General Notes About 2012 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be 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 the use of an 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 Exam equation sheets. 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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 2

10 points total	**Distribution of points**
(a) 2 points	
For a statement that shows the conservation of energy for the large sphere	1 point
$\Delta U_{3M} = \Delta K_{3M}$	
$3MgH = \frac{1}{2}(3M)v_b^2$	
For a correct answer (or equivalent expression for v_b)	1 point
$v_b = \sqrt{2gH}$	
Alternate solution	*Alternate points*
For using a proper kinematic approach	*1 point*
$v_f^2 = v_0^2 + 2a\Delta y$	
$v_b^2 = 2gH$	
For a correct answer	*1 point*
$v_b = \sqrt{2gH}$	
(b) 2 points	
For stating or showing the conservation of momentum applied to the collision	1 point
$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$	
For stating or showing that the spheres are initially traveling in opposite directions	1 point
$3Mv_b + M(-v_b) = 3Mv_L + Mv_S$	
$2v_b = 3v_L + v_S$	
(c) 1 point	
Substituting the given zero value into the answer from part (b)	
$2v_b = 3v_L + v_S$	
$2v_b = 0 + v_S$	
For a correct answer	1 point
$v_S = 2v_b$	

Question 2 (continued)

Distribution of points

(d) 3 points

For any correct attempt to compare total kinetic energy before the collision to total kinetic energy after the collision — 1 point

$K_i = K_{3Mi} + K_{Mi}$ and $K_f = K_{3Mf} + K_{Mf}$

For correct substitutions of υ_b, the expression for υ_S from part (c), and the correct masses in the kinetic energy terms — 1 point

$$K_i = \frac{1}{2}(3M)(\upsilon_b)^2 + \frac{1}{2}(M)(-\upsilon_b)^2 = 2M\upsilon_b^2$$

$$K_f = \frac{1}{2}(M)(2\upsilon_b)^2 = 2M\upsilon_b^2$$

For correctly stating that the collision is elastic (or inelastic if consistent with the comparison of initial and final kinetic energies) — 1 point

(e) 2 points

For a statement of conservation of energy for ball M as it rises to the new height h — 1 point

$$U_{gf} = K_0$$

$$Mgh = \frac{1}{2}M\upsilon_S^2$$

$$h = \frac{(2\upsilon_b)^2}{2g} = \frac{4\upsilon_b^2}{2g} = \frac{2\left(\sqrt{2gH}\right)^2}{g}$$

For a correct answer consistent with the expression for υ_b obtained in part (a) — 1 point

$$h = 4H$$

Alternate solution — *Alternate points*

For using a correct kinematic approach to solve for maximum height of ball M — *1 point*

$$\upsilon_f^2 = \upsilon_0^2 + 2a\Delta y$$

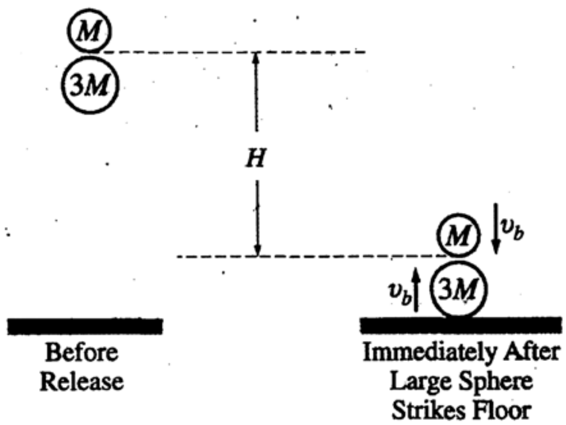
$$\upsilon_0 = \upsilon_S = 2\upsilon_b = 2\sqrt{2gH}$$

$$0 = \left(2\left(\sqrt{2gH}\right)\right)^2 - 2gh$$

For a correct answer consistent with the expression for υ_b obtained in part (a) — *1 point*

$$h = 4H$$

<u>Note</u>: Both points are awarded for any correctly determined value of h without any written justification.



2. (10 points)

A small and a large sphere, of mass M and $3M$ respectively, are arranged as shown on the left side of the figure above. The spheres are then simultaneously dropped from rest. When the large sphere strikes the floor, the spheres have fallen a height H. Assume air resistance is negligible. Express all answers in terms of M, H, and fundamental constants, as appropriate.

(a) Derive an expression for the speed v_b with which the large sphere strikes the floor.

law of Conservation of Energy:

$$E_T = E_T'$$

$$\cancel{K}^{0} + U = K + \cancel{U}^{0}$$

$$3\cancel{M}gH = \frac{1}{2}(3\cancel{M})v_b^2$$

$$v_b = \sqrt{2gH}$$

∴ The large sphere strikes the floor at speed $\sqrt{2gH}$.

