AP® PHYSICS B
2010 SCORING GUIDELINES

General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the 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 — for example, 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 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 Exams 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*.

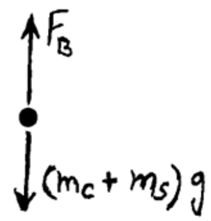
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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 2

15 points total | **Distribution of points**

(a) 2 points



For a single upward force, appropriately labeled, representing the buoyant force — 1 point

For downward gravitational force (or forces), appropriately labeled, representing the cup and the sample — 1 point

One earned point was deducted if any extraneous forces were present.

(b) 3 points

For any statement of equilibrium — 1 point

$F_B = F_g$

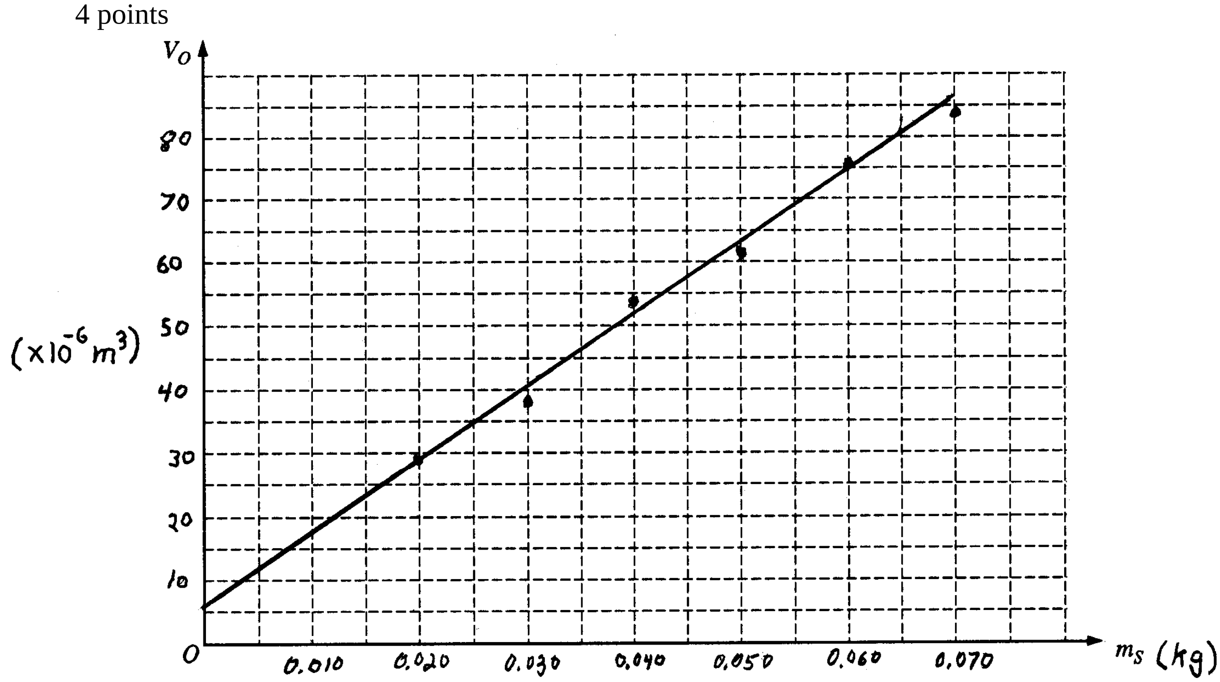
For a correct substitution including both masses m_C and m_S — 1 point

$\rho_O V_O g = (m_C + m_S)g$

For correct statement of the overflow volume, V_O — 1 point

$$V_O = \frac{m_C + m_S}{\rho_O}$$

(c) 4 points



Question 2 (continued)

Distribution of points

(c) (continued)

For data plotted correctly	1 point
For correct units on both axes	1 point
For numerical scales that are linear and allow the plotted data to extend over about half the grid area	1 point
For a reasonable single straight best-fit line that does not go through (0,0)	1 point

(d) 4 points

From part (b), $V_O = \dfrac{m_C}{\rho_O} + \dfrac{1}{\rho_O} m_S$

For properly calculating a slope using points on the straight line drawn, including data points only if they are on that line — 1 point

Example: Using the two points (0.060 kg, $75 \times 10^{-6}\ \text{m}^3$) and (0.025 kg, $35 \times 10^{-6}\ \text{m}^3$) that are on the line in the graph above

