AP® PHYSICS B
2007 SCORING GUIDELINES

General Notes About 2007 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 and 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.

Question 4

10 points total | **Distribution of points**

(a) 2 points

For any indication that the volume rate of flow is defined as volume/time — 1 point
Define the symbol $\mathcal{V}$ for the volume flow rate

$\mathcal{V} = 7.2 \times 10^{-4}\ \text{m}^3 \big/ [(2.0\ \text{min})(60\ \text{s/min})]$

For the correct answer, including units — 1 point

$\mathcal{V} = 6.0 \times 10^{-6}\ \text{m}^3/\text{s}$

(b) 2 points

For a correct relationship between volume flow rate, speed, and area — 1 point

$\mathcal{V} = \upsilon A$

$\upsilon = \mathcal{V}/A$

$\upsilon = \left(6.0 \times 10^{-6}\ \text{m}^3/\text{s}\right) \big/ \left(2.5 \times 10^{-6}\ \text{m}^2\right)$

For the correct answer, including units — 1 point

$\upsilon = 2.4\ \text{m/s}$

<u>Note</u>: *An attempt to use kinematics with the distance x and height d could earn a maximum of 1 point.*

(c) 3 points

For applying Bernoulli's Equation, either to points at the top of the liquid and the hole or to points just inside and outside of the hole, and recognizing the specific conditions for one of the three variables (pressure, speed, or height) — 1 point

For recognizing the conditions for the remaining two variables — 1 point

<u>Top and hole</u>	<u>Inside and outside</u>
$P_t + \rho g y_t + \frac{1}{2}\rho\upsilon_t^2 = P_h + \rho g y_h + \frac{1}{2}\rho\upsilon_h^2$	$P_{\text{in}} + \rho g y_{\text{in}} + \frac{1}{2}\rho\upsilon_{\text{in}}^2 = P_{\text{out}} + \rho g y_{\text{out}} + \frac{1}{2}\rho\upsilon_{\text{out}}^2$
$P_t = P_h = P_{atm}$	$P_{\text{in}} = P_{atm} + \rho g h$, $P_{\text{out}} = P_{atm}$
$\upsilon_t = 0$	$\upsilon_{\text{in}} = 0$
$y_t = h$, $y_h = 0$	$y_{\text{in}} = y_{\text{out}} = 0$

Both cases simplify to the same equation, where υ_e is the exit speed

$\rho g h = \rho\upsilon_e^2/2$

$h = \upsilon_e^2/2g = (2.4\ \text{m/s})^2 \big/ 2\left(9.8\ \text{m/s}^2\right)$

For the correct answer, including units — 1 point

$h = 0.29\ \text{m}$

<u>Notes:</u> *Solutions that begin with the equation $\rho g h = \rho\upsilon^2/2$ could earn 2 of the 3 points.*

Solutions that begin with the equation $mgh = m\upsilon^2/2$ could earn 1 of the 3 points.

Question 4 (continued)

Distribution of points

(c) (continued)

Alternate solution 1 — *Alternate points*

For explicitly stating by name that Torricelli's theorem applies — *1 point*

For writing the correct expression for the theorem — *1 point*

$\upsilon = \sqrt{2gh}$

$$h = \frac{\upsilon^2}{2g} = \frac{(2.4\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)}$$

For the correct answer, including units — *1 point*

$h = 0.29\ \text{m}$

Alternate solution 2 — *Alternate points*

For relating the pressure difference across the hole to the acceleration of the liquid through the hole — *1 point*

$F = ma = \Delta P\, A$

$\Delta P = \rho g h$

$a = \rho g h A/m = ghA/V$, *where V is the volume of the hole*

For applying an appropriate kinematics equation and substituting the expression for acceleration — *1 point*

$\upsilon^2 = \upsilon_0^2 + 2a\ell$, *where* $\upsilon_0 = 0$ *and* ℓ *is the thickness of the container wall*

$\upsilon^2 = 2(ghA/V)\ell = 2gh$

$$h = \frac{\upsilon^2}{2g} = \frac{(2.4\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)}$$

