AP® PHYSICS B
2010 SCORING GUIDELINES

General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong — for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exams equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 1

15 points total **Distribution of points**

(a) 3 points

For a correct relationship between the vertical distance and time — 1 point

$$h = \frac{1}{2}gt^2$$

For substitution of the vertical height and the acceleration due to gravity — 1 point

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(0.80\ \text{m})}{9.8\ \text{m/s}^2}}$$

For the correct answer — 1 point

$$t = 0.40\ \text{s}$$

Note: Credit was awarded for an alternate solution using $\upsilon_y^2 = 2gh$ with appropriate substitutions to find the vertical velocity when the block lands, followed by substitution of this velocity into $\upsilon_y = gt$ (or equivalent) to find the time.

(b) 2 points

For a correct relationship between the horizontal distance and time — 1 point

$$x = \upsilon t$$

For a consistent substitution of time from part (a) into the correct equation — 1 point

$$\upsilon = \frac{x}{t} = \frac{1.2\ \text{m}}{0.40\ \text{s}}$$

$$\upsilon = 3.0\ \text{m/s}$$

(c) 3 points

For any statement of conservation of energy — 1 point

For correct use of appropriate energy equations — 1 point

$$\frac{1}{2}kx^2 = \frac{1}{2}m\upsilon^2$$

For a consistent substitution of velocity from part (b) into the correct equation — 1 point

$$x = \sqrt{\frac{m}{k}}\upsilon = \sqrt{\frac{4\ \text{kg}}{650\ \text{N/m}}}(3.0\ \text{m/s})$$

$$x = 0.24\ \text{m}$$

Distribution of points

(d) 4 points

For any statement of conservation of momentum — 1 point

$m_A v_i = (m_A + m_B) v_f$

For substitution of both masses into the equation — 1 point

For substitution of the velocity from part (b) into the equation — 1 point

$$v_f = \left(\frac{m_A}{m_A + m_B}\right) v_i = \left(\frac{4\ \text{kg}}{4\ \text{kg} + 4\ \text{kg}}\right) 3.0\ \text{m/s} = 1.5\ \text{m/s}$$

For substitution of time from part (a) into a correct relationship between the horizontal distance and time — 1 point

$d = v_f t = (1.5\ \text{m/s})(0.40\ \text{s})$

$d = 0.60\ \text{m}$

(e) 2 points

For indicating that $E_2 < E_1$ — 1 point

For a correct justification stating one of the following: — 1 point

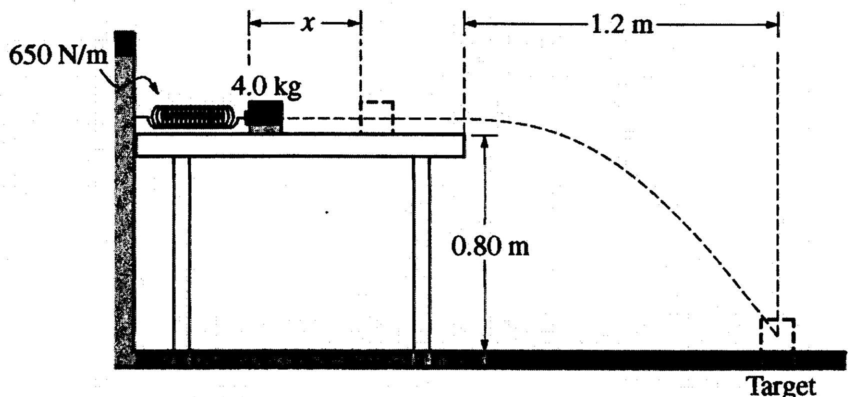
- the kinetic energy (or energy) is transformed into other forms of energy during the collision (e.g., by reference to heat, internal energy, sound)
- the kinetic energy is not conserved in an inelastic collision
- a numerical calculation of the relevant energies

Units 1 point

For correct units on all completed answers — 1 point

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1-2 and about 11 minutes for answering each of Questions 3-7. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



Note: Figure not drawn to scale.

