AP® PHYSICS
2011 SCORING GUIDELINES

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 $10\ \text{m/s}^2$ 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) 2 points

For any statement indicating that the total weight is the sum of three terms, that of the beaker, ball, and water — 1 point

$W_{tot} = W_{beaker} + W_{ball} + W_{water}$

For calculating W_{water} — 1 point

$\rho = m/V$, so $m = \rho V$

$W_{water} = m_{water}g = \rho_{water}V_{water}g$

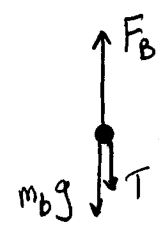
$W_{water} = \left(1000\ \text{kg/m}^3\right)\left(5.0\times10^{-3}\ \text{m}^3\right)\left(9.8\ \text{m/s}^2\right) = 49\ \text{N}$

$W_{water} = 49\ \text{N}$

$W_{tot} = 2.0\ \text{N} + 3.0\ \text{N} + 49\ \text{N}$

$W_{tot} = 54\ \text{N}$ (or 55 N using $g = 10\ \text{m/s}^2$)

(b) 3 points



One point for each of the three correctly drawn and appropriately labeled forces — 3 points
One point deducted for any extraneous forces or forces not drawn near the object

(c) 1 point

$\Sigma F_y = ma_y$

The ball is in equilibrium, so $a_y = 0$.

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

$F_B = T + m_b g$

$F_B = 4.0\ \text{N} + 3.0\ \text{N}$

For the correct answer — 1 point

$F_B = 7.0\ \text{N}$

Question 4 (continued)

Distribution of points

(d) 2 points

$P = \rho g h$

For correct substitutions — 1 point

$P = \left(1000 \ \text{kg}/\text{m}^3\right)\left(9.8 \ \text{m}/\text{s}^2\right)(0.20 \text{ m})$

For the correct answer with units — 1 point

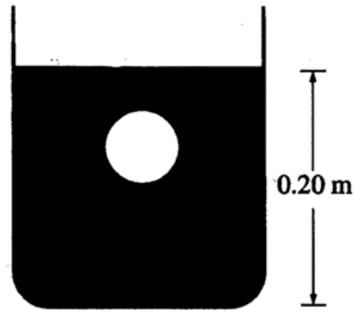
$P = 1960 \text{ Pa}$ (or 2000 Pa using $g = 10 \ \text{m}/\text{s}^2$)

(e) 2 points

For selecting "Lower" — 1 point

For an appropriate justification — 1 point

Example: Less fluid is displaced by the rubber ball because less of the ball's volume is submerged in the water.



Note: Figure not drawn to scale.

4. (10 points)

A beaker weighing 2.0 N is filled with $5.0 \times 10^{-3}\ m^3$ of water. A rubber ball weighing 3.0 N is held entirely underwater by a massless string attached to the bottom of the beaker, as represented in the figure above. The tension in the string is 4.0 N. The water fills the beaker to a depth of 0.20 m. Water has a density of $1000\ kg/m^3$. The effects of atmospheric pressure may be neglected.

(a) Calculate the weight of the entire apparatus.

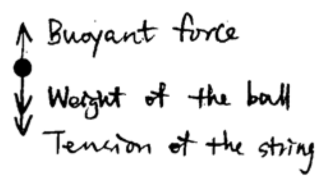
$W = W_b + W_{rb} + W_w$

$= 2N + 3N + \rho V g$

$= 2N + 3N + 1000\ kg/m^3 \times 5\times10^{-3} m^3 \times 9.8 m/s^2$

$= 54N$

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



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

$F_B = W_{rb} + T_s$

$= 3N + 4N$

$= 7N$

GO ON TO THE NEXT PAGE.

(d) Calculate the pressure due to the liquid (the gauge pressure) at the bottom of the beaker.

$$P = \rho g h$$

$$= 1000\,kg/m^3 \times 9.8\,m/s^2 \times 0.2\,m$$

$$= 1960\,Pa$$

(e) The string is cut, and the ball rises to the surface and floats. Indicate whether the water level is higher, lower, or the same after equilibrium is reached.

____ Higher   __✓__ Lower   ____ The same

Justify your answer.

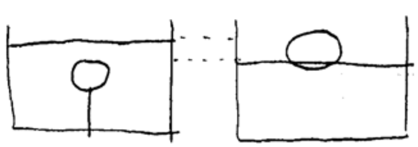
$$W_{rb} = \rho_w g V_{rbs}$$

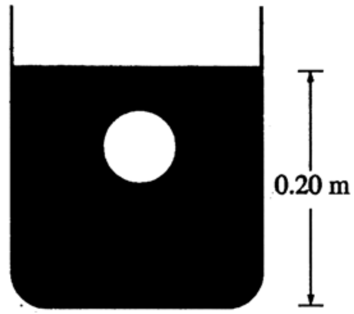
$$V_{rbs} = \frac{W_{rb}}{\rho_w g}$$

$$= \frac{3\,N}{1000\,kg/m^3 \times 9.8\,m/s^2}$$

$$= 3.061 \times 10^{-4}\,m^3$$

After the ball rises to the surface and floats, the volume of the ball under the water decreases. So the water level is lower than before.