Immediately after striking the floor, the large sphere is moving upward with speed v_b and collides head-on with the small sphere, which is moving downward with identical speed v_b at that instant. Immediately after the collision, the small sphere moves upward with speed v_S and the large sphere has speed v_L.

(b) Derive an equation that relates v_b, v_S, and v_L.

By the law of Conservation of Momentum : let down be positive.

$$\Sigma p = \Sigma p'$$

$$\therefore M v_b - 3M v_b = -M v_s - 3M v_L$$

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In this particular situation $v_L = 0$.

(c) Use your relationship from part (b) to determine the speed of the small sphere in terms of v_b.

$$Mv_b - 3Mv_b = -Mv_S - \cancel{3Mv_L}^{\,0}$$

$$-2Mv_b = -Mv_S$$

$$v_S = 2v_b \ //$$

∴ The speed of the small sphere is $2v_b$.

(d) Indicate whether the collision is elastic. Justify your answer using your results from parts (b) and (c).

A collision is elastic if and only if total kinetic energy is conserved.

Before the collision: $E_T = K_S + K_L = \frac{1}{2}Mv_b^2 + \frac{1}{2}(3M)v_b^2 = 2Mv_b^2 \ //$

After the collision: $E_T' = K_S + K_L = \frac{1}{2}Mv_S^2 + \cancel{\frac{1}{2}(3M)v_L^2} = \frac{1}{2}M(2v_b)^2 = 2Mv_b^2 \ //$

∴ $E_T = E_T'$

∴ The collision is elastic.

(e) Determine the height h that the small sphere rises above its lowest position, in terms of the original height H.

Law of Conservation of Energy: Let K and U be the energies at the lowest position.

$$E_T = E_T'$$

$$K + \cancel{U}^{0} = \cancel{K'}^{0} + U'$$

$$2Mv_b^2 = Mgh$$

From (a), $v = \sqrt{2gH}$, so the above becomes:

$$2M(2gH) = Mgh$$

$$h = 4H \ //$$

∴ The small sphere rises $4H$ above its lowest position

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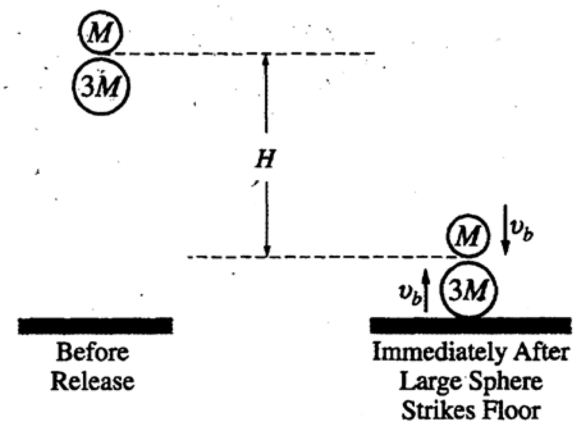

2. (10 points)

A small and a large sphere, of mass M and $3M$ respectively, are arranged as shown on the left side of the figure above. The spheres are then simultaneously dropped from rest. When the large sphere strikes the floor, the spheres have fallen a height H. Assume air resistance is negligible. Express all answers in terms of M, H, and fundamental constants, as appropriate.

(a) Derive an expression for the speed v_b with which the large sphere strikes the floor.

$$V_b^2 = \cancel{V_0^2}^{\,0} + 2gH$$

$$V_b = \sqrt{2gH}$$

Immediately after striking the floor, the large sphere is moving upward with speed v_b and collides head-on with the small sphere, which is moving downward with identical speed v_b at that instant. Immediately after the collision, the small sphere moves upward with speed v_S and the large sphere has speed v_L.

(b) Derive an equation that relates v_b, v_S, and v_L.

$p = mv$

$$3\cancel{M}V_b - \cancel{M}V_b = \cancel{M}V_s + \cancel{M}V_L$$

$$2V_b = V_s + V_L$$

$$V_b = \frac{V_s + V_L}{2}$$

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In this particular situation $v_L = 0$.

(c) Use your relationship from part (b) to determine the speed of the small sphere in terms of v_b.

$$V_s + 0 = 2V_b$$

$$V_s = 2V_b$$

(d) Indicate whether the collision is elastic. Justify your answer using your results from parts (b) and (c).

The collision is elastic because both balls are separate before and after the collision with their own velocities, as shown in b and c $V_b \neq V_s \neq V_L$ so it is not elastic.