1. (15 points)

Block A of mass 4.0 kg is on a horizontal, frictionless tabletop and is placed against a spring of negligible mass and spring constant 650 N/m. The other end of the spring is attached to a wall. The block is pushed toward the wall until the spring has been compressed a distance x, as shown above. The block is released and follows the trajectory shown, falling 0.80 m vertically and striking a target on the floor that is a horizontal distance of 1.2 m from the edge of the table. Air resistance is negligible.

(a) Calculate the time elapsed from the instant block A leaves the table to the instant it strikes the floor.

$h = .80m$

$v_I = 0 m/s$

$g = 9.8 m/s^2$

$d = v_I t + 1/2 a t^2$

$h = v_I t + 1/2 g t^2$

$.8 = 1/2 (9.8) t^2$

$\boxed{t = .404 s}$

(b) Calculate the speed of the block as it leaves the table.

$d = vt$

$1.2 = v(.404)$

$\boxed{v = 2.97 m/s}$

(c) Calculate the distance x the spring was compressed.

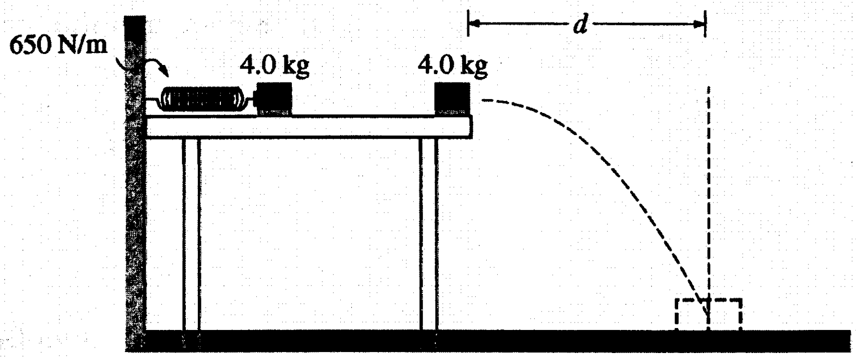
$PE_{spring} = KE_{block}$

$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$

$\frac{1}{2}(650)x^2 = \frac{1}{2}(4)(2.97)^2$

$\boxed{x = .233m}$

Block B, also of mass 4.0 kg, is now placed at the edge of the table. The spring is again compressed a distance x, and block A is released. As it nears the end of the table, it instantaneously collides with and sticks to block B. The blocks follow the trajectory shown in the figure below and strike the floor at a horizontal distance d from the edge of the table.



Note: Figure not drawn to scale.

(d) Calculate d if x is equal to the value determined in part (c).

$V_A = 2.97 m/s$

$V_B = 0 m/s$

$m_A = m_B = 4kg$

$t = .404s$

$P_{before} = P_{After}$

$m_A V_A + m_B V_B = (m_A + m_B)V$

$(4)(2.97) + (4)(0) = (4+4)V$

$V = 1.485 m/s$

$d = vt$

$d = (1.485)(.404)$

$\boxed{d = .6m}$

(e) Consider the system consisting of the spring, the blocks, and the table. How does the total mechanical energy E_2 of the system just before the blocks leave the table compare to the total mechanical energy E_1 of the system just before block A is released?

