CollegeBoard
Advanced Placement Program

Student Performance Q&A:

2007 AP® Physics C: Mechanics Free-Response Questions

The following comments on the 2007 free-response questions for AP® Physics C: Mechanics were written by the Chief Reader, William Ingham of James Madison University in Harrisonburg, Virginia. 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 was designed to assess students' understanding of Newton's second law, kinetic friction, and basic kinematics. The system in question was a block being pulled across a rough horizontal surface by an applied force directed at an angle to the horizontal. (The horizontal acceleration a_1 was specified, and answers were to be expressed in terms of a_1 and other given quantities.) Part (a) asked students to draw and label a free-body diagram for the block. Part (b) instructed them to derive an expression for the normal force exerted by the surface, while part (c) told them to derive an expression for the coefficient of kinetic friction between the block and the surface. In part (d) they were required to sketch graphs of the block's speed and displacement. Part (e) stated that if the applied force was large enough, the block would lose contact with the surface and then asked students to derive an expression for the magnitude of the greatest acceleration the block could have and still maintain contact with the ground.

How well did students perform on this question?

Students performed very well on this 15-point question. The mean score was 10.16. About 43 percent of students earned scores of 12 or higher, while about 4 percent earned scores of 3 or lower.

What were common student errors or omissions?

It was obvious from their responses which students could write expressions illustrating Newton's laws. The problem was not complicated, which allowed students the opportunity to demonstrate knowledge that most students should master in the Physics C: Mechanics course. Although students performed well on all parts of the problem, they had more difficulty with part (e) than any other part. Some students correctly solved the problem in terms of g and θ , while others gave a response containing F_1 and m. For many students, part (e) made the difference between a score of 15 and a score of 12.

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?

Constructing free-body diagrams and applying Newton's laws should be at the heart of any mechanics course. Similarly, students must be able to generate graphs (of displacement versus time and velocity versus time) for a body undergoing uniform acceleration.

Question 2

What was the intent of this question?

This question evaluated students' understanding of orbital motion and energetics. The specific system was an artificial satellite of the planet Mars. The satellite's orbital period and orbital speed were given, as were the satellite's mass and Mars's radius. Part (a) asked students to calculate the radius of the satellite orbit, and part (b) asked them to calculate the mass of Mars. Part (c) required them to calculate the total mechanical energy. In part (d) students were told to suppose that the satellite was placed in a lower circular orbit and to decide whether the resultant orbital period would be greater than or less than the original period. They were expected to justify their answers. In part (e) they were informed that the satellite orbit was slightly elliptical and were asked a question about the variation of orbital speed in such an orbit.

How well did students perform on this question?

The mean score on this 15-point question was 5.66. About 9 percent of students earned scores of 12 or higher, while about 37 percent earned scores of 3 or below.

What were common student errors or omissions?

In part (a), when calculating the radius by dividing the circumference by 2π, many students evidently entered "..÷2*π ," which gave the incorrect result. They should have entered "..÷(2*π) ."

In part (b) many students correctly wrote the centripetal force as mv^2/r but when substituting numerical values, they failed to square the speed; this was a very common error. Many other students incorrectly equated centripetal acceleration to gravitational force: $v^2/r = GMm/r^2$. Others wrote Kepler's third law incorrectly.

In part (c) many students assumed that the total mechanical energy was either all kinetic or all potential. Many students tried to include a rotational kinetic energy term, and most did not follow through with (or else did not even begin with) the appropriate minus sign for the potential energy. Many students incorrectly wrote *mgh* for the gravitational potential energy.

In part (d) most students correctly checked “less than” for the new orbital period, but most of these students were unable to fully justify their response. Many students simply said that it is a shorter orbital path, apparently assuming a constant speed. Many others incorrectly invoked conservation of energy, conservation of angular momentum, or Kepler’s second law. This justification is invalid because two different orbits are being compared.

Part (e) was the part that students missed the most. The most common error was using the given altitudes rather than distances from the center of Mars. Students also tried many other (nonexistent) conservation “laws,” such as $m_1 \upsilon_1^2 / r_1 = m_2 \upsilon_2^2 / r_2$ or $\upsilon_1 / r_1 = \upsilon_2 / r_2$.

In all five parts of the problem, presenting numerical answers with six or more digits was a very common mistake. The data for this problem were presented with three significant figures, so the calculated quantities should all have reflected that. Evidently, many students simply wrote all the digits displayed by the calculator.

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?

In addition to advising students on how to perform correct calculations and report calculated values using an appropriate number of figures, teachers should address the question of when it is appropriate to apply various conservation principles. Many students assumed that various quantities would remain unchanged when the satellite was placed in a new orbit, which indicates they did not know which quantities are constant when a satellite follows an elliptical orbit; they misunderstood the role of conservation principles; or both. Teachers should also consider giving more attention to gravitational potential energy as applied to satellite orbits, so that students realize that $U_G < 0$ for a bounded orbit.

Question 3

What was the intent of this question?

This question was intended to measure students’ knowledge about the conservation of mechanical energy; their ability to plot experimental data, draw a best-fit line, and utilize the fitted line to determine an unknown quantity (the mass of the glider); and their capacity to understand how and why the analysis would be affected if an initial assumption (that the track is level) was abandoned.

How well did students perform on this question?

The mean score on this 15-point question was 7.08. About 6 percent of students earned scores of 12 or higher, while about 15 percent earned scores of 3 or below.

What were common student errors or omissions?

In general, students performed well on parts (a), (b), and (c) and less well on part (d).

In part (a) most students were able to write an appropriate equation for the conservation of energy, and they recognized that $k = 40\ \text{N/m}$. It was fairly common for students to make the error of setting their expression for the total energy equal to zero.

In part (b) a majority of students constructed an appropriate, well-scaled graph, but then in part (c)(i), many of these students simply connected the dots rather than constructing a best-fit straight line.

In part (c)(ii) many students failed to use two points from their best-fit line to calculate the requested slope. Instead, they used the coordinates of a single point, or they used two points from the data table. A significant number of students confused the slope symbol *m* (in the generic slope-intercept equation $y = mx + b$) with the parameter *m* (the glider's mass).

Part (d) proved to be the most challenging part of this problem; most students attained between 0 and 2 points out of a possible 6. The most common error was not including the increase in elevation of the glider (when the spring is stretched) in the expression for U_g. Some of the students who did allow for the increase in elevation wrote expressions in which $\cos\theta$ appeared (rather than $\sin\theta$). Most of the students who correctly checked "No" in part (d)(ii) then failed to provide a clear justification.

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?

We recommend that teachers require some construction of graphs "by hand." With the reliance on graphing calculators and spreadsheets, fewer students are practicing hand-drawn graphs from lab data than was the case years ago. Nevertheless, these aspects of student performance were stronger on this problem than they were on other recent AP Physics C: Mechanics Exams.