For calculating a reasonable value of slope — 1 point

$$\text{slope} = \frac{1}{\rho_0} = \frac{(75 - 35) \times 10^{-6}\ \text{m}^3}{(.060 - 0.025)\ \text{kg}} = 1.14 \times 10^{-3}\ \text{m}^3/\text{kg}$$

For an explicit or implicit indication of inverting the slope — 1 point

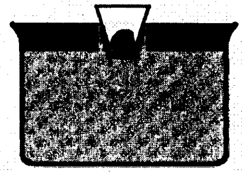
For calculating a reasonable value for the oil's density (including units and four significant figures or less) — 1 point

$$\rho_O = 8.8 \times 10^2\ \text{kg}/\text{m}^3$$

(e) 2 points

For a complete statement that the *y* intercept is the volume of the oil displaced by the empty cup — 2 points

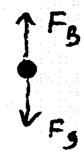
Note: 1 point is given for a partially correct answer



2. (15 points)

A large pan is filled to the top with oil of density ρ_O. A plastic cup of mass m_C, containing a sample of known mass m_S, is placed in the oil so that the cup and sample float, as shown above. The oil that overflows from the pan is collected, and its volume is measured. The procedure is repeated with a variety of samples of different mass, and the pan is refilled each time.

(a) On the dot below that represents the cup-sample system, draw and label the forces (not components) that act on the system when it is floating on the surface of the oil.



(b) Derive an expression for the overflow volume V_O (the volume of oil that overflows due to the floating system) in terms of ρ_O, m_S, m_C, and fundamental constants. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

$F_B = F_g$

$\rho_o V_o g = (m_s + m_c) g$

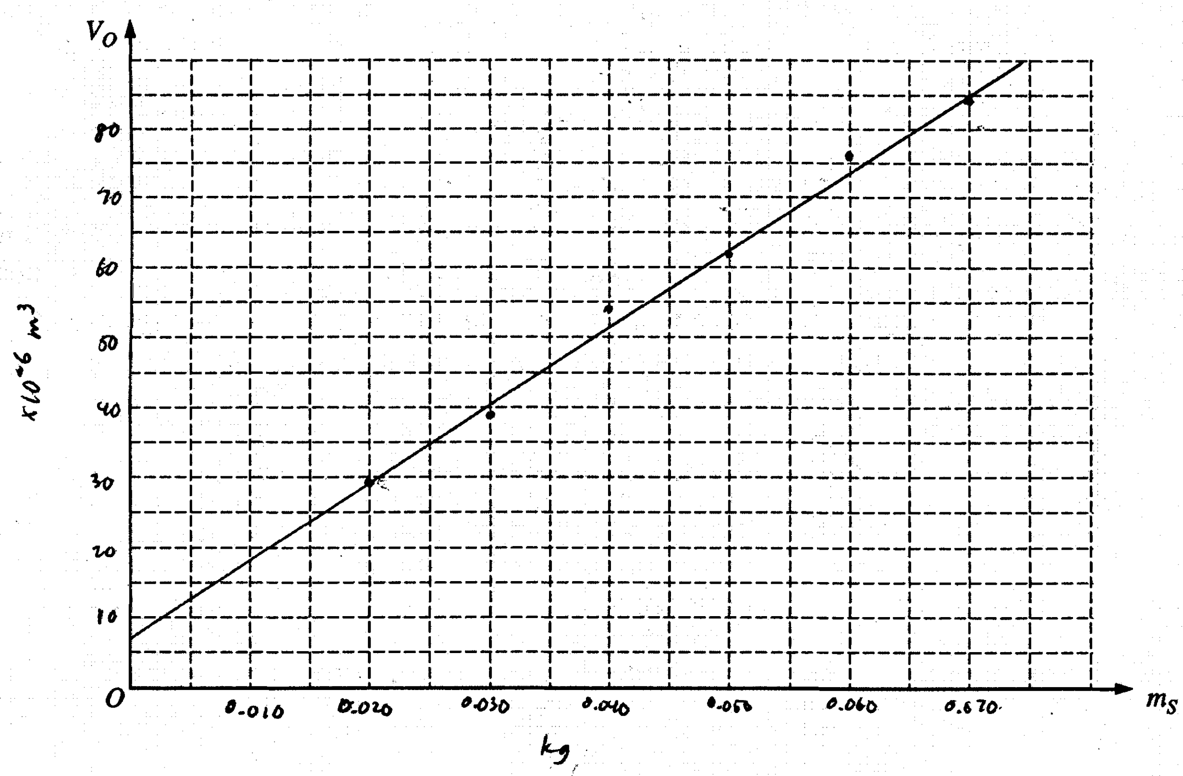
$\rho_o V_o = m_s + m_c$

$V_o = \frac{m_s + m_c}{\rho_o}$

Assume that the following data are obtained for the overflow volume V_O for several sample masses m_S.

