



## Student Performance Q&A: 2015 AP<sup>®</sup> Physics 1 Free-Response Questions

The following comments on the 2015 free-response questions for AP<sup>®</sup> Physics 1 were written by the Chief Reader, Peter Sheldon of Randolph College. 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?***

The intent of this question was application of Newton's second law to a modified Atwood's machine. The question requires a basic knowledge of free body diagrams and requires both quantitative and qualitative understanding of what affects the acceleration of the system.

#### ***How well did students perform on this question?***

The mean score was 2.23 out of a possible 7 points.

#### ***What were common student errors or omissions?***

- Many students had a hard time drawing vectors to relative scale in the free-body diagram.
- Pictures were often very messy and hard to read.
- Force vectors did not have clear labels that properly indicated what the force represents.
- Basic algebra was often weak. Deriving the acceleration from a set of two equations was a challenge for many.
- Students did not understand that the tension in the ideal string connecting the two masses was the same throughout.
- Many students did not know what was meant by the request to "derive" a quantity — either not showing a derivation or writing text descriptions.
- Students frequently confused mass and weight.

**Based on your experience of student responses at the AP<sup>®</sup> 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 should re-emphasize the meanings and implications of the words *explain*, *derive*, *calculate*, and *determine* in the context of the AP Physics exams.
- Teachers should spend time drilling students in basic algebra and geometry skills. Students should be doing more symbolic math solutions in class, rather than arithmetic calculations.
- Free-body diagrams should be more than just a superficial exercise. They should be detailed and meaningful.
- Students should be asked to write and support their arguments. Emphasis should be on complete and concise expression of logical reasoning.
- Students should understand that masses have inertia, and that friction is not the only factor that limits acceleration.

## **Question 2**

**What was the intent of this question?**

The primary focus of this question was on experimental design and data analysis (using circuit elements and meters), and student knowledge of series circuits. Students were also asked to account for uncertainty in the measurement and to discuss how it affects their results.

**How well did students perform on this question?**

The mean score was 3.29 out of a possible 12 points.

**What were common student errors or omissions?**

- The students commonly did not know how to diagram a circuit or connect meters correctly to the circuit.
- Students often did not show understanding of the relationship between current and electron flow, and did not show understanding of the relationship between potential difference and electric potential energy.
- Very few students understood what quantity should be varied in the experiment.

**Based on your experience of student responses at the AP<sup>®</sup> 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 be careful not to simply restate the question as their answer.
- Students should understand when to answer questions theoretically and when to use data to address the question.
- Students need to work on experimental design, and need to work on understanding of error and uncertainty.

### Question 3

#### ***What was the intent of this question?***

The purpose of the question is to examine the relationship between the energy stored in a compressed spring-block system and the work done by the friction force that stops the block once it leaves the spring. The intent is to test the student's understanding of energy principles in multiple representations including graphs, descriptions, and analytical relationships.

#### ***How well did students perform on this question?***

The mean score was 2.67 out of a possible 12 points.

#### ***What were common student errors or omissions?***

- Even if the analysis was done well using equations, many students didn't support their arguments effectively using words. Instead, they often referred to equations used in a previous part.
- Students who correctly recognized that potential energy for the block-spring system dropped to zero at  $x = 0$  often failed to continue the graph through  $x = 3D$ .
- Students were often not clear in their graphs, and graders could not tell the difference between a straight-line or curved relationship between energy and position.
- When evaluating the elastic potential energy at  $x = 2D$ , few students correctly substituted  $2D$  into the equation, squaring only the  $D$ .
- Many students did not recognize that the constant friction force resulted in constant acceleration, or that work by this force was linearly related to distance.

#### ***Based on your experience of student responses at the AP<sup>®</sup> 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 would benefit from having more experience describing and comparing — in words and using math — a physical event where some variables change and others are left unchanged. Students need to demonstrate their knowledge of physics through words, not just algebraic equations.
- Students should practice how to interpret problem solutions or evaluate problem solutions to find evidence to support or reject claims found in predictions.
- Enforce that students use physics in all their arguments.
- Students should practice doing a full explanation. When they are explaining their derivation or drawing conclusions, they should refer to a specific part or equation in their derivation and not just say “as you can see from my equations...”
- Students need practice in graphing mechanical energy of objects in a variety of conditions. They also need practice in how to easily distinguish multiple graphs on one set of axes (e.g., one bold line, one dashed).
- Students are allowed to have a straight-edge during their test, and should use it where appropriate.

## Question 4

### ***What was the intent of this question?***

The intent of this question was to assess the level of student understanding of 2D motion by describing in words (a coherent paragraph) and equations the physics behind one ball dropped from rest and a second identical ball projected with an initial horizontal velocity from the same height.

### ***How well did students perform on this question?***

The mean was 2.76 out of a possible 7 points.

### ***What were common student errors or omissions?***

- Students often did not fully describe how they arrived at their answer. For the balls to reach the ground at the same time they both would have the same initial vertical velocity, acceleration, and  $\Delta y$ . These observations were often not explicitly included in the students' reasoning.
- Students often included extraneous things on their free-body diagrams, such as velocity, acceleration, or a force no longer being applied.
- When asked for horizontal velocity, students often identified vertical velocity or speed instead.
- Although this question uses a situation that is a very common class example, demo, or lab, many students apparently do not know or understand that the two spheres do reach the ground at the same time.
- Many students believe that a greater mass would have a greater  $g$ .

### ***Based on your experience of student responses at the AP<sup>®</sup> 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 would benefit from having more experience describing and comparing, in words and using math, a physical event where some variables change and others are left unchanged.
- Students need to understand that justification requires using physical principles, and should not include statements such as this was something that was observed by Galileo or the Mythbusters.
- Teachers need to help students understand the difference between a conversation and a physical justification. Students do not need to include comments such as "I never used to believe that they would hit at the same time..." or "You might be surprised to find out..." While we are looking for words in justifications, students need to describe the physics and not their general thoughts that do not include the physics.
- Students should carefully review free-body diagrams.
- Students need to be aware that handwriting and readability matter.

## Question 5

### ***What was the intent of this question?***

The intent of this question was to examine the properties of standing waves and harmonics, and use the appropriate relationships between wavelength, frequency, and wave speed.

### ***How well did students perform on this question?***

The mean score was 1.60 out of a possible 7 points.

### ***What were common student errors or omissions?***

- Students often failed to recognize that wavelength was constant, and thus failed to recognize that frequency was linearly proportional to wave speed.
- Students often do not understand the difference between a linear, inverse, quadratic, and exponential relationship. Students tend to use exponential to describe any relationship.
- Students confused the second harmonic with the fundamental or the second overtone.
- Students often did not distinguish between the mass  $M$  of the hanging object and the mass  $m$  of the string.
- Students often thought all the strings were the same.
- Students often did not recognize that the tension is related to the hanging mass  $M$ .
- Many students also could not identify the antinodes as the locations of greatest average linear speed.

### ***Based on your experience of student responses at the AP<sup>®</sup> 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 crucial to students' success to perform labs in order to solidify concepts.
- Caution students to write neatly, clearly, and darkly enough.
- Students need a lot more instruction in how to craft an explanation, supporting their claims with equations, relationships, and definitions.
- Students need more practice in relating equations to graphs.
- Students should think first, then write.
- Unless it is applicable, students should not spend time explaining why things are not true.