✓ $E_2 < E_1$ ____ $E_2 = E_1$ ____ $E_2 > E_1$

Justify your answer. $E_1 = PE_{spring}$

$E_1 = \frac{1}{2}kx^2$

$E_1 = \frac{1}{2}(650)(.233)^2$

$E_1 = 17.644 J >$

$E_2 = KE_{blocks}$

$E_2 = \frac{1}{2}mv^2$

$E_2 = \frac{1}{2}(8)(1.485)^2$

$E_2 = 8.82 J$

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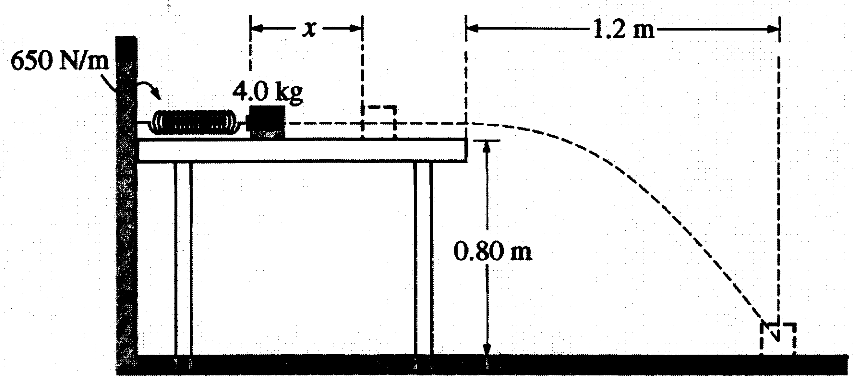


Note: Figure not drawn to scale.

1. (15 points)

Block A of mass 4.0 kg is on a horizontal, frictionless tabletop and is placed against a spring of negligible mass and spring constant 650 N/m. The other end of the spring is attached to a wall. The block is pushed toward the wall until the spring has been compressed a distance x, as shown above. The block is released and follows the trajectory shown, falling 0.80 m vertically and striking a target on the floor that is a horizontal distance of 1.2 m from the edge of the table. Air resistance is negligible.

(a) Calculate the time elapsed from the instant block A leaves the table to the instant it strikes the floor.

Y direction
$V_0 = 0$
$V =$
$X_0 = 0$
$X = .8$
$a = 9.8 m/s^2$
$t =$

$X = X_0 + V_0 t + \frac{1}{2} a t^2$
$.8 = \frac{1}{2} \cdot 9.8 \cdot t^2$

$t = .4$ sec

(b) Calculate the speed of the block as it leaves the table.

X direction
$V_0 = V$
$V = V$
$X_0 = 0$
$X = 1.2 m$
$a = 0 m/s^2$
$t = .4$ sec

$X = X_0 + V_0 t + \frac{1}{2} a t^2$
$\frac{1.2}{.4} = \frac{V \cdot .4 + 0}{.4}$

$V = 3 m/s$

(c) Calculate the distance x the spring was compressed.

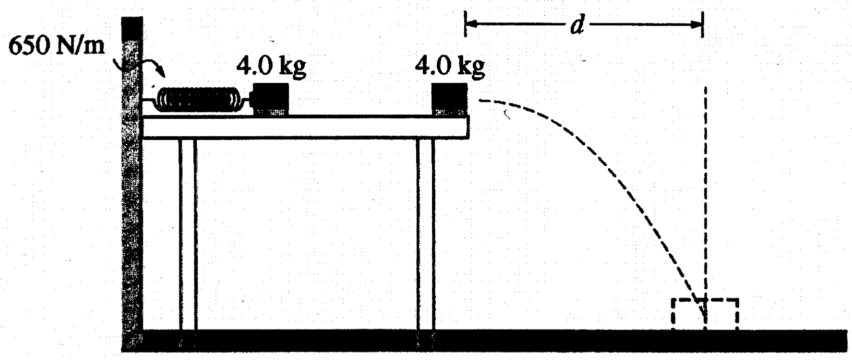
$KE + PE = KE + PE$ $\quad \cancel{\frac{1}{2}mv_i^2} + \frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2 + \cancel{\frac{1}{2}kx_f^2}$

$v_i = 0$ $\quad x_f = 0$

$\frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2$

$\frac{1}{2}\cdot 650 \cdot x_i^2 = \frac{1}{2}\cdot 4 \cdot 3^2 \, m/s$ $\quad x = .24 m$

Block B, also of mass 4.0 kg, is now placed at the edge of the table. The spring is again compressed a distance x, and block A is released. As it nears the end of the table, it instantaneously collides with and sticks to block B. The blocks follow the trajectory shown in the figure below and strike the floor at a horizontal distance d from the edge of the table.