Sample mass m_S (kg)	0.020	0.030	0.040	0.050	0.060	0.070
Overflow volume V_O (m^3)	29×10^{-6}	38×10^{-6}	54×10^{-6}	62×10^{-6}	76×10^{-6}	84×10^{-6}

(c) Graph the data on the axes below, plotting the overflow volume as a function of sample mass. Place numbers and units on both axes. Draw a straight line that best represents the data.

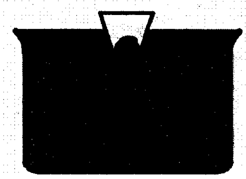


(d) Use the slope of the best-fit line to calculate the density of the oil.

$$\rho_0 = \frac{0.070 \text{ kg} - 0.020 \text{ kg}}{85 \times 10^{-6} \text{ m}^3 - 29 \times 10^{-6} \text{ m}^3} = 893 \text{ kg/m}^3$$

(e) What is the physical significance of the intercept of your line with the vertical axis?

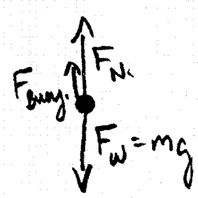
The y-intercept of the line represents the volume of oil overflow caused by ~~an em~~ the empty plastic cup.



2. (15 points)

A large pan is filled to the top with oil of density ρ_O. A plastic cup of mass m_C, containing a sample of known mass m_S, is placed in the oil so that the cup and sample float, as shown above. The oil that overflows from the pan is collected, and its volume is measured. The procedure is repeated with a variety of samples of different mass, and the pan is refilled each time.

(a) On the dot below that represents the cup-sample system, draw and label the forces (not components) that act on the system when it is floating on the surface of the oil.



(b) Derive an expression for the overflow volume V_O (the volume of oil that overflows due to the floating system) in terms of ρ_O, m_S, m_C, and fundamental constants. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

