

2016 AP® PHYSICS 1 FREE-RESPONSE QUESTIONS

2. (12 points, suggested time 25 minutes)

A new kind of toy ball is advertised to “bounce perfectly elastically” off hard surfaces. A student suspects, however, that no collision can be perfectly elastic. The student hypothesizes that the collisions are very close to being perfectly elastic for low-speed collisions but that they deviate more and more from being perfectly elastic as the collision speed increases.

- (a) Design an experiment to test the student’s hypothesis about collisions of the ball with a hard surface. The student has equipment that would usually be found in a school physics laboratory.
- i. What quantities would be measured?
 - ii. What equipment would be used for the measurements, and how would that equipment be used?
 - iii. Describe the procedure to be used to test the student’s hypothesis. Give enough detail so that another student could replicate the experiment.
- (b) Describe how you would represent the data in a graph or table. Explain how that representation would be used to determine whether the data are consistent with the student’s hypothesis.
- (c) A student carries out the experiment and analysis described in parts (a) and (b). The student immediately concludes that something went wrong in the experiment because the graph or table shows behavior that is elastic for low-speed collisions but appears to violate a basic physics principle for high-speed collisions.
- i. Give an example of a graph or table that indicates nearly elastic behavior for low-speed collisions but appears to violate a basic physics principle for high-speed collisions.
 - ii. State one physics principle that appears to be violated in the graph or table given in part (c)i. Several physics principles might appear to be violated, but you only need to identify one.

Briefly explain what aspect of the graph or table indicates that the physics principle is violated, and why.

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Question 2

12 points total

**Distribution
of points**

Note: For parts (a) and (b), quantities that are proportional to mechanical energy, rather than energy itself, may be calculated, because terms like g or the ball's mass do not change during the experiment.

(a) 4 points

Parts i, ii, and iii are scored as a unit.

For an overall plan in which quantities are measured that could be used to compare mechanical energy before and after a collision with a hard surface

1 point

For a conceptually plausible plan to measure pre- and post-collision positions and/or speeds that could be used to compare pre- and post-collision mechanical energies, without extraneous equipment and/or measurements

1 point

For having lab equipment and measurement procedures well specified

1 point

For a procedure that includes trials of different pre-collision speeds, ranging from low speed to high speed (as is needed to test the student's hypothesis)

1 point

Example 1:

- i. The drop height of the ball and the bounce height.
- ii. A meterstick to measure the heights and a video camera to record the ball's motion.
- iii. Place the meterstick upright against the wall.

Drop the ball from 10 different drop heights, using the video camera to record the bounce heights.

Example 2:

- i. The speed of the ball immediately before and immediately after it bounces.
 - ii. A photogate near the floor, at a height just above the diameter of the ball, to measure the ball's speed.
 - iii. Drop the ball through the photogate.
- Record the speeds measured by the photogate before and after the bounce. Change the drop height of the ball at least five times, covering a range of heights from "low" to "high."

(b) 4 points

For describing how to plot or otherwise represent the data in a way that could be used to test the hypothesis

1 point

For describing how to compare the post-collision to pre-collision mechanical energy (or a plausible alternative) to quantify the elasticity of the collision

1 point

For comparing the low-speed versus high-speed results

1 point

For addressing the hypothesis with an analysis such as a slope, ratio, or difference

1 point

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Question 2 (continued)

**Distribution
of points**

(b) (continued)

Example 1:

Make a graph of the bounce height h_f as a function of the drop height h_i . If the data are consistent with the hypothesis, then the data will (1) lie close to the line $h_f = h_i$ for low drop heights, and (2) lie below this line for high drop heights.

Example 2:

Make a graph of $v_f^2 - v_i^2$ as a function of v_i , where v_f and v_i are the ball's speed just after and just before the bounce, respectively. If the data are consistent with the hypothesis, then $v_f^2 - v_i^2$ will (1) be close to zero for low speeds, and (2) be negative for high speeds.

(c)

i. 2 points

For drawing a graph or table that shows that the low-speed collisions are nearly perfectly elastic

1 point

For drawing a graph or table that shows a violation of a physics principle for higher-speed collisions

1 point

Example for energy conservation:

A graph of the ratio $\frac{\text{Post-collision mechanical energy}}{\text{Pre-collision mechanical energy}}$ as a function of pre-

collision speed, in which the graph stays near 1.0 for low initial speeds but becomes greater than 1.0 for high-speed collisions.

ii. 2 points

For a correct description of the aspect of the graph or table that shows a violation of the physical principle indicated

1 point

For a correct explanation of why the representation shows a violation of the physical principle indicated

1 point

Example for energy conservation using the graph described above: The value of the energy ratio shows a violation of conservation of energy when it becomes greater than 1.0 because the final energy cannot be greater than the initial energy.