For the correct answer, including units — *1 point*

$h = 0.29\ \text{m}$

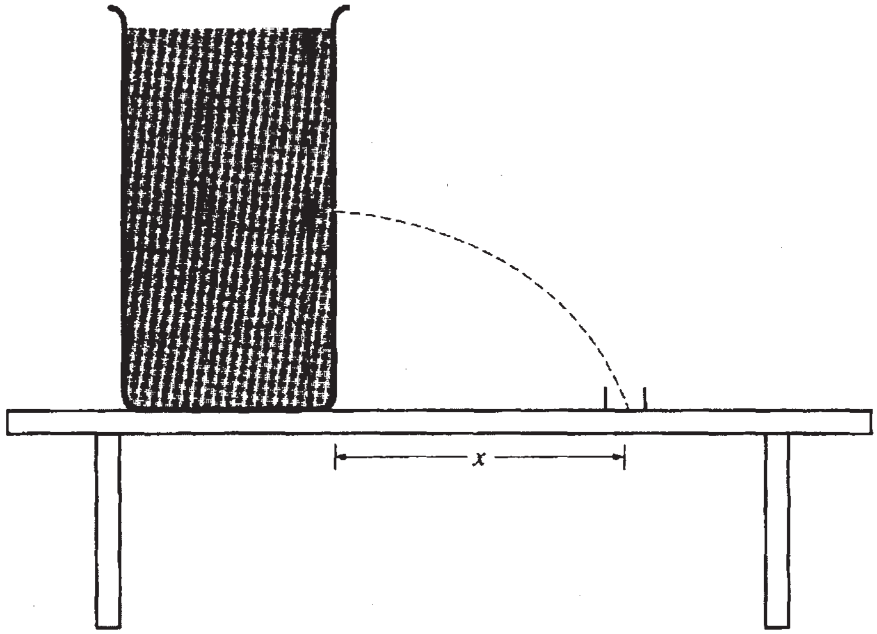
(d) 3 points

For correctly indicating that the liquid will hit to the left of the beaker — 1 point

For an explanation that relates the decrease in water height to a decrease in the pressure at the hole and a decrease in velocity exiting the hole — 2 points

Other explanations, such as relating force and acceleration at the hole, describing changes in potential and kinetic energy, or using a relationship from part (c), could earn full credit.

Note: In the exam booklets, the container was erroneously referred to as the beaker in this part. Answers indicating that the liquid would hit to the right of the beaker received full credit if there was an explanation indicating that the student was now using the container as the reference object.



4. (10 points)

The large container shown in the cross section above is filled with a liquid of density $1.1 \times 10^3\ \text{kg/m}^3$. A small hole of area $2.5 \times 10^{-6}\ \text{m}^2$ is opened in the side of the container a distance h below the liquid surface, which allows a stream of liquid to flow through the hole and into a beaker placed to the right of the container. At the same time, liquid is also added to the container at an appropriate rate so that h remains constant. The amount of liquid collected in the beaker in 2.0 minutes is $7.2 \times 10^{-4}\ \text{m}^3$.

(a) Calculate the volume rate of flow of liquid from the hole in m^3/s.

$f_r = AV = \frac{Vol}{t}$

~~$f_r = (2.5 \times 10^{-6}\ m^2)($~~

$f_r = \frac{7.2 \times 10^{-4} m^3}{(2 min)(60 sec)} = \boxed{6 \times 10^{-6} \frac{m^3}{sec}}$

(b) Calculate the speed of the liquid as it exits from the hole.

$P + \rho g y + \frac{1}{2}\rho v^2 = P + \rho g y + \frac{1}{2}\rho v^2$

$P_o + (1.1 \times 10^3 \frac{kg}{m^3})(9.8\ m/s^2)(h) = P_o + \frac{1}{2}\rho$

$f_r = AV$

$6 \times 10^{-6} \frac{m^3}{sec} = (2.5 \times 10^{-6} m^2)(v)$

$\boxed{v = 2.4\ m/s}$

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(c) Calculate the height h of liquid needed above the hole to cause the speed you determined in part (b).

