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 $10\ \text{m/s}^2$ 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 3

15 points total **Distribution of points**

(a) 3 points

For a meaningful use of the correct expression for flow rate, $A\upsilon$ (e.g., an attempt to substitute for volume and speed) — 1 point

For relating the flow rates at points A and B — 1 point

$A_A\upsilon_A = A_B\upsilon_B$

$\upsilon_A = A_B\upsilon_B / A_A = \left(0.50 \times 10^{-4}\ \text{m}^2\right)(8.2\ \text{m/s}) \Big/ \left(1.0 \times 10^{-4}\ \text{m}^2\right)$

For the correct answer — 1 point

$\upsilon_A = 4.1\ \text{m/s}$

(b) 5 points

For applying Bernoulli's equation to this situation — 1 point

$P_A + \rho g y_A + \frac{1}{2}\rho\upsilon_A^2 = P_B + \rho g y_B + \frac{1}{2}\rho\upsilon_B^2$

$P_A = P_B + \rho g(y_B - y_A) + \frac{1}{2}\rho\left(\upsilon_B^2 - \upsilon_A^2\right)$

For using atmospheric pressure $\left(1.0 \times 10^5\ \text{Pa}\right)$ for the pressure at point B — 1 point

For correctly substituting values for y_A and y_B — 1 point

For correctly substituting values for υ_A and υ_B consistent with the work in part (a) — 1 point

$P_A = \left(1.0 \times 10^5\ \text{Pa}\right) + \left(1000\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)(0.50\ \text{m} - 0)$

$\qquad + \frac{1}{2}\left(1000\ \text{kg/m}^3\right)\left([8.2\ \text{m/s}]^2 - [4.1\ \text{m/s}]^2\right)$

For correct units for the answer — 1 point

$P_A = 1.3 \times 10^5\ \text{N/m}^2$ (or Pa)

(c) 2 points

For correctly relating the initial speed and the maximum height — 1 point

$\upsilon^2 = \upsilon_0{}^2 + 2a(x - x_0)$ OR $\frac{1}{2}m\upsilon^2 = mgh$

$\upsilon_B^2 = 2gh$

$h = \upsilon_B^2 / 2g = (8.2\ \text{m/s})^2 \Big/ 2\left(9.8\ \text{m/s}^2\right)$

For the correct answer with correct units — 1 point

$h = 3.4\ \text{m}$

Question 3 (continued)

Distribution of points

(d) 5 points

For correctly analyzing the vertical motion with constant acceleration, to find the time for the water to reach maximum height — 1 point

$v = v_0 + at$

$0 = v_{By} + gt$

$v_{By} = gt$

For the correct vertical component of speed — 1 point

$v_{By} = v_B \sin\theta$

$t = v_{By}/g = v_B \sin\theta/g$

For correctly analyzing the horizontal motion with constant speed — 1 point

$x = v_{Bx}(2t)$

For the correct horizontal component of speed — 1 point

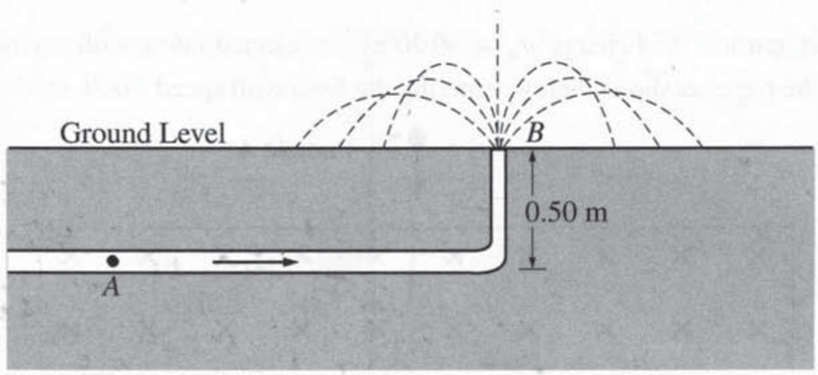
$v_{Bx} = v_B \cos\theta$

$x = v_B \cos\theta(2v_B \sin\theta/g) = 2v_B^2 \cos\theta \sin\theta/g$

$x = 2(8.2\ \text{m/s})^2 \cos 60° \sin 60° / (9.8\ \text{m/s}^2)$

For the correct answer with units — 1 point

$x = 5.9\ \text{m}$ (or 5.8 m using $g = 10\ \text{m/s}^2$)



3. (15 points)

An underground pipe carries water of density $1000\ \text{kg/m}^3$ to a fountain at ground level, as shown above. At point *A*, 0.50 m below ground level, the pipe has a cross-sectional area of $1.0 \times 10^{-4}\ \text{m}^2$. At ground level, the pipe has a cross-sectional area of $0.50 \times 10^{-4}\ \text{m}^2$. The water leaves the pipe at point *B* at a speed of 8.2 m/s.

