Student Performance Q&A:

2016 AP® Physics C – Mechanics Free-Response Questions

The following comments on the 2016 free-response questions for AP® Physics C: Mechanics 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?

Students were expected to demonstrate an understanding of Newton's second law and kinematics in a motion that consisted of two distinct parts: a cart being pulled by a string and then slowed by friction. The main intent of this question was to assess the students' mastery of graphical analysis. Students were asked to properly build a graph from a given data table, with the expectation that they would correctly label and scale the axes, draw a best-fit straight line, and determine the slope. Students were expected to interpret the graph to obtain relationships between physical quantities and find numerical values of dynamic and kinematic quantities.

How well did students perform on this question?

The mean score was 9.35 out of a possible 15 points.

What were common student errors or omissions?

a) When asked to use a best-fit line to determine a quantity, students frequently used given data points instead of points on the best-fit line to calculate the slope. Students often drew a "best-fit" line that did not have data points both above and below it, or they connected all the data points. Students had difficulty in interpreting the graph and realizing that the horizontal intercept represented a physical quantity in the experiment.

b) When asked to calculate the force of friction, students often attempted to calculate only μ (the coefficient of friction) instead.

c) Some students were not able to correctly identify the forces or determine their sum correctly in order to apply Newton's second law.

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 should get a lot of practice plotting graphs by hand, and determining quantities from best-fit lines. Students also need practice interpreting information obtained from graphs, e.g., understanding that slope and intercept each have a physical significance.

Question 2

What was the intent of this question?

The question had a block sliding on a horizontal frictionless surface and colliding with another block that was attached to a nonlinear spring. It required knowledge of free body diagrams, forces, integral calculus (determining potential energy from a force function), conservation of energy, conservation of momentum, conceptual understanding of interactions in collisions, and simple harmonic motion.

How well did students perform on this question?

The mean score was 5.94 out of a possible 15 points.

What were common student errors or omissions?

a) There were many errors in the free-body diagrams. Common errors were: putting a horizontal force on a block that is sliding with constant velocity on a frictionless surface; not clearly labeling forces with appropriate names; and not differentiating between the forces (e.g., simply calling every weight "mg").

b) There were many algebraic errors such as dropping terms along the way, improper simplification, and not checking a final answer for correct physical dimensions.

c) Students often did not show appropriate integration or use the appropriate symbols. Many students did not explicitly write dx or dt or include appropriate limits in their integrals.

d) When asked to "derive," students often did not show a clear starting point from first principles, and some showed carelessness in their intermediate steps and the logic leading to a final answer.

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?

a) Students could really use some instruction and/or appropriate practice in reading and following test directions carefully, and in not being careless with their mathematical work.

b) Students would benefit from practice with algebraic manipulation using symbols and dimensional analysis of an answer.

c) Students could use more review of free-body diagrams: identifying forces and their directions, appropriate labeling, and drawing vectors to scale.

d) Providing some rigorous derivations for your students to work through is another useful skill for the AP Physics C classroom. There are many examples of this sort of exercise in all of the standard college textbooks.

Question 3

What was the intent of this question?

The question had a rotating platform with a mass on a spring. This question assessed student comprehension and ability to make connections in the topics of rotational motion, rotational inertia, angular momentum, and behavior of springs.

How well did students perform on this question?

The mean score was 4.13 out of a possible 15 points.

What were common student errors or omissions?

a) Many students incorrectly used conservation of energy to determine the behavior of the mass on the spring even though the problem could not be solved this way.

b) Many students had difficulty determining rotational inertia even for just the "point mass" block. The parallel axis theorem and/or an application of integrals to determine rotational inertia was frequently applied incorrectly.

c) Basic algebra errors were common, such as when solving for a variable or making a substitution.

d) Many students failed to show an understanding of the application of the conservation laws of momentum and energy when an external force is being applied to a system.

e) Very few students correctly gave the direction of the block's acceleration when it was not moving with constant speed. Most students indicated a purely centripetal acceleration with no tangential component.

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?

a) Given that students most frequently attempted to apply energy conservation when it was not viable, it would be a good idea to give students adequate practice analyzing the force dynamics of a spring using Hooke's law.

b) Students need to learn that acceleration associated with circular motion is not always toward the center of the circle, and gain experience working with non-uniform circular motion.

c) Teaching should emphasize clearly showing the steps to an algebraic solution.

d) Students need to recognize that directions are an outcome of the adoption of an arbitrary choice of frame of reference, for example, that counterclockwise isn't universally a negative direction.