Student Performance Q&A:

2016 AP® Physics 1 Free-Response Questions

The following comments on the 2016 free-response questions for AP® Physics 1 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?

This question assessed learning objectives 3.B.1.1, 3.B.1.3, 4.A.3.1, 4.D.1.1, 5.B.4.1, and 5.B.4.2. It explored student understanding of factors influencing the motion of rigid bodies on an inclined plane, including rolling without slipping motion. Analysis focused on force diagrams, energy conservation, translation and rotation, and applications of Newton's second law.

How well did students perform on this question?

The mean score was 1.89 out of a possible 7 points.

What were common student errors or omissions?

a) The problem specifically asked for a force diagram with vector tails originating at the point at which the force is exerted. However, most students treated the entire wheel as the center of mass of a free body diagram, or assumed all forces were applied at the center of mass, and drew all forces originating from the center of the wheel.

b) Many students were not able to identify which force was directly responsible for the rotation of the wheel, and did not show a clear understanding that a torque is necessary to make the wheel roll down the ramp.

c) Many students expressed the component of the force of gravity along the ramp as $mg\cos\theta$. Many also left the answer in terms of their own variables, such as W or F_g, rather than in terms of the given variables.

d) Many students identified static friction as being responsible for converting mechanical energy into heat rather than converting potential energy into rotational kinetic energy of the wheel rolling down the ramp.

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 should be instructed to carefully read directions and answer the question asked. It is not necessary or recommended to restate what is written in the question, or restate what was indicated with a check box.

b) Differentiate between "determine" and "derive" (and other AP prompts). In the derive part of the question, many students did not show appropriate work.

Question 2

What was the intent of this question?

This question assessed learning objectives 4.C.1.1, 5.A.2.1, 5.B.2.1, 5.B.4.2, and 5.B.5.1. The question's main purpose was to evaluate a student's ability to communicate experimental design and experimental evidence that a collision is elastic. This question assessed experimental design and data analysis, energy conservation, work, and elastic/inelastic collisions.

How well did students perform on this question?

The mean score was 4.32 out of a possible 12 points.

What were common student errors or omissions?

a) The most common error in this lab problem was to describe measurements that were irrelevant or extraneous to the purpose of the experiment. Many students who stated that energy was conserved in elastic collisions nonetheless could not appropriately describe a way to measure quantities that could be used to compare the mechanical energy of a ball before and after a collision. Students often described measuring quantities that were not relevant to their method of determining energy conservation.

b) Students didn't always understand the function and the use of the equipment they described — for example, a force probe cannot easily measure the force used to throw a ball; a stopwatch cannot easily be used to create a position-time graph for a falling ball.

c) Students were asked for a representation of data that would determine if a collision were elastic at various speeds. The best way to represent these data is with a graph. Tables were certainly acceptable, but often did not earn full credit because they included extraneous information that could not be used to test the hypothesis.

d) Many of those who could represent experimental results that violated energy conservation referred instead to momentum conservation being violated, which was not so readily verifiable.

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) It was readily apparent from the responses which students had worked regularly and creatively with experimental physics equipment. Students need practice in designing and carrying out experiments.

b) Perhaps most importantly, students should learn to describe experimental procedures and results concisely. A laboratory procedure question can almost always be answered in three sentences, as the audience should be assumed to understand basic laboratory protocols. Those students who start with "gather your materials" or who reminded us that "all measurements must be recorded carefully in the notebook" are not communicating useful information. Students should practice writing concise and relevant procedures.

Question 3

What was the intent of this question?

This question assessed learning objectives 2.B.1.1, 3.A.1.1, 3.A.3.1, 3.B.1.1, and 3.B.1.3. It probed students' conceptual and graphical understanding of kinematics, particularly how speed and average velocity are impacted by changing conditions of the motion of a cart rolling down a bumpy hill. The question focused on scientific thinking and the testing of a hypothesis with data and scientific reasoning.

How well did students perform on this question?

The mean score was 3.71 out of a possible 12 points.