$P + \rho g y + \frac{1}{2}\rho v^2 = P + \rho g y + \frac{1}{2}\rho v^2$

$P_0 + (\rho)(9.8 m/s^2)(h) = P_0 + \frac{1}{2}\rho(2.4 m/s)^2$

$(\rho)(9.8 m/s^2)(h) = (\frac{1}{2})(\rho)(2.4 m/s)^2$

$h = .293 m$

(d) Suppose that there is now less liquid in the beaker so that the height h is reduced to $h/2$. In relation to the beaker, where will the liquid hit the tabletop?

__✓__ Left of the beaker ____ In the beaker ____ Right of the beaker

Justify your answer.

There is less force on the hole, & the water comes out with less velocity, therefore it does not reach the beaker

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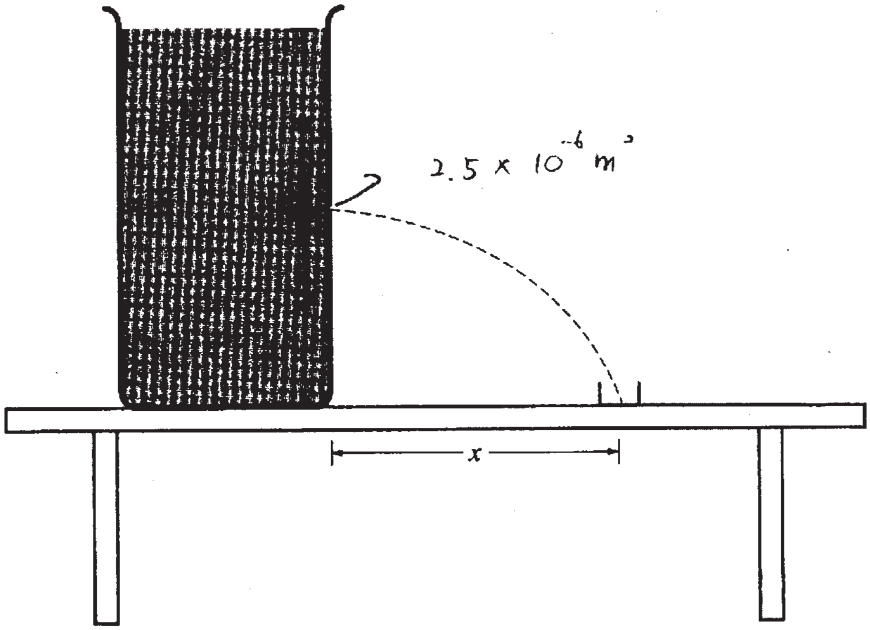

4. (10 points)

The large container shown in the cross section above is filled with a liquid of density 1.1×10^3 kg/m^3. A small hole of area 2.5×10^{-6} m^2 is opened in the side of the container a distance h below the liquid surface, which allows a stream of liquid to flow through the hole and into a beaker placed to the right of the container. At the same time, liquid is also added to the container at an appropriate rate so that h remains constant. The amount of liquid collected in the beaker in 2.0 minutes is 7.2×10^{-4} m^3.

(a) Calculate the volume rate of flow of liquid from the hole in m^3/s.

$P = \frac{F}{A}$. $\rho = 1.1 \times 10^3$ kg/m³

2 min = 120 s

7.2×10^{-4} m³ ÷ 120 s = 0.000006 = 6.0×10^{-6} m³/s

(b) Calculate the speed of the liquid as it exits from the hole.

6.0×10^{-6} m³/s ÷ 2.5×10^{-6} m²

= 2.4 m/s

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(c) Calculate the height h of liquid needed above the hole to cause the speed you determined in part (b).

$P = h \cdot d$

(d) Suppose that there is now less liquid in the beaker so that the height h is reduced to $h/2$. In relation to the beaker, where will the liquid hit the tabletop?

