AP® PHYSICS
2012 SCORING GUIDELINES

General Notes About 2012 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.

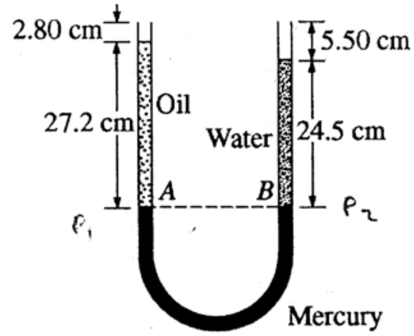
3. Implicit statements of concepts normally receive credit. For example, if the use of an equation expressing a particular concept is worth 1 point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still 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 sheets. 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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 3

10 points total	**Distribution of points**
(a) 3 points	
For a statement or equation that the pressures at interfaces A and B are equal $P_{atm} + \rho_o g h_o = P_{atm} + \rho_w g h_w$	1 point
For a substitution of the correct density and the correct heights $\rho_o = \rho_w h_w / h_o = \left(1000\ \text{kg/m}^3\right)(24.5\ \text{cm})/(27.2\ \text{cm})$	1 point
For the correct answer $\rho_o = 901\ \text{kg/m}^3$	1 point
(b) 2 points	
Use equation for absolute pressure $P = P_0 + \rho g h$	
For using atmospheric pressure for P_0	1 point
For using the correct height (in meters) with the correct density and a correct acceleration owing to gravity $P = P_0 + \rho g h = \left(1.0 \times 10^5\ \text{Pa}\right) + \left(1000\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)(0.245\ \text{m})$ $P = 1.02 \times 10^5\ \text{Pa}$	1 point
Note: The use of $1.013 \times 10^5\ \text{Pa}$ and $10\ \text{m/s}^2$ is acceptable.	
(c) 3 points	
For selecting "Below A"	1 point
For a statement that the height of the oil above the mercury is now lower	1 point
For a statement that the pressure is lower at interface A owing to the lower height	1 point
(d) 1 point	
For selecting "Increases"	1 point
Units 1 point	
For correct units in both numerical answers of parts (a) and (b)	1 point



3. (10 points)

A glass U-tube with a uniform diameter of 0.850 cm is used to determine the density of an oil. As shown in the figure above, a 24.5 cm column of water balances a 27.2 cm column of the oil so that interfaces *A* and *B* of the mercury with the other liquids are at the same height. The density of water is $1.00 \times 10^3\ \text{kg/m}^3$.

(a) Calculate the density of the oil.

$P_A = P_B$

$P_{atm} + \rho g h_o = P_{atm} + \rho_w g h_w$

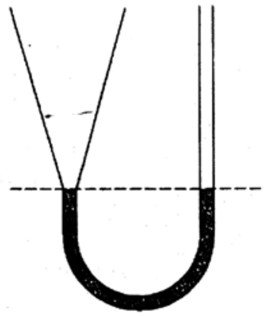
$\rho_o = \frac{\rho_w h_w}{h_o} = \frac{1000(.245)}{.272} = \boxed{900.7\ \text{kg/m}^3}$

(b) Calculate the absolute pressure at *B*, the interface between the water and the mercury.

$P_B = P_{atm} + \rho_w g h_w$

$= 1.01E5 + 1000(9.81)(.245)$

$= \boxed{1.03E5\ \text{Pa}}$



A new tube, identical to the U-tube except for a cone shape on the left, as shown above, is filled with the same volume of mercury that was in the U-tube. The mercury is at the same height on both sides of the new tube as it was in the U-tube, as shown by the dashed line. The same volumes of oil and water that were in the U-tube are now poured into the new tube, on the left and right respectively.

(c) Indicate the new position of *B* relative to *A*.

____ Above *A*   _✓_ Below *A*   ____ At the same height as *A*

Justify your answer.

~~$V_{oil} = (.272)\pi(.425)^2$ > $V_{H_2O} = (.245)\pi(.425)^2$~~
~~$= .154$ $= .139$~~

B is below A because the pressure at A is less due to decreased height of the oil in the cone.

(d) A small piece of wood with density less than that of the oil is placed so that it floats in the left side of the tube. Indicate whether the pressure at the bottom of the tube increases, decreases, or remains the same.

_✓_ Increases   ____ Decreases   ____ Remains the same

Increases

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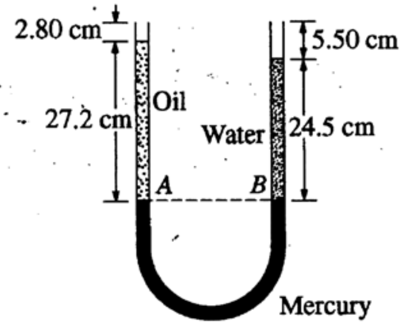

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(a) Calculate the density of the oil.

$m_w = m_o$ $V_{oil} = \pi(.00425m)^2(.272m)$ $\rho = \frac{m}{V}$

$V_o = 1.54 \times 10^{-5} m^3$

$\frac{1.39 \times 10^{-2} kg}{1.54 \times 10^{-5} m^3} = \boxed{9.03 \times 10^2 kg/m^3}$

$V_{oil} = \pi r^2 h_o$ $\frac{.850cm}{2} = .425cm$ $.00425m$

$V_{water} = \pi r^2 h_w$

$V_{water} = \pi(.00425m)^2 .245m$

$V_w = 1.39 \times 10^{-5} m^3$

$m = \rho V$

$m_w = 1.39 \times 10^{-5}(1.00 \times 10^3 ...)$

$m_w = 1.39 \times 10^{-2} kg$

(b) Calculate the absolute pressure at *B*, the interface between the water and the mercury.

