Student Performance Q&A:

2016 AP® Physics 2 Free-Response Questions

The following comments on the 2016 free-response questions for AP® Physics 2 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 5.B.4.2, 5.B.7.1, 5.B.7.3, 7.A.1.2, 7.A.2.1, and 7.A.3.3. The question assessed student understanding of the thermodynamic state properties and energy processes for a closed cycle of an ideal gas. The question asked students to make connections between microscopic and macroscopic properties of the gas.

How well did students perform on this question?

The mean score was 2.55 out of a possible 10 points.

What were common student errors or omissions?

a) Students were often not able to explain the microscopic origin of the force on the piston or the microscopic property characterized by temperature. Students often included just numerical answers in part (a) with no attempt to address the issues requiring prose. If they did answer, they would often simply restate that the gas atoms exerted a force on the piston, but not explain how. They often knew that temperature is related to kinetic energy, but most often stated that temperature was a measure of the kinetic energy of the atoms, leaving out the word "average."

b) It was often very unclear how students were arriving at their value of Q, or what they were calculating at all. There were numbers or equations written down with no semblance of a logical order.

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 have practice in multi-step derivations. They particularly need to be clear and orderly with questions that ask them to "derive" or "calculate," since they are graded on the steps to the answer. If something is not relevant, they should cross it out. They should not write in the corners, should not write at angles, but should practice putting calculation steps in rows.

b) It should be reiterated to students that it is important to read and follow directions. They should remember to answer all parts of a question, and when asked to justify, the response should go beyond just restating the question. Once they have answered, if they have time, they should be sure to go back and read the prompt and make sure they have answered it.

Question 2

What was the intent of this question?

This question assessed learning objectives 1.A.4.1, 6.E.3.2, 6.E.3.3, and 7.C.4.1. The question evaluated student understanding of Snell's law and energy level diagrams. The basic intent was to assess students' experimental design skills. These include experimental procedure design, a description of what data needs to be analyzed, and how to perform that analysis.

How well did students perform on this question?

The mean score was 5.10 out of a possible 12 points.

What were common student errors or omissions?

a) Students commonly said "the data" would give them the index of refraction of the glass block, but did not specifically say what analysis (i.e., the slope of an appropriate graph) would elicit this information.

b) Students often said what should be graphed, but did not say on which axis each variable should be plotted.

c) Students often spent time describing aspects of the procedure that had no bearing on what actually needed to be measured. For example, "gather your materials," or "clamp the block to the table."

d) Some students said they would "measure the angles," but did not state how or what measuring instrument they would use.

e) While it was indicated that the student should describe a procedure another classmate could follow, this was rarely achieved due to lack of detail or clarity. A common omission was that the angle of the beam of light should be measured relative to the normal.

f) Often students chose to have the incident light beam perpendicular to the glass (angle of incidence = zero), and then would measure the refracted angle.

g) While students often were able to explain atomic transitions that resulted in light emission, energy level diagrams were most often unclear, incorrect, or non-existent.

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) A well-labeled diagram is always a good idea for the lab question, and can really clarify what the student is trying to say.

b) Students should practice writing procedures and justifications, and should get help on what is useful information and what is not. Students should not repeat the question or give unasked for information.

Question 3

What was the intent of this question?

This question assessed learning objectives 2.E.2.1, 2.E.2.2, 2.E.3.2, 3.A.3.4, 3.C.2.2, 5.B.4.1, 5.B.4.2, and 5.B.5.4. The question assessed student understanding of an electric potential map, and how the resulting electric forces do work and change the energy of charged masses. The question also assessed understanding of the similarities and differences between the electric and gravitational field.

How well did students perform on this question?

The mean score was 3.44 out of a possible 12 points.

What were common student errors or omissions?

a) Parts of the question asked for two items to be addressed and students commonly would only address one (e.g., they would discuss a similarity but not a difference).

b) Students often made unclear or seemingly contradictory statements, for example seeming to arguing that student 1 is correct, but then finishing by saying that student 1 is incorrect.

c) Common mistakes included interchanging of terms or misuse of terms such as "sign," "magnitude," "field" and "force," "potential" and "potential energy."

d) Students commonly referred to inverse square, $1/r$, and exponential relationships interchangeably. Particularly, students like to refer to most any relationship that is not linear as exponential.

e) When asked to justify, many students just restate the correct responses without adding any justification or insight.

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) Teachers need to emphasize the need for writing legibly. Very significant numbers of students are writing too messily, too small, and too lightly.

b) Teachers should have students practice writing justifications, being careful not to just restate the prompts, and being sure to answer the question asked. Students shouldn't be afraid to be brief, and to the point. Encourage them to think about what they're trying to say first, and then to re-read their response.

Question 4

What was the intent of this question?

This question assessed learning objectives 4.E.4.1, 4.E.5.1, 4.E.5.2, and 5.B.9.5. The intent of this question was to see if students could analyze the behavior of DC circuits with capacitors and resistors and determine how changes in the circuit would change that behavior. Students were asked to present their analyses in both mathematical and coherent paragraph form.

How well did students perform on this question?

The mean score was 3.28 out of a possible 10 points.

What were common student errors or omissions?

a) Students commonly do not show an understanding of the steady-state or initial-state behavior of an *RC* circuit.

b) Students very commonly state that current will flow in a branch parallel to a capacitor only when the capacitor is completely charged, and not when it is partially charged.

c) A frequent student error is conflating the properties of electric current and potential difference, such "voltage flows through a capacitor leaving less for the lightbulb."

d) Students often do not structure their writing of the paragraph response according to the AP guidelines.

e) Students frequently indicate that changing the order of placement of resistors and capacitors in series affects the circuit behavior.

f) Students very frequently did not include all the required elements in the diagrams, in particular the switch.

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) While the use of analogies in writing can help quickly convey a basic understanding, the students need to show an understanding of the underlying physics.

b) Before students can understand the underlying physics in this question, they really need to work on the basics of current and potential differences in series and parallel circuits.