AP® PHYSICS
2011 SCORING GUIDELINES (Form B)

General Notes About 2011 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 earned. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally earn credit. For example, if use of the equation expressing a particular concept is worth one 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 earned. 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 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 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 earn 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 4

10 points total | **Distribution of points**

(a) 3 points

For each correct force on the dot for which the vector drawn has the correct direction and a correct label such as those in the figure above, 1 point was earned. — 3 points

No points were earned for an appropriately labeled force if the direction was incorrect.

1 earned point was deducted for each additional force or components.

(b) 3 points

For recognition that the balloon is in equilibrium, so $\sum F_y = ma_y = 0$ — 1 point

For an expression for F_B that matches the free-body diagram — 1 point

$\sum F_y = F_B - m_b g - T = 0$

$F_B = m_b g + T$

The 0.015 kg object is also in equilibrium, so $T - m_{obj} g = 0$

$T = m_{obj} g$

$F_B = m_b g + m_{obj} g$

$F_B = (0.005\ \text{kg} + 0.0150\ \text{kg})(9.8\ \text{m/s}^2)$

For a correct answer with units — 1 point

$F_B = 0.196\ \text{N}$ (or 0.20 N using $g = 10\ \text{m/s}^2$)

Question 4 (continued)

Distribution of points

(c) 2 points

The buoyant force equals the weight of the air displaced by the balloon, so the volume of the balloon equals the volume of that amount of air.

$F_B = m_{air}g$

$m_{air} = \rho_{air}V_b$

For a correct expression relating the buoyant force to the volume of the balloon — 1 point

$F_B = \rho_{air}V_b g$

$V_b = \dfrac{F_B}{\rho_{air}g}$

For correct substitutions of ρ_{air} and the value of F_B from part (b) — 1 point

$$V_b = \frac{0.196\ \text{N}}{\left(1.29\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)} = 0.0155\ \text{m}^3$$

(d) 2 points

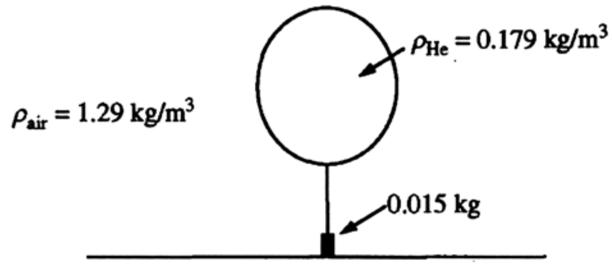
For selecting "It swings toward the back of the car." — 1 point

For an appropriate explanation — 1 point

Examples:

The inertia of the hanging 0.015 kg object leaves it behind as the car accelerates out from under it.

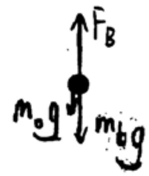
As the car and the child holding the string accelerate forward, the hanging object must also accelerate forward. Thus the force exerted on the object by the string must have an unbalanced component in the forward direction. This can occur only if the object swings backward so that the string slants forward.



4. (10 points)

A helium-filled balloon is attached by a string of negligible mass to a small 0.015 kg object that is just heavy enough to keep the balloon from rising. The total mass of the balloon, including the helium, is 0.0050 kg. The density of air is $\rho_{air} = 1.29$ kg/m^3, and the density of helium is $\rho_{He} = 0.179$ kg/m^3. The buoyant force on the 0.015 kg object is small enough to be negligible.

(a) On the dot below that represents the balloon, draw and label the forces (not components) that act on the balloon.



(b) Calculate the buoyant force on the balloon. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

~~$V_{ballon} = V_{He} = \frac{m_{He}}{\rho_{He}}$~~

$F_B = F_{object} + F_{ballon} = M_o g + M_b g$ ~~= 0.015kg × 9.8 m/s² + 0.005...~~

$= 0.015\text{kg} \times 9.8\text{m/s}^2 + 0.0050\text{kg} \times 9.8\text{m/s}^2$

$= 0.196\text{N}$

(c) Calculate the volume of the balloon.

$V_b = V_{air} = \frac{F_B}{\rho_{air} g} = \frac{0.196\text{N}}{1.29\text{kg/m}^3 \times 9.8\text{m/s}^2} =$ ~~0.15~~ 0.0155 m^3

V

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(d) A child holds the string midway between the balloon and the 0.015 kg object. The child gets into a car, brings the balloon and the 0.015 kg object into the car, and holds the string so that neither the balloon nor the 0.015 kg object touches any surface. The car then begins to move forward, accelerating in a straight line. What behavior does the 0.015 kg object exhibit when the car accelerates?

___ It swings toward the front of the car.

✓ It swings toward the back of the car.

___ It swings toward the right side of the car.

___ It swings toward the left side of the car.

___ It remains vertical below the child's hand.

Explain your reasoning.

As the car move ~~to the front~~, the child move ~~with~~ to the same direction with the ~~can~~ car, so the force ~~the child~~ act on the child is toward the front of the car. So the child give ~~a~~ ~~a fo~~ string a force ~~to w~~ towards front of the car. ~~as~~ As the Newton's third Law, the ballon has a force toward the ~~oppose~~ ~~diff~~ opposite direction ~~of~~. So the ballon swings toward the back of the car.