Note: Figure not drawn to scale.

(d) Calculate d if x is equal to the value determined in part (c).

$E_i = E_f$ $\quad \cancel{\frac{1}{2}mv_i^2} + \frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2 + \cancel{\frac{1}{2}kx_f^2}$

$v_i = 0$ $\quad x_f = 0$

$\frac{1}{2}\cdot 650 \cdot .24^2 = \frac{1}{2}\cdot 8 \cdot v_f^2$ $\quad v_f = 2.2 m/s$ $\quad t = .4 sec$ $\quad a = 0 m/s^2$

$x_0 = 0$

$x = \cancel{x_0} + v_0 t + \cancel{\frac{1}{2}at^2}$ $\quad d = .88 m$

$x = 2.2 \cdot .4$

(e) Consider the system consisting of the spring, the blocks, and the table. How does the total mechanical energy E_2 of the system just before the blocks leave the table compare to the total mechanical energy E_1 of the system just before block A is released?

____ $E_2 < E_1$ $\quad$ ✓ $E_2 = E_1$ $\quad$ ____ $E_2 > E_1$

Justify your answer. It's going to be the same because energy will not be lost or added in the system. The potential energy before will equal the kinetic after.

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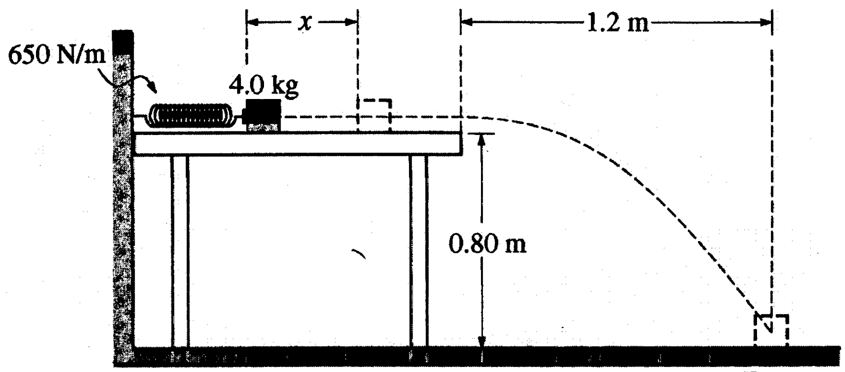


Note: Figure not drawn to scale.

1. (15 points)

Block *A* of mass 4.0 kg is on a horizontal, frictionless tabletop and is placed against a spring of negligible mass and spring constant 650 N/m. The other end of the spring is attached to a wall. The block is pushed toward the wall until the spring has been compressed a distance *x*, as shown above. The block is released and follows the trajectory shown, falling 0.80 m vertically and striking a target on the floor that is a horizontal distance of 1.2 m from the edge of the table. Air resistance is negligible.

(a) Calculate the time elapsed from the instant block *A* leaves the table to the instant it strikes the floor.

$X = X_0 + V_0 t + \frac{1}{2}at^2$

$X_y = \cancel{X_y} + \cancel{V_0 t} + \frac{1}{2}at^2$

$-.8m = \frac{1}{2}(9.8m/s^2)(t^2)$

$(.5)(9.8m/s^2) \quad (.5)(9.8m/s^2)$

$\sqrt{.163265} = \sqrt{t^2}$

$\boxed{.40s = t}$

(b) Calculate the speed of the block as it leaves the table.

$E_1 = E_2$

$\frac{1}{2}Kx^2 = \frac{1}{2}mv^2$

$\frac{1}{2}(650N/m)(.31)^2 = \frac{1}{2}(4.0kg)(v^2)$

$\frac{31.2325}{2} = \frac{2v^2}{2}$

$\sqrt{15.6163} = \sqrt{v^2}$

$\boxed{3.95m/s = v}$

$E_1 = E_2$

$\frac{1}{2}kx^2 = mgh$

$\frac{\frac{1}{2}(650N/m)x^2}{\frac{1}{2}(650N/m)} = \frac{(4kg)(9.8m/s^2)(.8m)}{\frac{1}{2}(650N/m)}$

$\sqrt{x^2} = \sqrt{.096492}$

$\boxed{x = .31}$

GO ON TO THE NEXT PAGE.

