AP® PHYSICS B
2009 SCORING GUIDELINES

General Notes About 2009 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. 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 receive 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 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 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.

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Question 5

10 points total **Distribution of points**

(a) 3 points

For checking "No" 1 point
For a complete and correct justification, with no incorrect statements 2 points
For example: the tension in each string depends on the weight and the buoyant force. The buoyant force depends on the volume of the object. Objects of identical mass have the same weight but need not have identical volumes.
One point could be earned for a partial justification, or one that contained an incorrect statement.

(b) 3 points

For any correct expression of the equilibrium of the three forces on object A 1 point
$T = mg - B$, where B is the buoyant force
For correctly using the density and volume of object A to calculate its weight and labeling as such 1 point

$$mg = \rho Vg = \left(1300\ \text{kg/m}^3\right)\left(1.0 \times 10^{-5}\ \text{m}^3\right)\left(9.8\ \text{m/s}^2\right) = 0.13\ \text{N}$$

$$B = mg - T = 0.13\ \text{N} - 0.0098\ \text{N}$$

For an answer consistent with preceding work 1 point
$B = 0.12$ N

(c) 2 points

The buoyant force equals the weight of the displaced liquid, which depends on its density.

$$B = \rho_\ell Vg$$

$$\rho_\ell = B/Vg$$

For substituting the buoyant force from part (b) and the correct values for volume and g into a correct expression 1 point

$$\rho_\ell = (0.12\ \text{N})/\left(1.0 \times 10^{-5}\ \text{m}^3\right)\left(9.8\ \text{m/s}^2\right)$$

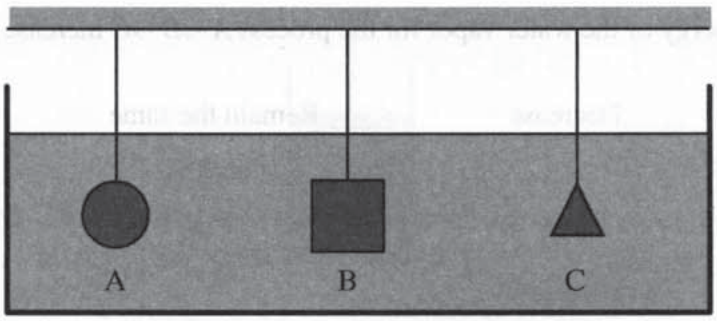
For an answer consistent with the above substitutions, including correct units 1 point

$$\rho_\ell = 1200\ \text{kg/m}^3$$

An alternate solution using the ratio of forces $F_B/F_g = \rho_\ell Vg/\rho_A Vg = \rho_\ell/\rho_A$ earned similar substitution and answer points.

(d) 2 points

For indicating that the tension increases 1 point
For a correct justification 1 point
For example: less of the object submerged means less liquid displaced, which means less buoyant force. By the equation in part (b), the tension is greater.



5. (10 points)

Three objects of identical mass attached to strings are suspended in a large tank of liquid, as shown above.

(a) Must all three strings have the same tension?

____ Yes ✓ No

Justify your answer.

Because even though all 3 objects have the same mass, they may not have the same V, which would affect their buoyant forces. Then, if you do ΣF_y with different values for F_B, the tensions in the 3 strings will have different values (since the force of gravity for all 3 objects is the same).

Object A has a volume of 1.0×10^{-5} m^3 and a density of 1300 kg/m^3. The tension in the string to which object A is attached is 0.0098 N.

(b) Calculate the buoyant force on object A.

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

$\frac{1300\ kg}{m^3} = \frac{m}{1 \times 10^{-5} m^3}$

$m = .013\ kg$

$.013\ kg\ (9.8\ m/s^2) = .13\ N$

$\Sigma F_y = 0N$

$F_g - T - F_B = 0N$

$.13N - .0098\ N - F_B = 0N$

$F_B = .12N$

(c) Calculate the density of the liquid.

$F_B = \rho V g$

$.12\ N = \rho\ (1.0 \times 10^{-5}\ m^3)(9.8\ m/s^2)$

$\rho = 1224.5\ \frac{kg}{m^3}$

(d) Some of the liquid is now drained from the tank until only half of the volume of object A is submerged. Would the tension in the string to which object A is attached increase, decrease, or remain the same?

✓ Increase ____ Decrease ____ Remain the same

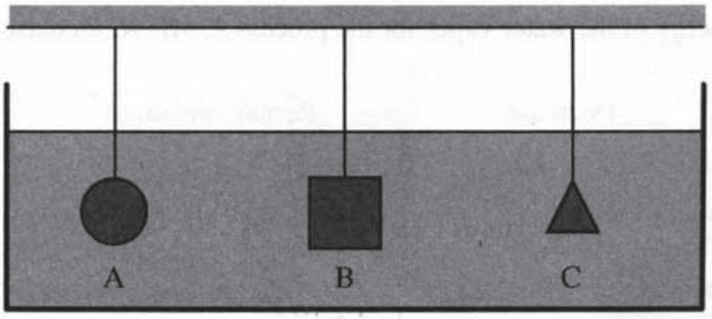
Justify your answer.