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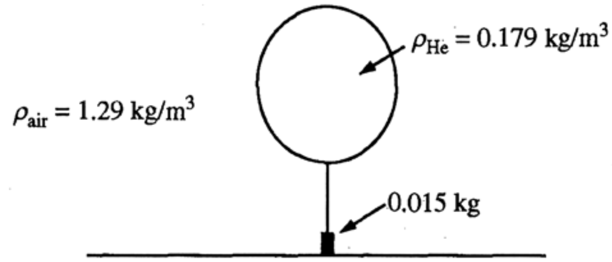

4. (10 points)

A helium-filled balloon is attached by a string of negligible mass to a small 0.015 kg object that is just heavy enough to keep the balloon from rising. The total mass of the balloon, including the helium, is 0.0050 kg. The density of air is $\rho_{air} = 1.29\ kg/m^3$, and the density of helium is $\rho_{He} = 0.179\ kg/m^3$. The buoyant force on the 0.015 kg object is small enough to be negligible.

(a) On the dot below that represents the balloon, draw and label the forces (not components) that act on the balloon.

(b) Calculate the buoyant force on the balloon. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

$F_T = F_g = (9.81)(0.015)$
$= 0.14715 \approx 0.147 N$

(c) Calculate the volume of the balloon.

$F_B = V \rho_{air} g$

$0.14715 = (V)(0.179)(9.81)$

$V = 0.083799 \approx 0.0838\ m^3$

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(d) A child holds the string midway between the balloon and the 0.015 kg object. The child gets into a car, brings the balloon and the 0.015 kg object into the car, and holds the string so that neither the balloon nor the 0.015 kg object touches any surface. The car then begins to move forward, accelerating in a straight line. What behavior does the 0.015 kg object exhibit when the car accelerates?

___ It swings toward the front of the car.

_X_ It swings toward the back of the car.

___ It swings toward the right side of the car.

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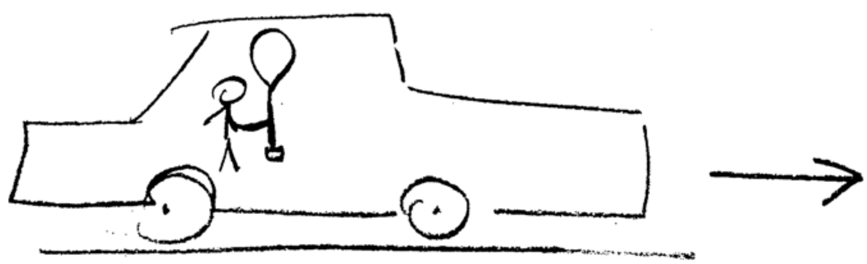
___ It remains vertical below the child's hand.

Explain your reasoning.



The mass swings to the back of the car because of the law of inertia. Before the car started to move, the object was not moving, but as the car starts to move, the object wants to keep its non-moving state, thus it is swinging to the back of the car.

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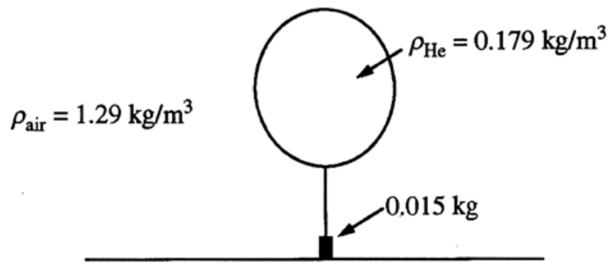

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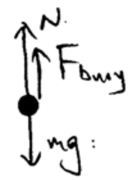

$\rho = \frac{m}{V}$

$V = \frac{m}{D}$

(b) Calculate the buoyant force on the balloon. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

~~$F_{buoy} = \rho V g = 1.29 \times \frac{0.005}{0.179} \times 9.8$~~ ~~$mg - F_N$~~

~~$= 1.06\ N$~~ ~~$= 0.015 \times 9.8 =$~~

$F_{buoy} = mg = 0.015 \times 9.8 = 0.147\ N.$

(c) Calculate the volume of the balloon.

$\rho = \frac{m}{V} \Rightarrow \frac{0.015}{V} = 0.179.$

$V = 0.0838\ m^3.$

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(d) A child holds the string midway between the balloon and the 0.015 kg object. The child gets into a car, brings the balloon and the 0.015 kg object into the car, and holds the string so that neither the balloon nor the 0.015 kg object touches any surface. The car then begins to move forward, accelerating in a straight line. What behavior does the 0.015 kg object exhibit when the car accelerates?

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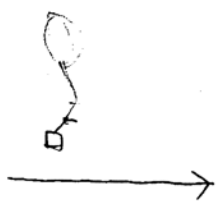
____ It remains vertical below the child's hand.

Explain your reasoning.



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Question 4

Sample: B4A
Score: 9

The work shown on this response is orderly and easy to follow. It received full credit except for part (d), where the explanation is incorrect.

Sample: B4B
Score: 6

Part (a) earned 2 points for drawing two of the three forces. Part (b) earned 1 point for showing the ball was in equilibrium (this is indicated by the new diagram and setting the forces equal). Part (c) uses the correct formula but the wrong density and so earned 1 point. Part (d) received full credit.

Sample: B4C
Score: 2

In part (a) two of the three forces are identified but an additional incorrect force is included, so only 1 point was earned. The expression given in part (b) does not match the free-body diagram and does not show recognition of equilibrium, so no points were earned. Part (c) earned no credit. Part (d) earned 1 point for the correct selection, but there is no justification.