Newton's Second Law.

How well did students perform on this question?

The mean score was 3.87 out of a possible 10 points. Only 11 percent of the students earned a score of 0 on this question, but only 25 percent earned a score of 6 or better.

What were common student errors or omissions?

The first two parts of this question required students to calculate the pressure, in absolute and gauge terms, at a certain depth in the ocean. Many students did not know the difference between the two pressures. Some assumed that the absolute pressure referred to the absolute value of the pressure.

The second two parts of the problem were an exercise involving Archimedes' principle. The most common misconception here was that the buoyant force acted downward. One might think that if one uses the term "buoyant" one would know the correct direction, but such was not the case. The last part of the problem was an application of Newton's Second Law. Students who got this far in the problem, and had the right idea about the buoyant force, had little difficulty here.

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?

Fluid mechanics and Archimedes' principle are recent additions to the B curriculum, which probably explains some of the difficulty students had with this problem. Even if Archimedes' principle is not covered, students should be made familiar with the meanings of gauge and absolute pressure.

Question 7

What was the intent of this question?

This question tested students' ability to apply the principles of conservation of energy and momentum and tested their knowledge of how to calculate the deBroglie wavelength of a particle. The second section of the problem dealt with the operation of a HeNe laser and required students to apply their knowledge of energy levels in a quantum system.

How well did students perform on this question?

The mean score for this question was 1.37 out of a possible 10 points. As is usually the case for the modern physics question, students did not do well. Over 62 percent of the students earned a score of 0. Only one out of every eight students earned a score of 5 or better.

What were common student errors or omissions?

The first two parts of this question were difficult and required students to realize that the momentum of the helium and neon atoms must be conserved and that the kinetic energy is not conserved. Some kinetic energy is used to excite an electron in the neon atom.

If students ignored the conservation of momentum and assumed that all the kinetic energy of the helium atom was used to excite the neon atom, they could do Parts (a) and (b) while losing only one point for neglecting the conservation of momentum.

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?

The low scores were the result of the lack of coverage of modern physics in the B course. Considering how full the B curriculum is, and the fact that modern physics is usually taught at the end of the school year, this lack of coverage is understandable.

Overview of the AP Physics B Exam

This year's AP Physics B Exam was slightly more difficult than it has been in years past but not significantly so. The good news is that students seemed comfortable with problems in mechanics. The bad news is that their performance in other areas was not nearly as good. Students did poorly, on average, on problems involving circuits, electricity and magnetism, geometrical optics, thermodynamics, and modern physics. The poor performance on Question 3, which involved mechanics and electricity and magnetism, and Question 5, which involved the thermodynamics of *PV* diagrams, were particularly striking. The performance on Question 2, the circuits problem, and Question 5 indicate that students often learn formulaic approaches to problems and solve them by rote rather than through the application of fundamental principles.

As has been the case in the past, students did poorly on the lab problem. The inclusion of lab experiences is critical to the B course. It is clear that students, even when they do labs, often do them in a cookbook manner. This approach does not lend itself to success on the exam.

This year's exam was particularly helpful in pointing out deficiencies in student preparation in a number of areas. The B curriculum is certainly a crowded one, particularly for those students who have not had a physics course before AP Physics B. If the B course is to be offered as a one-year, first-year course, more attention should be paid to fewer topics. This will increase student comprehension and lead to better student performance on the exam.