Student Performance Q&A:

2012 AP® Physics B Free-Response Questions

The following comments on the 2012 free-response questions for AP® Physics B were written by the Chief Reader, Jiang Yu of Fitchburg State University in Fitchburg, Mass. 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 Newton's second law for two cases: a single moving object and a two-object system. Students were asked to draw free-body diagrams and to analyze processes involving friction and motion of coupled objects. They were also asked to conceptually identify experimental error sources.

How well did students perform on this question?

The mean score was 7.75 out of a possible 15 points.

What were common student errors or omissions?

Many students struggled to solve the two-body problem. They seemed to have difficulties maintaining consistent coordinate systems for the two separate objects. They did not combine masses when treating the system as a single object with external forces acting upon it. Students often equated the force of gravity on the 1.5 kg object to the tension, neglecting the acceleration of the system. They also often equated the force of gravity on the 2 kg object with the tension in the string.

Many students related the change of elevation to an excessive change of the acceleration of gravity. Many believed that human error, rounding error, calculation error, and significant figures are acceptable explanations for experimental errors. Students often did not connect cause with effect (cause: friction of the pulley; effect: loss of energy, extra resistive force, nonconservative work).

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' algebra skills need to be addressed.

- Students need to be taught how to organize their approach before putting pencil to paper.
- Students should recognize the words “justify,” “explain,” “calculate,” “what is,” “determine,” “derive,” “sketch,” and “plot” as common words used by AP Physics and the expectations that are associated with these words.

Question 2

What was the intent of this question?

This question assessed students’ understanding of conservation of energy and conservation of momentum in the contexts of free fall and collision. Students were asked to calculate various velocities and a final height of rebound for one of the balls involved. They were also asked to determine the type of collision by considering the energy changes.

How well did students perform on this question?

The mean score was 3.44 out of a possible 10 points.

What were common student errors or omissions?

Students made all sorts of basic algebra mistakes. They also often left answers without simplifying. For example, many students did not use the convenient equation $v_f^2 = v_i^2 + 2ax$ but instead used the combination of $v_f = v_0 + at$ and $v = x/t$, which is fine if done correctly. However, students made algebraic mistakes that led them to nothing useful or correct.

Students used the conservation of momentum to determine whether a collision is elastic or inelastic. They tried to get a solution using only velocity terms, as if they had never encountered conservation of momentum or energy where the masses did not conveniently cancel.

There was much confusion about inelastic and elastic collisions. For example, many students indicated that if kinetic energy is conserved then the collision is inelastic. There was also confusion between a collision that is elastic and one that is completely inelastic. For example, many determined the collisions were “partially elastic” or “not elastic because the spheres don’t stay together.”

Students often neglected the vector nature of momentum and therefore did not include a sign difference for balls moving in opposite directions in their velocity substitutions and momentum calculations.

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 improve their basic algebra skills. For symbolic questions, they need to be able to reduce their answers to the simplest form.
- Problem solving with conservation of momentum and energy needs to include situations with objects of different masses. Teachers should help students become accustomed to using notation like m_1 and m_2 even though it makes the equations more cluttered.
- Collision problems need to be taught with clear definitions and correct application of the conservation laws. The vector nature of momentum has to be stressed.

Question 3

What was the intent of this question?

This question assessed students' understanding of fluid statics. Students were asked to calculate densities and pressures of fluids in a U-shaped tube. They were also asked to make judgments about changes in the system, based on pressure, fluid heights, gravity, and the densities of fluids in the tube.

How well did students perform on this question?

The mean score was 3.70 out of a possible 10 points.

What were common student errors or omissions?

In part (a) many students set the mass of oil equal to the mass of water without explaining why that was true. The question was looking for students to set the pressures of the oil and water equal to one another. In part (b) a common error was either not including atmospheric pressure when finding absolute pressure or using the wrong height in the gauge pressure of the water. In part (c) many students incorrectly stated that the density of the oil would change owing to the change in volume of the funnel.

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 achieve an understanding of basic fluid concepts that goes deeper than simple applications of Bernoulli's equation and Archimedes' principle.

Question 4

What was the intent of this question?

This question assessed students' understanding of thermodynamics, specifically the relationship between pressure, volume, and temperature under isothermic, adiabatic, or isochoric conditions.

How well did students perform on this question?

The mean score was 3.28 out of a possible 10 points.

What were common student errors or omissions?

In part (a) the most common errors were not starting the graph at the correct initial conditions or not showing a proportional relationship between pressure and temperature. Some students stated that the relationship was proportional (or wrote relevant equations) but did not draw a graph that matched that statement. Finally, many students did not label the direction of the process as indicated.