(a) Calculate the speed of the water in the pipe at point *A*.

flow rate is constant. $f = A_A V_A = A_B V_B$

$1.0\times10^{-4}\,m^2 \cdot V_A = 0.5\times10^{-4}\,m^2 \cdot 8.2\,m/s$

$V_A = 4.1\,m/s$

(b) Calculate the absolute water pressure in the pipe at point *A*.

$P_A + \rho g y_A + \frac{1}{2}\rho V_A^2 = P_B + \rho g y_B + \frac{1}{2}\rho V_B^2$

$P_A = P_B + \rho g y_B + \frac{1}{2}\rho V_B^2 - \rho g y_A - \frac{1}{2}\rho V_A^2$

$P_A = \rho g(y_B - y_A) + \frac{1}{2}\rho(V_B^2 - V_A^2) + P_B$

$P_A = 1000\,kg/m^3 \cdot 10\,m/s^2 \cdot 0.5\,m + \frac{1}{2} \cdot 1000\,kg/m^3 \cdot (8.2^2 - 4.1^2)\,m^2/s^2 + 1.0\times10^5\,Pa$

$= 5000\,kg/ms^2 + 125215\,kg/ms^2 = 130215\,Pa$

$= 130.215\,kPa$

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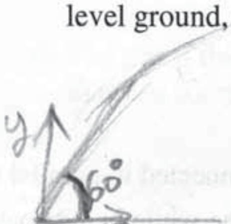
(c) Calculate the maximum height above the ground that the water reaches upon leaving the pipe vertically at ground level, assuming air resistance is negligible.

$2as = V^2 - V_0^2$

$2as = -V_0^2$

$s = \frac{-V_0^2}{2a} = \frac{-8.2^2 \, m^2/s^2}{2 \cdot -10 m/s^2} = 3.362m$

(d) Calculate the horizontal distance from the pipe that is reached by water exiting the pipe at 60° from the level ground, assuming air resistance is negligible.



y component is $V\sin 60° = 7.10 m/s$

x component is $V\cos 60° = 4.1 m/s$

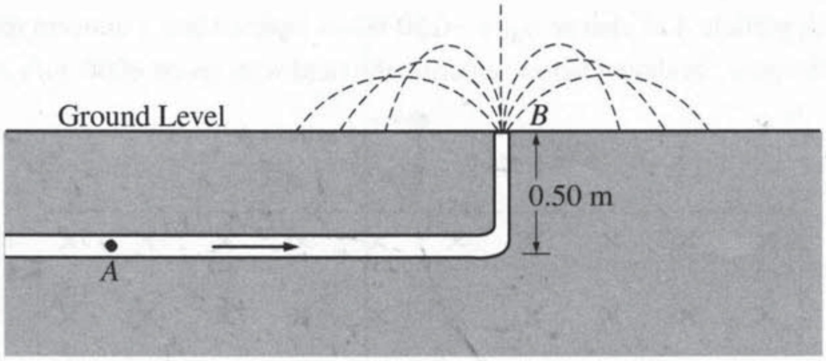
$7.1 m/s - 10 m/s^2 \, t = 0$

$t = \frac{7.10 m/s}{10 m/s^2} = 0.710$ second

$2t = 1.42$ seconds

the distance the x componet covers in 1.42 seconds is

$4.1 m/s \cdot 1.42$ seconds $= 5.82 m$



3. (15 points)

An underground pipe carries water of density $1000\ \text{kg/m}^3$ to a fountain at ground level, as shown above. At point A, 0.50 m below ground level, the pipe has a cross-sectional area of $1.0 \times 10^{-4}\ \text{m}^2$. At ground level, the pipe has a cross-sectional area of $0.50 \times 10^{-4}\ \text{m}^2$. The water leaves the pipe at point B at a speed of 8.2 m/s.

(a) Calculate the speed of the water in the pipe at point A.

$$A_A \cdot V_A = A_B \cdot V_B.$$
$$1\times10^{-4}\text{m}^2 \times V_A = 0.5\times10^{-4}\text{m}^2 \times 8.2\text{m/s}.$$
$$V_A = 4.1\ \text{m/s}.$$

(b) Calculate the absolute water pressure in the pipe at point A.

$$P = P_{atm} + P$$
$$= 10^5\,\text{Pa} + \rho g h$$
$$= 10^5\,\text{Pa} + (1000\times10\times0.5)\,\text{Pa}$$
$$= 1.05\times10^5\,\text{Pa}.$$

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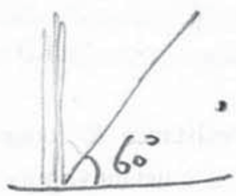
(c) Calculate the maximum height above the ground that the water reaches upon leaving the pipe vertically at ground level, assuming air resistance is negligible.

