CollegeBoard AP

Student Performance Q&A:

2011 AP® Physics C: Mechanics Free-Response Questions

The following comments on the 2011 free-response questions for AP® Physics C: Mechanics 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 impulse, momentum, work, kinetic energy and the relationship between net work and the change in kinetic energy. It tested the application of these concepts in one-dimensional situations involving collisions between a projectile and a fixed block, and a projectile and a block that is allowed to move along a horizontal surface with friction. Parts (e) and (f) required students to distinguish the details regarding work and energy before, during and after the collision. The problem could also be addressed using combinations of kinematics and Newton's second law.

How well did students perform on this question?

The mean score was 4.47 out of a possible 15 points. Some 98 percent of students attempted to answer at least one part of the question; 80 percent earned a nonzero score. A significant number of students attempted parts (a) through (d); many found parts (a) and (b) to be easy but parts (e) and (f) to be very difficult.

What were common student errors or omissions?

Algebra errors were very common, and subscripts were often omitted on variables, which made the student's intent unclear. Answers were often not expressed in terms of the requested variables.

Some students confused the change in a variable with the variable itself — for example, Δv was used instead of v_x. Many students reversed the signs of the initial and final values when determining the change in a quantity.

Many students were unclear about the requirements for successful application of the terms "determine" and "derive." Many did not indicate a clear starting concept or equation in parts (c) through (f), where a derivation was required. Students often omitted important algebraic steps and lacked sufficient details to clearly delineate their solution.

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?

- Introduce and practice the proper use of the AP Physics Exam terminologies, such as "calculate," "determine," and "derive." The functional definitions of these terms can be found in the AP Physics Course Description.
- Familiarize students with the equation sheet that is provided with the free response section of the exam. Provide practice problems in which the students are required to begin with these general equations and work through detailed algebraic steps that delineate the starting concept and methodology clearly.
- Help students to develop skills in evaluating the reasonability and validity of their solutions.
- Stress the need to be precise in labeling variables. Assign symbolic problems in which the students are required to manipulate equations while carrying through subscripted variables.

Question 2

What was the intent of this question?

This question assessed students' understanding of conservation of energy, circular motion in a vertical plane, work done by a constant retarding force, and velocity and acceleration of a particle under the influence of a variable retarding force.

How well did students perform on this question?

The mean score was 6.30 out of a possible 15 points. Almost all students (99 percent) attempted to answer at least one part of the question; 97 percent earned a nonzero score. Most attempted parts (a) through (d), with various degrees of success. Many showed deficiency of calculus in part (e).

What were common student errors or omissions?

In parts (a) and (b) many students commonly added a centripetal force to their free-body diagram, set the normal force equal to the centripetal force, and then set it equal to a component of the weight.

In part (c) the most common error was taking the height through which the object fell to be $3R/4$ instead of $7R/4$.

In part (e) i the most common error was setting the retarding force $-kv$ equal to dv/dt without equating it to *ma*. Most students chose to solve the equation in (e) ii with indefinite integrals, but many either forgot the constant or could not associate the constant with correct physical quantities in the problem.

Common errors in (e) iii were assuming that the acceleration was constant from point D to point E, or that the acceleration was zero starting at point D. Many students did not realize that the acceleration was exponentially decreasing.

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 idea of centripetal force needs to be better studied. Students need to develop the understanding that there is no physical centripetal force making an object move in a circular path. Rather, the quantity mv^2/r is attributable to one or more physical forces exerted on an object.
- It is clear that many students had not seen exponential decay or the method(s) for negotiating such problems. Teachers should explore more variable retarding force problems beyond the usual object-falling-through-the-air scenario.
- Students should work on solving problems using calculus.

Question 3

What was the intent of this question?

This lab question assessed students' understanding of simple harmonic motion and the standard linearization method of data analysis by analyzing the oscillation of a torsion pendulum.

How well did students perform on this question?

The mean score was 5.68 out of a possible 15 points. At least one part of the question was attempted by 96 percent of students; 94 percent earned a nonzero score. Many were uncomfortable with calculus, and many needed to develop basic skills in data analysis.

What were common mistakes student errors or omissions?

Basic algebraic manipulation of simple equations proved to be problematic for some students. Many lacked basic calculus skills, and some did not know the differences between derivatives and integrals.

It is also clear that many students were unable to apply basic physics concepts to unfamiliar situations such as a torsion pendulum. Among the students who attempted the question, many omitted units for the physical quantities in the work that involved rotational terms.

In part (a) most students were not proficient with the differential form of variables, in particular, $\alpha = d^2\theta/dt^2$. They did not do the final step of substituting $d^2\theta/dt^2$ for α in order to finish the part as required but simply left the equation as $-\beta\theta = I\alpha$.

In part (b) many students did not make the connection that allowed the two required analogies: between mass and moment of inertia as well as between linear spring constant and torque constant. They also did not understand the connection of part (b) to part (e) in order to calculate the torque constant β . Many students wrote $T = 2\pi/\omega$ in (b) but did not proceed further.

In part (d) many students left their equation in terms of *y* as a function *x* instead of the given variables T^2 and *I*. Too many students showed a lack of understanding of how to determine slope from a best-fit line. They typically used data points that did not lie on the best-fit line that they drew.

In part (f) most students were unable to make the physical connection between the nonzero T^2-intercept and the physical constant. Many either forced their best-fit line through the origin or simply explained the nonzero intercept as an error in the data.

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?

- Lab skills:
    - Students need to develop a good understanding of and skill with graphical analysis of experimental data, including plotting points, drawing linear best fits, calculating slopes of the graphs drawn, determining the representative equations, and interpreting the physical meanings of the intercepts and slopes.
    - Although a variety of linearization problems have appeared on the exam in recent years, many students still seemed unfamiliar with the basic techniques and did not make the connection in this problem. Students need to do more exercises that relate actual data and relationships that follow the data. Teachers need to help students to connect the experimental data and the theory they predict.
- Calculus and algebra skills:
    - Many students were clearly uncomfortable or even unfamiliar with basic calculus: They did not know what a differential equation was. Teachers need to teach with more calculus-based thinking skills as well as calculus-based problem solving.
    - In addition, teachers need to help students to practice problem solving by starting with the basic equations such as those given with the AP Physics Exam, showing intermediate derivation steps, and then substituting and calculating the final answers.
- Students should include units in numerical calculations.
- Students should be familiar with the AP Physics definitions of “calculate,” “what is,” “determine,” “derive,” “sketch” and “plot.”. Very clear definitions can be found in the AP Physics Course Description. Teachers need to better familiarize their students with the expectations of free-response questions.
- Students should understand that not every best-fit line needs to be forced to go through the origin.
- Teach the course at the appropriate level — every year there will be calculus and data analysis on the exam.