Note: Figure not drawn to scale.

4. (10 points)

A beaker weighing 2.0 N is filled with $5.0 \times 10^{-3}\ \text{m}^3$ of water. A rubber ball weighing 3.0 N is held entirely underwater by a massless string attached to the bottom of the beaker, as represented in the figure above. The tension in the string is 4.0 N. The water fills the beaker to a depth of 0.20 m. Water has a density of $1000\ \text{kg/m}^3$. The effects of atmospheric pressure may be neglected.

(a) Calculate the weight of the entire apparatus.

$\rho = \frac{m_{water}}{V}$

$1000 = \frac{m}{5.0 \times 10^{-3}}$ $m_{water} = 5\ \text{kg} = 49\ \text{N}$

$49 + 2 + 1 = 52\ \text{N}$

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

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

$F_b = \rho V g$

$= (1000)(5.0 \times 10^{-3})(9.8)$

$= 49\ \text{N}$

GO ON TO THE NEXT PAGE.

(d) Calculate the pressure due to the liquid (the gauge pressure) at the bottom of the beaker.

$P = P_0 + \rho g h$

$= 0 + (1000)(9.8)(.2)$

$= 1960\ N/m^2$

(e) The string is cut, and the ball rises to the surface and floats. Indicate whether the water level is higher, lower, or the same after equilibrium is reached.

____ Higher _✓_ Lower ____ The same

Justify your answer.

when the ball is fully submerged, it's entire volume accounts for the amount of water displaced. when it floats, part of the ball isn't underwater anymore. Thus, less space is taken up in the water which would lower the height due to the fact that less space is occupied.

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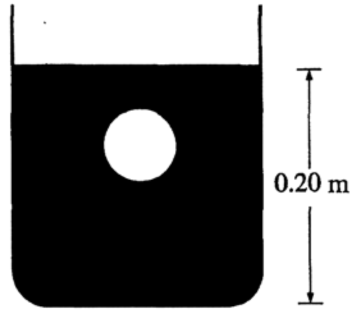

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4. (10 points)

A beaker weighing 2.0 N is filled with $5.0 \times 10^{-3}\ \text{m}^3$ of water. A rubber ball weighing 3.0 N is held entirely underwater by a massless string attached to the bottom of the beaker, as represented in the figure above. The tension in the string is 4.0 N. The water fills the beaker to a depth of 0.20 m. Water has a density of $1000\ \text{kg/m}^3$. The effects of atmospheric pressure may be neglected.

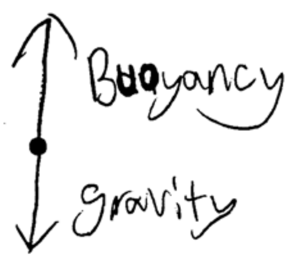
(a) Calculate the weight of the entire apparatus.

beaker = 2 N
ball = 3 N

200000 kg
1960005 N

$V = 5 \times 10^{-3}$
$d = 1000$
$\frac{1000}{5 \times 10^{-3}} = \frac{x}{5 \times 10^{-3}}$

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



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

$1000(5 \times 10^{-3})9.8$

49 N

(d) Calculate the pressure due to the liquid (the gauge pressure) at the bottom of the beaker.

1000(.2)(9.8)

1960

(e) The string is cut, and the ball rises to the surface and floats. Indicate whether the water level is higher, lower, or the same after equilibrium is reached.

____ Higher X Lower ____ The same

Justify your answer.

If some of the ball floats outside the water, the water will need to fill in the new space, making the water level go down a little.

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Question 4

Overview

This question assessed students' understanding of density, buoyancy and pressure under static conditions.

Sample: B4A
Score: 10

The work shown on this problem is clean, orderly and easy to follow. Note that the explanation in part (e) would be complete even without the calculation shown.

Sample: B4B
Score: 7

Part (a) earned one point for calculating the weight of the water. The summation shown has an incorrect term (which may be from subtracting the weight of the ball from the tension). Part (b) earned only 2 points because weight vector is missing. Part (c) calculates the weight of the water instead of the buoyant force and earned no points. Parts (d) and (e) earned full points.

Sample: B4C
Score: 4

Part (a) earned no points because the student does not correctly calculate the weight of the water and does not show a clear summing of forces. In part (b) the word "gravity" or "*g*" was taken by the graders to mean an acceleration, not a force. Use of F_g, mg, or "weight of ball" were all acceptable. The student also omits the tension of the string; therefore part (b) earned only 1 point. Part (c) calculated the weight of the water instead of the buoyant force and earned no credit. Part (d) earned 1 point for the correct substitutions but there are no units. Part (e) earned full credit.