$2gh = V_f^2 - V_i^2$

$2 \times (-10 m/s^2) h = 0 - (8.2 m/s)^2$

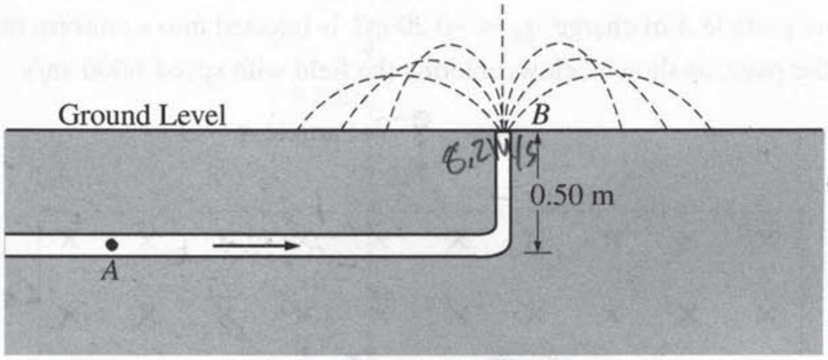
$h = 3.36 m$

(d) Calculate the horizontal distance from the pipe that is reached by water exiting the pipe at 60° from the level ground, assuming air resistance is negligible.



$t = \frac{V_y}{g} = \frac{8.2 m/s \times \sin 60}{10 m/s^2} = 0.71 s$

$d_x = V_x t = 8.2 m/s \times \cos 60 \times 0.71 s = 2.911 m$



3. (15 points)

$\rho = 1000\ kg/m^3$

An underground pipe carries water of density $1000\ \text{kg/m}^3$ to a fountain at ground level, as shown above. At point *A*, 0.50 m below ground level, the pipe has a cross-sectional area of $1.0 \times 10^{-4}\ \text{m}^2$. At ground level, the pipe has a cross-sectional area of $0.50 \times 10^{-4}\ \text{m}^2$. The water leaves the pipe at point *B* at a speed of 8.2 m/s.

(a) Calculate the speed of the water in the pipe at point *A*.

$A_1 v_1 = A_2 v_2$

$\pi(1 \times 10^{-4})^2 (v) = \pi(0.5 \times 10^{-4})^2 (8.2)$

$v = \frac{(0.5 \times 10^{-4})^2 (8.2)}{(1 \times 10^{-4})^2}$

$= 2.05\ m/s$ m/s

(b) Calculate the absolute water pressure in the pipe at point *A*.

$P = P_0 + \rho g h$

$P = 1 \times 10^5 + 1000(9.8)(0.5)$

$= 1.049 \times 10^5\ pa$

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(c) Calculate the maximum height above the ground that the water reaches upon leaving the pipe vertically at ground level, assuming air resistance is negligible.

$V = 8.2$ m/s

$2ad = V_f^2 - V_i^2$

$2(-9.8)(D) = (0)^2 - (8.2)^2$

$2(-9.8)(D) = -(8.2)^2$

$D = \frac{-(8.2)^2}{(-9.8)(2)}$

$= 3.431$

$= 3.4$ meter

(d) Calculate the horizontal distance from the pipe that is reached by water exiting the pipe at 60° from the level ground, assuming air resistance is negligible.

$\sin(60) = \frac{O}{H}$

$\sin(60°) = \frac{8.2 \text{ m/s}}{H}$

$H = \frac{8.2 \text{ m/s}}{\sin(60°)}$

$= 9.4685$ m/s

$t = \frac{8.2 \text{ m/s}}{9.8 \text{ m/s}^2} = 0.83673$ sec

$\cos(60°) = \frac{X}{9.4685 \text{ m/s}}$

$X = 4.73427$ m/s

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

$4.73427 \text{ m/s} = \frac{D}{0.83673}$

$D = 3.96$ meter

about 4 meter

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Question 3

Sample: B-3A
Score: 15

This response earned the maximum points available. It is very well organized and closely follows the scoring guideline.

Sample: B-3B
Score: 8

Part (a) earned all 3 points, but part (b) earned no points because the student uses the wrong approach. Part (c) earned 2 points. Part (d) earned only 3 points. The equation for the horizontal distance does not use double the time to maximum height, and the answer is incorrect.

Sample: B-3C
Score: 4

In part (a) the response uses the given areas as if they are radii and lost the point for the answer. Part (b) received no points because the wrong approach is used. Part (c) is correct and received both points. In part (d) most of the equations used are incorrect. For example, the response starts out with $\sin 60° = O/H$ (i.e., opposite over hypotenuse) and then substitutes the given speed for the wrong side of the triangle. Despite all the work presented, the response thus earned no points for part (d).