In part (b) students missed the fact that the piston returns to room temperature and responded as if the internal pressure was still elevated. Of those who understood that the piston had reached thermal equilibrium, most neglected to consider the weight of the piston.

Parts (c) and (d) asked students to draw pressure versus volume graphs for an isothermic and an adiabatic process, and most students were unclear on the difference between these two. Many students did not show an inverse relationship between volume and pressure for these processes. Of those who did, many drew linear graphs instead of inverse proportions (P versus $1/V$ or $1/V^n$). Most students did not properly show that the final state of the process in part (c) was the initial state of the process in part (d). Many students did not properly label the direction of the processes or did not clearly label which process was which. There were many extraneous arrows and lines on the graphs that made the graphs hard for AP Readers to interpret.

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?

- Have students draw graphs of pressure versus temperature, pressure versus volume, and volume versus temperature for a variety of processes. Many students seemed to think that all processes were cyclical. Students also need to understand that not all graphs show how variables change with *time*. Having students describe what the graphs' direction, slope, intercept, and so forth mean in words might help this understanding.
- Review the difference between heat and temperature. Many students could not distinguish constant temperature from an adiabatic process.

Question 5

What was the intent of this question?

This question assessed students' understanding of energy and electric current in a circuit containing four resistors/lightbulbs, arranged with two pairs of parallel resistors in a series configuration.

How well did students perform on this question?

The mean score was 6.40 out of a possible 15 points.

What were common student errors or omissions?

The most common errors were the usual electric circuit errors — for example, assuming the battery voltage is the voltage across each resistance, and assuming the total circuit current is the current that flows through each resistance.

In part (a) a large percentage of the nonblank responses seemed to imply that the students were interpreting "electric potential energy" to mean electric potential, as many stated "24 V" as the answer.

In parts (a) and (d) many responses used the capacitance relation $U_C = \left(1/2\right)QV$. In part (d) a charge Q was usually calculated using $Q = I\Delta t$ with some value for I.

Students had difficulty distinguishing between Joules and eV for the units of energy. In part (c) i. a large percentage of students calculated a current using the battery voltage and a resistance value of 11 Ω. They found this value by adding the 8 Ω parallel resistance of the second resistance combination to the 3 Ω resistance of bulb *B*. Also, after finding a total circuit current, many students assumed the current split evenly between the branches going to bulbs *A* and *B*.

In part (c) ii. many students showed the current in the loop containing point *Y* as a circulating current going clockwise (or counterclockwise) completely around the loop. Many students calculated electric energy as power divided by time: $E = P/t$.

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 show their work in the space provided for each question. They also need to read the question carefully and follow the directions.
- Students need to develop a clear understanding of the difference between electric potential and electric potential energy.

Question 6

What was the intent of this question?

This question assessed students' understanding of lab measurements and procedures by asking them to experimentally determine the speed of sound in air with a given set of tools. It assessed their knowledge of standing waves, and particularly sound wave resonance, in a tube closed at one end and open at the other.

How well did students perform on this question?

The mean score was 2.62 out of a possible 10 points.

What were common student errors or omissions?

In part (a) students did not always define their choice of variable or accurately describe how each lab tool would be used. One common mistake was to choose tools that were not given in the problem, such as a stopwatch (to time an echo). Students also sometimes used the tools incorrectly, such as using the piston to create a puff of air or using the meterstick on the waveform display to measure wavelength.

In part (b) common errors included use of an incorrect equation, such as equations for the Doppler effect, single slit diffraction, and the radius of curvature of a spherical mirror.

In part (c) many students correctly identified a variable that could be changed to increase the accuracy of the experimental measurement of the speed of sound but could not choose the independent and dependent variables correctly. The majority of students did not describe an appropriate plot (lambda versus one over f or f versus one over lambda), and without an appropriate plot the slope of the graph could not be dimensionally correct (the slope must be in units of meters per second).

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?

Teachers need to train students to write clearly for effective communications. Defining variables and describing how a particular lab instrument is used are necessary in any effective lab procedure write-up; the language needs to be precise and concise.

Question 7

What was the intent of this question?

This question assessed students' understanding of the wave nature of protons, nuclear collision, and the energy involved in spontaneous nuclear fission.

How well did students perform on this question?

The mean score was 3.05 out of a possible 10 points.

What were common student errors or omissions?

The most common errors were the result of a lack of understanding of nuclear collisions in which the conservation of energy and the Coulomb potential energy apply. Students seemed to choose and use the equations without any physics reasoning.

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?

Teachers need to spend time on modern physics with students. They need to teach students to solve problems by applying physics principles and not blindly choosing equations to perform plug-and-chug calculations.