(c) Calculate the distance x the spring was compressed.

$E_1 = E_2$

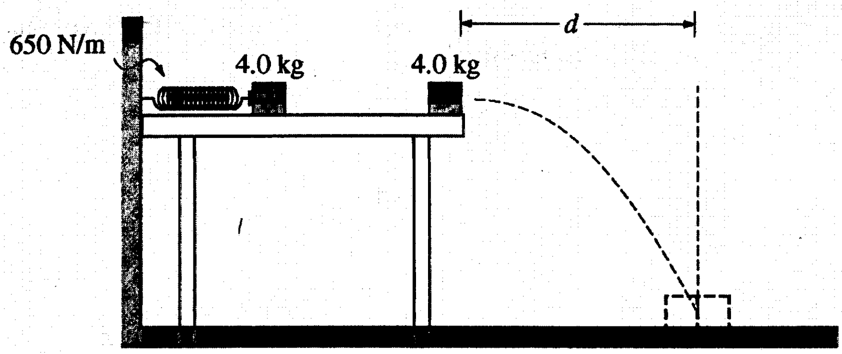
$\frac{1}{2}kx^2 = mgh$

$\frac{1}{2}(650\,N/m)(x^2) = (4kg)(9.8m/s^2)(.8m)$

$\sqrt{x^2} = \sqrt{.096492}$

$\boxed{x = .31m}$

Block B, also of mass 4.0 kg, is now placed at the edge of the table. The spring is again compressed a distance x, and block A is released. As it nears the end of the table, it instantaneously collides with and sticks to block B. The blocks follow the trajectory shown in the figure below and strike the floor at a horizontal distance d from the edge of the table.



Note: Figure not drawn to scale.

(d) Calculate d if x is equal to the value determined in part (c).

$E_1 = E_2$

$\frac{1}{2}kx^2 = mgh$

$\frac{1}{2}(650N/m)(.31^2) = (8Kg)(9.8m/s^2)(d)$

$\frac{31.2325}{78.4} = \frac{78.4\,d}{78.4}$

$\boxed{.398m = d}$

(e) Consider the system consisting of the spring, the blocks, and the table. How does the total mechanical energy E_2 of the system just before the blocks leave the table compare to the total mechanical energy E_1 of the system just before block A is released?

____ $E_2 < E_1$ ____ $E_2 = E_1$ ✓ $E_2 > E_1$

Justify your answer.

The energy is E_2 is greater because an extra mass of 4.0kg is added that was not present in the previous situation.

Question 1

Overview

This question was designed to assess students' knowledge of projectile motion, conservation of energy, conservation of momentum and inelastic collisions.

Sample: B1-A
Score: 15

This response is very clear and well organized, which helped to ensure that it received full credit. Note that the justification in part (e) is provided by calculations of the relevant energies.

Sample: B1-B
Score: 10

This response earned full credit in the first three parts. Part (d) uses conservation of energy instead of momentum to determine a speed for the combined blocks. Only 1 point was earned in part (d), for substituting the time from part (b) into an appropriate distance equation. Part (e) illustrates a typical response that incorrectly applies conservation of energy. The units are all correct so that point was earned.

Sample: B1-C
Score: 5

This response earned full credit in part (a). In part (b) conservation of energy is incorrectly used on the right to determine a value for the spring compression. That value is then used in energy conservation that is correct for this situation but cannot be applied at this point given the values known. Therefore, no credit was earned. Part (c) earned 1 point for a statement of conservation of energy but repeats the incorrect use of gravitational potential energy from part (b). The approach in part (d) is incorrect and the response to part (e) is wrong, so neither part earned credit. The units are all correct so that point was earned.