$\downarrow F_B = \rho \downarrow V g$

$\Sigma F_y = 0N = F_g - T - F_B$

$\uparrow T = F_g - \downarrow F_B$

Because if volume of object A decreases, then the buoyant force will decrease. If the buoyant force decreases, less must be subtracted from F_g to get T, so T will increase.



5. (10 points)

Three objects of identical mass attached to strings are suspended in a large tank of liquid, as shown above.

(a) Must all three strings have the same tension?

___ Yes ✓ No

Justify your answer.

If the masses are different, the objects will feel equal buoyant forces and can result in different string tensions.

Object A has a volume of 1.0×10^{-5} m^3 and a density of 1300 kg/m^3. The tension in the string to which object A is attached is 0.0098 N.

(b) Calculate the buoyant force on object A.

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

$1300 = \frac{m}{1 \times 10^{-5}}$

$m = .013$

$F = mg$

$F = .013(9.8)$

$F = .1274$ N

$F_{Buoy} = .1274 - .0098$

$F_{Buoy} = .1176$ N

(c) Calculate the density of the liquid.

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

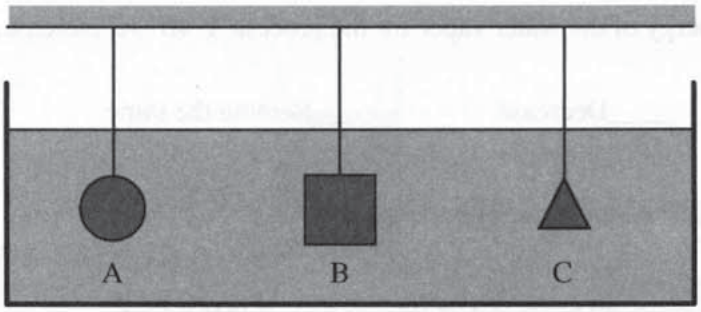
$D = \frac{.1176(9.8)}{1E-5} = 1.15 \times 10^5$ kg/m3

(d) Some of the liquid is now drained from the tank until only half of the volume of object A is submerged. Would the tension in the string to which object A is attached increase, decrease, or remain the same?

✓ Increase ___ Decrease ___ Remain the same

Justify your answer.

This loss in volume is lowering the buoyancy force, therefore, increasing the tension in the string.



5. (10 points)

Three objects of identical mass attached to strings are suspended in a large tank of liquid, as shown above.

(a) Must all three strings have the same tension?

✓ Yes ____ No

Justify your answer.

Each mass is the same, so they experience the same force due to grauty, thus the same tension. Because they are also submerged in the same liquid, it must have the same density, so each mass exerts identical amounts of tension.

Object A has a volume of 1.0×10^{-5} m^3 and a density of 1300 kg/m^3. The tension in the string to which object A is attached is 0.0098 N.

(b) Calculate the buoyant force on object A.

$F_{buoy} = .0098\ N$

(c) Calculate the density of the liquid.

$\frac{F_{buoy}}{Vg} = \frac{\rho Vg}{Vg}$ $\quad \rho = \frac{F_b}{Vg} = \frac{.0098\ N}{1.0 \times 10^{-5}\ m^3 \cdot 9.80\ m/s^2}$

$= 100\ \frac{kg}{m^3}$

(d) Some of the liquid is now drained from the tank until only half of the volume of object A is submerged. Would the tension in the string to which object A is attached increase, decrease, or remain the same?

✓ Increase ____ Decrease ____ Remain the same

Justify your answer.

There is less bouyant force on object A, so the tension will increase by the amount of bouyant force lost

AP® PHYSICS B
2009 SCORING COMMENTARY

Question 5

Overview

This question assessed students' understanding of the concepts of buoyancy and static equilibrium. In part (a) an understanding of Archimedes' principle was needed to explain differences in the buoyant force, and a free-body analysis was required to compare the tensions in the strings for three objects of equal mass hanging in a fluid. In part (b) the buoyant force was to be calculated using the tension and weight of the object. In part (c) this buoyant force was to be used to determine the density of the fluid. Finally, in part (d) students needed to explain changes in tension that would occur if the object was only half submerged.

Sample: B-5A
Score: 10

This response contains clear and complete explanations and calculations and earned the maximum of 10 points. In part (d) it is clear from the context that "volume of object *A* decreases" is a reference to the submerged volume mentioned in the question, so no points were deducted.

Sample: B-5B
Score: 6

Part (a) earned 1 point for the correct choice. Part (b) earned all 3 points. In part (c) the student has *g* in the numerator instead of the denominator, and the units on the answer do not follow from this substitution, so no points were earned. Part (d) has a good justification and earned both points.

Sample: B-5C
Score: 4

Parts (a) and (b) earned no points. Part (c) has a correct calculation using the incorrect answer to part (b), and part (d) has a good justification. Both these parts earned 2 points.