$F_{net} = 0$ $P_{water} = P_{Hg}$ $P_{water} = \rho g h$ $P_{atm} = 1 N/m^2$

$P_{interface} = 2(P_{water} + P_{atm})$ $(1.00 \times 10^3 kg/m^3)(9.8 m/s^2)(.245m)$

$P_{water} =$

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B3-B $P = P_0 + \rho g h$

$\rho = m/V$

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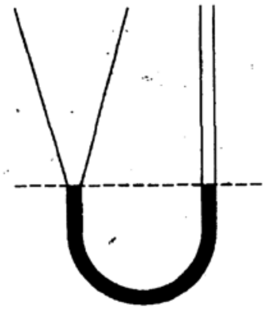

A new tube, identical to the U-tube except for a cone shape on the left, as shown above, is filled with the same volume of mercury that was in the U-tube. The mercury is at the same height on both sides of the new tube as it was in the U-tube, as shown by the dashed line. The same volumes of oil and water that were in the U-tube are now poured into the new tube, on the left and right respectively.

(c) Indicate the new position of *B* relative to *A*.

____ Above *A* __✓__ Below *A* ____ At the same height as *A*

Justify your answer.

pressure is determined by the mass of fluid directly above the mercury. with the cone shape, not all of the oil is above the mercury so the pressure is less on the oil side so mercury will move towards A, lowering B.

(d) A small piece of wood with density less than that of the oil is placed so that it floats in the left side of the tube. Indicate whether the pressure at the bottom of the tube increases, decreases, or remains the same.

__✓__ Increases ____ Decreases ____ Remains the same

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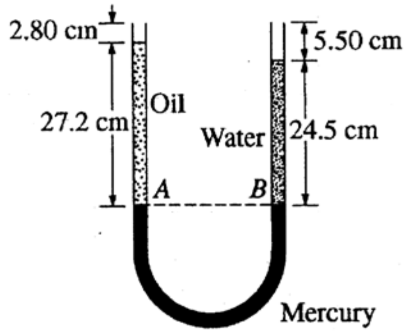

3. (10 points)

A glass U-tube with a uniform diameter of 0.850 cm is used to determine the density of an oil. As shown in the figure above, a 24.5 cm column of water balances a 27.2 cm column of the oil so that interfaces *A* and *B* of the mercury with the other liquids are at the same height. The density of water is $1.00 \times 10^3\ \text{kg/m}^3$.

(a) Calculate the density of the oil.

$m_{H_2O} = \rho_{H_2O} V_{H_2O} = (1 \times 10^3\ kg/m^3\ (0.245m\ (\pi (\frac{0.0085m}{2})^2)) = 0.0139\ kg$

$m_{H_2O} = m_{oil}$

$\rho_{oil} = \frac{m_{oil}}{V_{oil}} = \frac{0.0139^{-3}\ kg}{(0.272m(\pi(\frac{0.0085m}{2})^2)} = 8888.28\ kg/m^3$

(b) Calculate the absolute pressure at *B*, the interface between the water and the mercury.

$P = P_0 + \rho g h$

$P = (1 \times 10^3 \frac{kg}{m^3})(10 m/s^2)(0.245m) + 1 \times 10^5 N/m^2 = 102450\ N/m^2$

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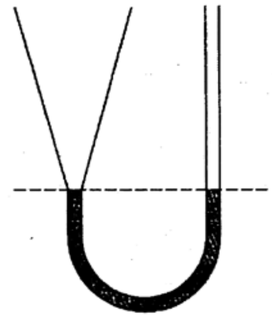

A new tube, identical to the U-tube except for a cone shape on the left, as shown above, is filled with the same volume of mercury that was in the U-tube. The mercury is at the same height on both sides of the new tube as it was in the U-tube, as shown by the dashed line. The same volumes of oil and water that were in the U-tube are now poured into the new tube, on the left and right respectively.

(c) Indicate the new position of *B* relative to *A*.

____ Above *A* ____ Below *A* X At the same height as *A*

Justify your answer.

The shape of the volume doesn't affect the mass of each fluid, and therefore the force each fluid exerts on the mercury remains the same.

(d) A small piece of wood with density less than that of the oil is placed so that it floats in the left side of the tube. Indicate whether the pressure at the bottom of the tube increases, decreases, or remains the same.

____ Increases ____ Decreases X Remains the same

Question 3

Overview

This question assessed students' understanding of fluid statics. The students were asked to calculate densities and pressures of fluids in a U-shaped tube. They were also asked to make judgments about changes in the system, based on pressure, fluid heights, gravity, and the densities of fluids in the tube.

Sample: B3-A
Score: 10

This student's work matches up exactly with the scoring guidelines. Part (a) begins with a statement of equal pressures, leading to the correct density of the oil. Part (b) offers a straightforward calculation of total pressure, along with the correct substitutions. The correct choices have been checked in the last two parts, and the brief justification in part (c) is well stated. The units point was earned.

Sample: B3-B
Score: 6

Two points were earned in part (a). There is no statement of equal pressure, but the equations do match the correct height with the correct density, and the answer is correct. Part (b) shows the correct substitution of height, density, and acceleration resulting from gravity, but the student does not add atmospheric pressure to this equation, so only 1 point was earned. Only 2 of the 3 points were awarded in part (c), because the justification does not mention the lower height. One point was earned in part (d) for choosing the correct answer. The units point was lost because there is no numerical answer with units in part (b).

Sample: B3-C
Score: 4

A common alternate solution employed by students in part (a) was the use of the mass/density of the oil and water. This solution always lost 1 point for the lack of a statement of equal pressures. This student's response also lost 1 point for an incorrect final answer, so only 1 point was earned in part (a). Full credit was earned in part (b). No points were awarded in parts (c) and (d), because the wrong answers were selected. The units point was earned.