



## Student Performance Q&A: 2013 AP<sup>®</sup> Physics C-Mechanics Free-Response Questions

The following comments on the 2013 free-response questions for AP<sup>®</sup> Physics C-Mechanics were written by the Chief Reader, Jiang Yu of Fitchburg State University, Fitchburg, Massachusetts. 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 to analyze and interpret motion with a variable force in a simple harmonic motion by graphical and analytical method.

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

Almost all students attempted the question and they did well. The mean score was 7.6 out of a possible 15 points, with 16.4 percent of the scores  $\geq 12$  and 11.4 percent  $\leq 3$ .

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

- When asked to draw a smooth graph, some students joined points by straight lines or curved segments.
- Difficulties with sketching linear and non-linear graphs
- Some students utilized graphing and other software in their graphing calculators to answer some parts of the questions; for example, obtaining the equation for best fit graph for the given data points.
- Many students draw graphs in ink and made a mess when they had to correct the graph.

#### ***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 need to develop better graphing skills.
- Students need to better organize their work for free-response questions.
- Students must use pencils and not ink to draw graphs.
- Students need to be familiar with the terms "derive," "determine," "indicate," "calculate," etc., as

defined in the course description book.

## Question 2

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

The intent of this question was to test students' ability to develop and solve a mechanical problem by using differential equations. The physical concepts involved included free-body diagram, Newton's second law, terminal velocity, and exponential rise or decay of a mathematical description.

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

Almost all students attempted this question and they did very well. The mean score was 8.3 out of a possible 15 points, with 22.0 percent of the scores  $\geq 12$  and 8.1 percent  $\leq 3$ .

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

- Some students apparently had no calculus ability; they either did not know what a differential equation is or did not know how to handle differential equations.
- Student displayed various problems in drawing a free-body diagram. Examples include not drawing vertical forces, missing a vertical force, and omitting drag force.
- Omitting mass from Newton's second law.
- Using incorrect results from part (d) to plot part (e), even if they had the correct terminal velocity in part (c)

### ***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 must be taught to draw free-body diagrams correctly.
- Students have to have the ability to manipulate differential equations. They need to recognize exponential rise and decay.
- Students need to work in a more orderly fashion to show their work in sequence.
- Students need to know the standard AP<sup>®</sup> directory language. For example, "derive" means derive from first principles.

## Question 3

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

The intent of this question was to test students' ability to apply the laws of mechanics to a rigid body that was in equilibrium or rotating while its center of mass was also in motion.

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

Students did not do well on this question. About 98.6 percent of them attempted the question. The mean score was 4.2 out of a possible 15 points, with 1.3 percent of the scores  $\geq 12$  and 46.9 percent  $\leq 3$ .

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

- In part (b), most students assumed that the tension on the left and right sides were equal when they were not. They were equal in part (a) when the object was in equilibrium.
- In part (c), students confused the angular acceleration with the linear acceleration.

- In part (d), students either ignored translational kinetic energy or gravitational potential energy.

***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 show calculations and not just show the final result from the calculator.
- Students should write more and complete the expression of their thinking.
- Students should always write equations before substituting values.