What were common student errors or omissions?

a) Students very commonly defined instantaneous velocity as displacement (or distance) divided by time, but this is not the case when acceleration is non-zero.

b) Students frequently mixed up components or did not define their axes. Many assumed the y-axis was down without defining it. Students often confused sine and cosine.

c) Students were not able to sketch the average velocity on a graph of velocity versus time. Very frequently the average velocity seemed not to have anything to do with the velocity over time. Often an average velocity line was drawn without any time dependent velocity.

d) Students frequently did not realize the difference between a linear relationship and a general proportional relationship.

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) When the question says briefly explain, do be brief. Do not re-phrase the question. Get straight to the point. Follow the instructions and answer only what is asked. Students really need practice doing this. Students should use precise, relevant language.

b) Students should write legibly and reasonably dark. A response that cannot be read due to poor handwriting or exceedingly light characters may not earn credit that it could have if it was legible.

c) Give students practice in not skipping steps in developing a logical argument. Have students practice full, logical answers in class. Do not allow them to answer questions with "you know what I mean."

d) Some students need practice in graphing.

e) Some students did not realize that a constant in an equation is not necessarily dimensionless.

Question 4

What was the intent of this question?

This question assessed learning objectives 5.B.9.3, 5.C.3.1, and 5.C.3.3. The intent of the question was to determine student understanding of series/parallel resistor circuits and the application of Ohm's law. The students were asked to analyze the effects of changes made to the circuit.

How well did students perform on this question?

The mean score was 2.27 out of a possible 7 points.

What were common student errors or omissions?

a) Students very commonly think that the order of the resistors in a circuit determines the values of current or potential difference through or across them.

b) Students also often believe batteries supply a constant current that does not change even when the components connected to it change.

c) Many students do not clearly understand the definition of current, electric potential, and potential difference.

d) Students commonly refer to the speed of the current as opposed to the amount of current.

e) Students often do not understand the difference between geometrically parallel in a drawing versus electrically parallel circuit components.

f) Students frequently did not understand that resistors in series add differently than resistors in parallel, often indicating that the total number of resistors determines the overall resistance regardless of the arrangement of resistors.

g) Students used imprecise and incorrect language to describe the circuit such as using electricity, energy, and power incorrectly.

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 need to be precise in their use of the language and terminology, and should practice justifications.

b) Students need to practice analyzing the effect of changes to series and parallel circuits. Working only with circuits in which no components change does not prepare them for cases in which they must adjust or redo their analysis.

c) Students should make use of algebraic expressions to help support their claims.

Question 5

What was the intent of this question?

This question assessed learning objectives 3.A.3.1, 3.B.1.1, 3.B.2.1, 6.A.1.2, 6.D.3.2, and 6.D.3.4. The question assessed the understanding of how tension is created by a hanging weight, balancing forces, and the relationship between the basic characteristics of a wave. The student had to create a scientific explanation in a coherent paragraph from a described observation and image.

How well did students perform on this question?

The mean score was 2.24 out of a possible 7 points.

What were common student errors or omissions?

a) Students frequently thought that the tension in a rope hanging from an oscillator was greater at higher points on the rope because higher points were closer to the oscillator.

b) Students often tried to use properties of the wave to argue that the tension had to be greater at higher points, when the intention was to recognize the tension is greater at higher points and use that fact to talk about properties of the wave.

c) Students evidently did not read the problem carefully given that their answers did not directly address the questions.

d) Students were directed to use properties of the diagram to determine the relationship between velocity and tension, but more often referred unnecessarily to the relationship $v = \sqrt{F/\mu}$, which did not help answer the question. Students often gave theoretical answers without connecting it to the diagram.

e) Often students did not recognize that frequency was constant through the rope when it was being vibrated with a constant frequency oscillator.

f) Students confused tension T with period T in equations.

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 should carefully read the problem and address only what is being asked. Practice with justification and paragraph questions would be useful to students.

b) Students should support their ideas completely and precisely, without repeating the question.

c) Students should be careful about legibility of handwriting and lightness of writing.