$F_{Buoy} = \rho_o V_c g$

$\rho_o = m_o / V_o$

if V_c = volume of sample in cup, $V_o = V_c$

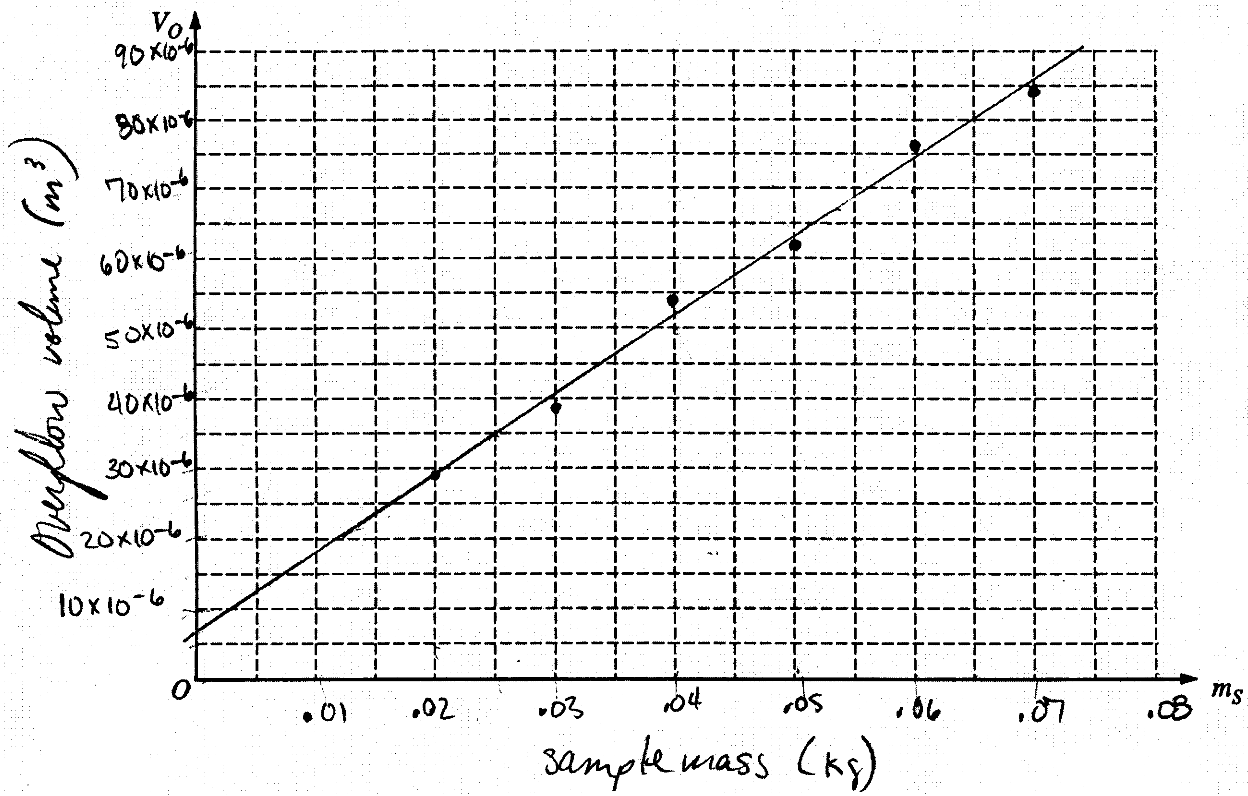
m_o (mass of oil) $= m_s - m_c$

$$\frac{m_s - m_c}{\rho_o} = V_o$$

Assume that the following data are obtained for the overflow volume V_O for several sample masses m_S.

Sample mass m_S (kg)	0.020	0.030	0.040	0.050	0.060	0.070
Overflow volume V_O (m^3)	29×10^{-6}	38×10^{-6}	54×10^{-6}	62×10^{-6}	76×10^{-6}	84×10^{-6}

(c) Graph the data on the axes below, plotting the overflow volume as a function of sample mass. Place numbers and units on both axes. Draw a straight line that best represents the data.



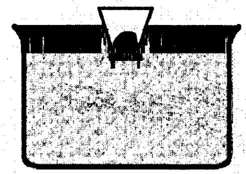
(d) Use the slope of the best-fit line to calculate the density of the oil.

$$m = \frac{y_2 - y_1}{x_1 - x_2} = \frac{80\times10^{-6}\,m^3 - 35\times10^{-6}\,m^3}{.065\,kg - .025\,kg} = \frac{4.5\times10^{-5}\,m^3}{.04\,kg} =$$

$$V_o = .001125\ m^3/kg$$

(e) What is the physical significance of the intercept of your line with the vertical axis?

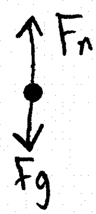
This is the volume of oil displaced by just the cup (when the sample mass is zero).



2. (15 points)

A large pan is filled to the top with oil of density ρ_O. A plastic cup of mass m_C, containing a sample of known mass m_S, is placed in the oil so that the cup and sample float, as shown above. The oil that overflows from the pan is collected, and its volume is measured. The procedure is repeated with a variety of samples of different mass, and the pan is refilled each time.

(a) On the dot below that represents the cup-sample system, draw and label the forces (not components) that act on the system when it is floating on the surface of the oil.



(b) Derive an expression for the overflow volume V_O (the volume of oil that overflows due to the floating system) in terms of ρ_O, m_S, m_C, and fundamental constants. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