(e) Determine the height h that the small sphere rises above its lowest position, in terms of the original height H.

$$V_s^2 = V_b^2 + 2gh$$

$$h = \frac{(V_s^2 - V_b^2)}{2g}$$

$$h = \frac{V_s^2}{2g} - \frac{V_b^2}{2g}$$

$$h = \frac{V_s^2}{2g} - H$$

$$V_b^2 = \cancel{V_0^2}^{0} + 2gH$$

$$H = \frac{V_b^2}{2g}$$

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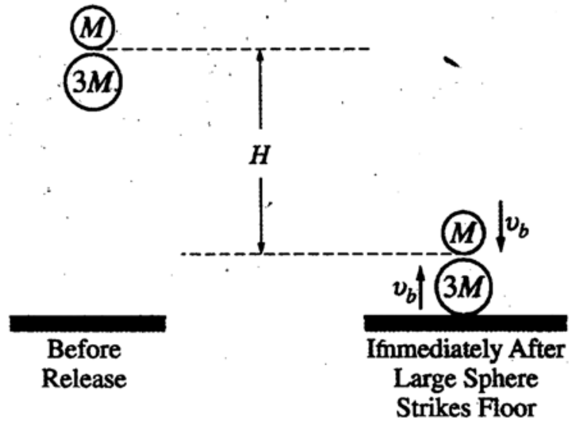

2. (10 points)

A small and a large sphere, of mass M and $3M$ respectively, are arranged as shown on the left side of the figure above. The spheres are then simultaneously dropped from rest. When the large sphere strikes the floor, the spheres have fallen a height H. Assume air resistance is negligible. Express all answers in terms of M, H, and fundamental constants, as appropriate.

(a) Derive an expression for the speed v_b with which the large sphere strikes the floor.

$V_b = V_i + 2gH \qquad v_i = 0 \qquad V_b = 2gH$

Immediately after striking the floor, the large sphere is moving upward with speed v_b and collides head-on with the small sphere, which is moving downward with identical speed v_b at that instant. Immediately after the collision, the small sphere moves upward with speed v_S and the large sphere has speed v_L.

(b) Derive an equation that relates v_b, v_S, and v_L.

$mv = mv$

$\cancel{(M + 3M)(v_b) = Mv_s + 3Mv_L}$

$(3M)(v_b) + (M)(v_b) = (3M)(v_L) + (M)(v_s)$

GO ON TO THE NEXT PAGE.

In this particular situation $v_L = 0$.

(c) Use your relationship from part (b) to determine the speed of the small sphere in terms of v_b.

$v_b =$

$$U_s = \frac{4M \cdot U_b}{M} \qquad U_s = 4\, U_b$$

(d) Indicate whether the collision is elastic. Justify your answer using your results from parts (b) and (c).

The collision is ~~in~~elastic because the momentum in system before the collision is equal to ~~[illegible]~~ the momentum in the system after the collision. This is shown because ~~[illegible]~~ upon collision, U_b gets transferred to both spheres in the form of U_s and U_L. Since no velocity or mass is lost, energy is conserved.

(e) Determine the height h that the small sphere rises above its lowest position, in terms of the original height H.

$U_i = U_s \qquad U_f = 0\,m/s \qquad d = ? \qquad a = g$

$$0\,m/s = U_b + 2gd$$

$$d = \frac{U_b}{2g} \qquad U_b = 2gH$$

$$d = \frac{2gH}{2g} \qquad \boxed{d = H}$$

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AP® PHYSICS B
2012 SCORING COMMENTARY

Question 2

Overview

This question assessed students' understanding of conservation of energy and conservation of momentum in the contexts of free fall and collision. Students were asked to calculate various velocities and a final height of rebound for one of the balls involved. They were also asked to determine the type of collision by considering the energy changes.

Sample: B2-A
Score: 10

This is a good example of a response that demonstrates understanding of each item in the scoring guidelines; it earned all 10 points. In parts (b) and (c) the student provides a correct statement of momentum and final value for the ball's speed. Notice that in part (b) no point was lost for not reducing the expression.

Sample: B2-B
Score: 6

Both points were earned in part (a). Two points were also earned in part (b), even though the student makes an erroneous statement of conservation of momentum (the masses are incorrect on the right-hand side of the equation). Note that the scoring guidelines are not based on a correct final statement of conservation of momentum; rather, 1 point is awarded for any statement of conservation of momentum in the collision, and 1 point is awarded for showing that the 3M and the M balls are moving in opposite directions at impact. This response satisfies both of those statements. In part (c) the answer point was earned (notice that the error in the student's momentum statement does not change the student's final answer for v_S). No points were earned in part (d), as the student tries to base the definition of *elastic* on the balls being "separate before and after the collision." In part (e) 1 point was earned for attempting a kinematics approach.

Sample: B2-C
Score: 1

No points were awarded in part (a): the student provides neither a correct energy statement nor a correct kinematic statement. In part (b) 1 point was earned for a statement of conservation of momentum, but it does not indicate that the balls are moving in opposite directions before the collision. No points were earned in part (c). In part (d) the student shows an understanding of the textbook definition of *elastic* but makes no attempt to compare total kinetic energies and justifies an elastic collision by using the results from parts (a) and (c); therefore, this answer does not satisfy the scoring guidelines for part (d) and earned no points. No credit was earned in part (e). Notice that the student writes an incorrect kinematic relationship.