__✓__ Left of the beaker ____ In the beaker ____ Right of the beaker

Justify your answer.

The pressure is less since the highe is reduced. $\downarrow F = m \cdot a \downarrow$ the velocity decrease and the stream won't be able to hit the beaker.

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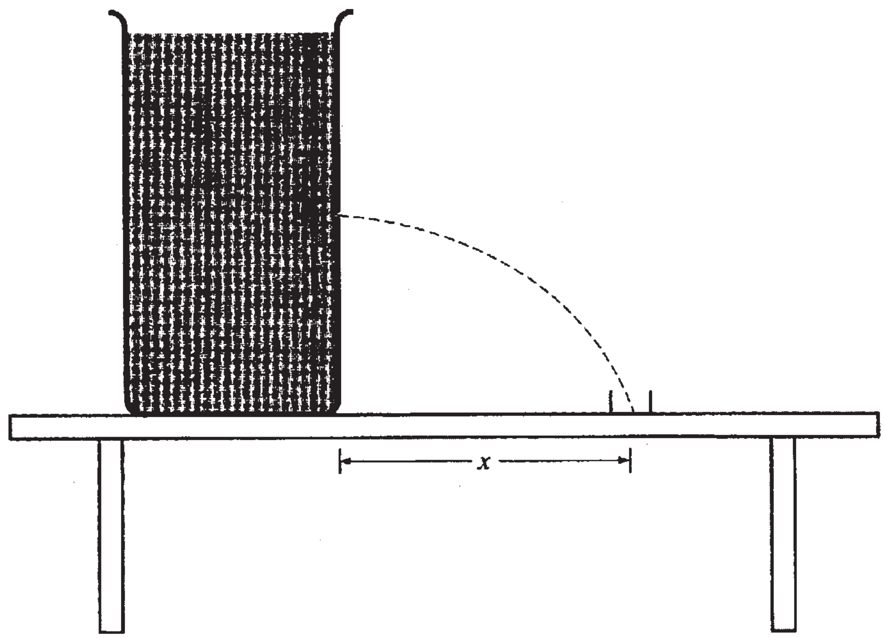

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(a) Calculate the volume rate of flow of liquid from the hole in m^3/s.

$$\frac{7.2 \times 10^{-4}\ m^3}{2\ min} \times \frac{1\ min}{60\ seconds} = 6 \times 10^{-6}\ m^3/s$$

(b) Calculate the speed of the liquid as it exits from the hole.

$F_{NET} = ma$

$K = \frac{1}{2}mv^2$

Energy is conserved

(c) Calculate the height h of liquid needed above the hole to cause the speed you determined in part (b). B4C2

$P = \rho g h$

$P + \rho g h + \frac{1}{2}\rho v^2 =$ const.

(d) Suppose that there is now less liquid in the beaker so that the height h is reduced to $h/2$. In relation to the beaker, where will the liquid hit the tabletop?

__✓__ Left of the beaker ____ In the beaker ____ Right of the beaker

Justify your answer.

Less pressure above the hole will exert less force, less force will push the stream less far.

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Question 4

Overview

This was a 10-point question intended to evaluate students' understanding of fluid motion. Part (a) judged their ability to calculate the volume flow rate of water through a hole, given the total volume collected during a specified time interval. In part (b) students were asked to calculate the flow speed based on the hole's diameter and volume rate, and in part (c) to calculate the height of the water surface, based on the speed obtained in part (b). In part (d) they had to decide how the height of the water surface affects the point along the tabletop at which the water stream lands.

Sample: 4A
Score: 10

The student refers to force instead of pressure in part (d) but has a complete, correct justification and thus earned full credit.

Sample: 4B
Score: 7

This response earned full credit except for part (c), where nothing was earned. Part (d) includes a good explanation relating force, acceleration, and velocity.

Sample: 4C
Score: 4

Part (a) earned full credit. In parts (b) and (c) the student makes some attempts at using relationships for fluids but gets nowhere, so no credit was earned. Part (d) earned only 2 points, since the justification is incomplete.