Student Performance Q&A:

2012 AP® Physics C: Mechanics Free-Response Questions

The following comments on the 2012 free-response questions for AP® Physics C: Mechanics were written by the Chief Reader, Jiang Yu of Fitchburg State University in Fitchburg, Mass. 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 students' understanding of simple harmonic motion for a spring/mass system and the damping effects of friction. Students were also tested on free-body diagrams and calculation of the spring constant.

How well did students perform on this question?

The mean score was 6.89 out of a possible 15 points. Overall, students did well on the simple harmonic motion equations and on the force constant and force diagrams.

What were common student errors or omissions?

In part (a) the most common error was using kinematics and conservation of energy to obtain an equation for velocity in terms of time. Students did not recognize that the equation should be a sinusoidal function dependent on time. In part (b) the most common error was taking the incorrect integral of the trigonometry function found in part (a).

There were several methods used to solve part (c). Students seemed to have most difficulty in rearranging the equations correctly to get the right answer. In part (d) many students did not include the vertical forces of gravity and normal force. Often students had the friction or spring force, or both, to the left on the "Away from the equilibrium position" diagram. Force vectors were not labeled or not touching the dot provided. Many students labeled the force vectors with equations rather than a label. When this occurred and the equation was incorrect, students did not receive credit.

In part (e) many students recognized that friction would dampen the system, making the maximum velocity less. However, students did not seem to understand how to correctly draw the graph in terms of both the shape of the graph and the initial value.

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 need to be helped on basic algebraic operations. One would expect that students taking the Physics C: Mechanics course would demonstrate better algebra skills.

Students also should understand the need for clarity in free-body diagrams. The diagrams should clearly show what object the forces are applied on, the directions that the forces are pointing, and clear labels for all force vectors drawn. The free-body diagrams drawn on the AP Exams are intended to assess students' understanding, so they need to be clear and complete.

Question 2

What was the intent of this question?

This question assessed students' ability to outline a laboratory procedure to investigate energy transformation — specifically, the transformation of gravitational potential energy to translational kinetic energy.

How well did students perform on this question?

The mean score was 8.37 out of a possible 15 points. Generally, students were able to select appropriate equipment and create a reasonable experimental design. Additionally, most students indicated a clear understanding that a nonconservative force will decrease the mechanical energy of a system. Students who started with a drop or incline design were most successful in completing the problem.

What were common student errors or omissions?

The most common error was in the calculation of instantaneous velocity at the end of the transformation. A majority of students indicated calculations that led to the average velocity of the object rather than the instantaneous velocity, or they assumed a theoretical acceleration (e.g., $9.8\ m/s^2$) instead of calculating an experimental acceleration.

Many students started with an Atwood/modified Atwood machine setup. Although the procedure was valid, part (c) instructed students to give a detailed description of the gravitational and kinetic energies of the system before and after the transformation. Most students did not account for the energy of both objects. For the modified Atwood design, most students did not account for the energy of the cart on the flat track. Many students did not explicitly account for energies that were assumed to be zero in their calculations.

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 need to learn to design labs that are practical in their execution and effective in measurement. Students also need to be taught how to write up their lab designs precisely and concisely and to communicate their ideas clearly and effectively.

Question 3

What was the intent of this question?

This question assessed students' understanding of slipping and rolling motion caused by a frictional force applying a torque. It required students to evaluate both the linear motion and the rotational motion of a hoop moving across a level surface.

How well did students perform on this question?

The mean score was 2.71 out of a possible 15 points. Generally, students were able to set up the differential equation for both the linear motion and the rotational motion. The derivation of the velocity function and the angular speed function from the differential equation was also well done by most students.

What were common student errors or omissions?

Most students had difficulty deriving the time for the hoop to move through the given distance L. In this case, the solution for time greatly affected how the student completed parts (d) and (e). If students were able to solve for the time, most were able to employ a correct kinematics equation and solve for the speed required in part (d) and the length required in part (e).

Many students used an energy approach to this problem, which will not yield the correct solution. Most students who approached the problem in this way did not accurately account for the distance over which the frictional force was acting on the rotating hoop.

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 need to be taught to follow the established problem-solving methods in mechanics, especially when the problem is unfamiliar and the situation is new to them. Almost half the students received a zero on this problem, mostly because they chose to give up instead of calmly work through it by applying the standard procedures for solving problems. This question is much simpler than it appears, so students could have done better.