$\rho_o = m/V$

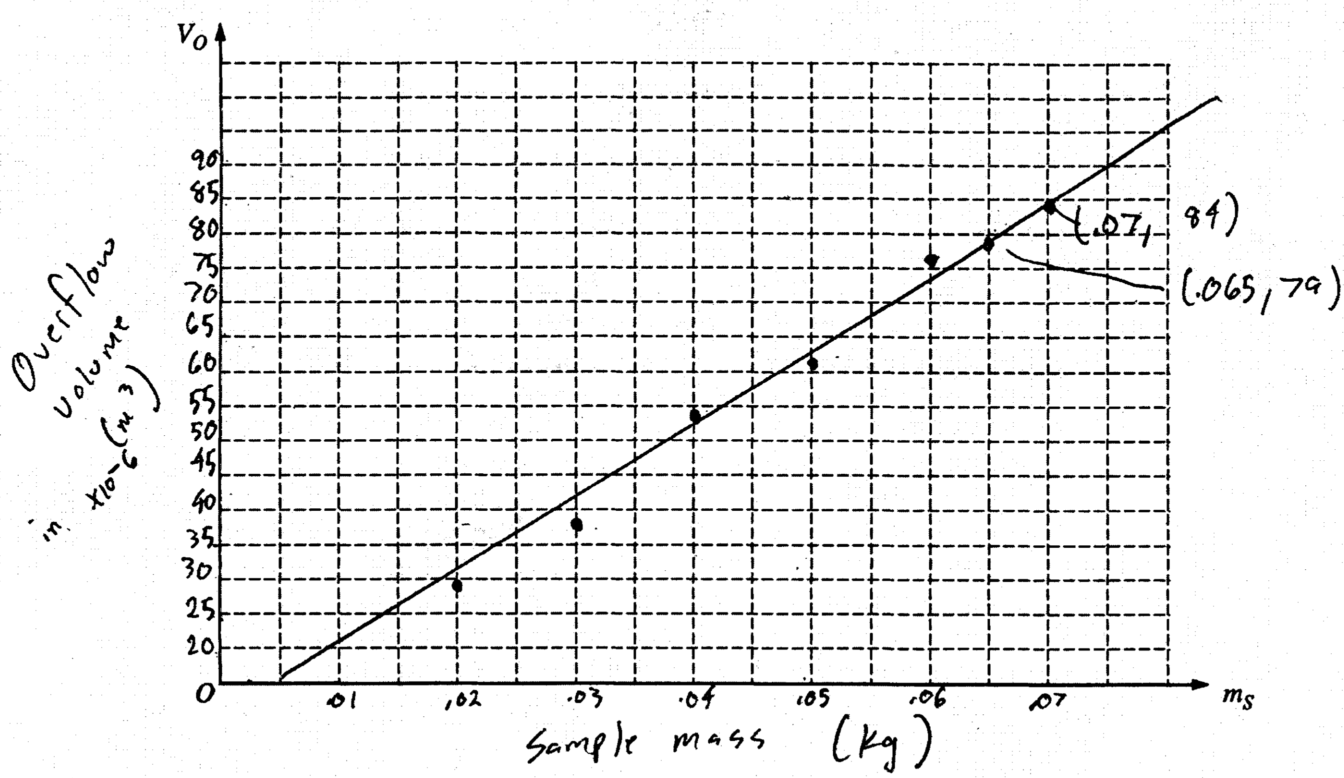
~~$V_o = \frac{m_c - m_s}{V}$~~

$V_o = \frac{m_c - m_s}{v}$

Assume that the following data are obtained for the overflow volume V_O for several sample masses m_S.

Sample mass m_S (kg)	0.020	0.030	0.040	0.050	0.060	0.070
Overflow volume V_O (m^3)	29×10^{-6}	38×10^{-6}	54×10^{-6}	62×10^{-6}	76×10^{-6}	84×10^{-6}

(c) Graph the data on the axes below, plotting the overflow volume as a function of sample mass. Place numbers and units on both axes. Draw a straight line that best represents the data.



(d) Use the slope of the best-fit line to calculate the density of the oil.

$\frac{y_2 - y_1}{x_2 - x_1}$ [redacted] $\frac{84 - 79}{.07 - .065} =$ $\boxed{1,000 \text{ kg} \cdot \text{m}^3}$

(e) What is the physical significance of the intercept of your line with the vertical axis?

The intercept line represents the increase in overflow volume as more & more weight is added to the cup.

Question 2

Overview

This question was based on a hydrostatics experiment. Parts (a) and (b) evaluated students' ability to deal with equilibrium situations in a fluid mechanics setting. Parts (c) through (e) asked students to analyze and interpret experimental data. This question in particular gave students with strong laboratory skills a chance to show their knowledge.

Sample: B2-A
Score: 15

This response earned full credit. Note that in part (d) the response meets all the requirements for full credit in one process. An acceptable value for the density implies that the value for the slope would have been reasonable if the intermediate step were shown. Part (e) has a short but complete answer.

Sample: B2-B
Score: 9

Part (a) received only 1 point since both a buoyant force and an upward normal force are included. Part (b) received no credit because the logic is incorrect and also results in subtracting the masses instead of adding them. Part (c) received full credit. Part (d) earned 2 points for the correct method and value for the slope. Part (e) received full credit.

Sample: B2-C
Score: 6

Part (a) lost 1 point for a label that does not have meaning in context; the upward force is labeled as a normal force. Part (b) earned no credit. Part (c) earned full credit; there was no penalty for overriding the given axis origin label and effectively redefining the zero of either axis. Part (d) earned 1 point for a correct slope method. The student forgets the factor of 10^{-6} and does not get a correct slope value. Part (e) earned no credit.