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 $g = 9.8\ \mathrm{m/s^2}$, but use of $10\ \mathrm{m/s^2}$ 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 2

15 points total | **Distribution of points**

(a)

i. 3 points

For writing the appropriate expression for the electric potential, given the spherical symmetry of the situation — 1 point

$$V = \frac{kq}{r}$$

The electric field inside a conducting sphere in equilibrium is zero, so the potential inside the sphere is constant, uniform, and equal to the potential at the surface.

$$V = \frac{kq}{R_1}$$

For correct substitutions — 1 point

$$V = \frac{\left(9.0 \times 10^9 \ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(6.4 \times 10^{-9} \ \text{C}\right)}{0.12 \text{ m}}$$

For the correct answer — 1 point

$V = 480$ V

ii. 2 points

For writing the appropriate expression for the electric potential — 1 point

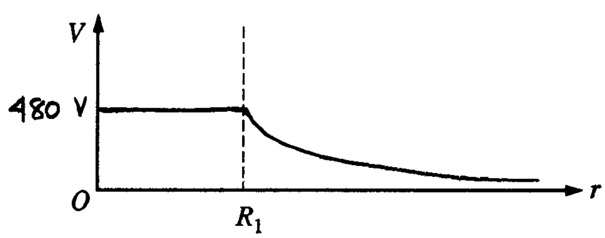
$$V = \frac{kq}{r}$$

$$V = \frac{\left(9.0 \times 10^9 \ \text{N}\bullet\text{m}^2/\text{C}^2\right)\left(6.4 \times 10^{-9} \ \text{C}\right)}{0.24 \text{ m}}$$

For the correct answer calculated from a correct expression showing substitutions — 1 point

$V = 240$ V

(b) 3 points



For labeling the potential at $r = 0$ with the value from part (a) i — 1 point

For drawing a horizontal line from $r = 0$ to $r = R_1$ that is continuous with the other part of the graph — 1 point

For drawing a reasonable curve for the $1/r$ dependence in the region beyond R_1 — 1 point

Question 2 (continued)

Distribution of points

(c)

i. 2 points

$r = 0.10 \text{ m} < 0.12 \text{ m} = R_1$

There is no electric field inside a conducting sphere in equilibrium.

For the correct answer — 2 points

$E = 0 \text{ N/C}$

ii. 2 points

$r = 0.24 \text{ m} > 0.12 \text{ m} = R_1$, so the charge can be treated as a point charge at the center of the sphere.

For writing the appropriate expression for the electric field — 1 point

$$E = \frac{kq}{r^2}$$

$$E = \frac{\left(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(6.4 \times 10^{-9} \text{ C}\right)}{(0.24 \text{ m})^2}$$

For the correct answer — 1 point

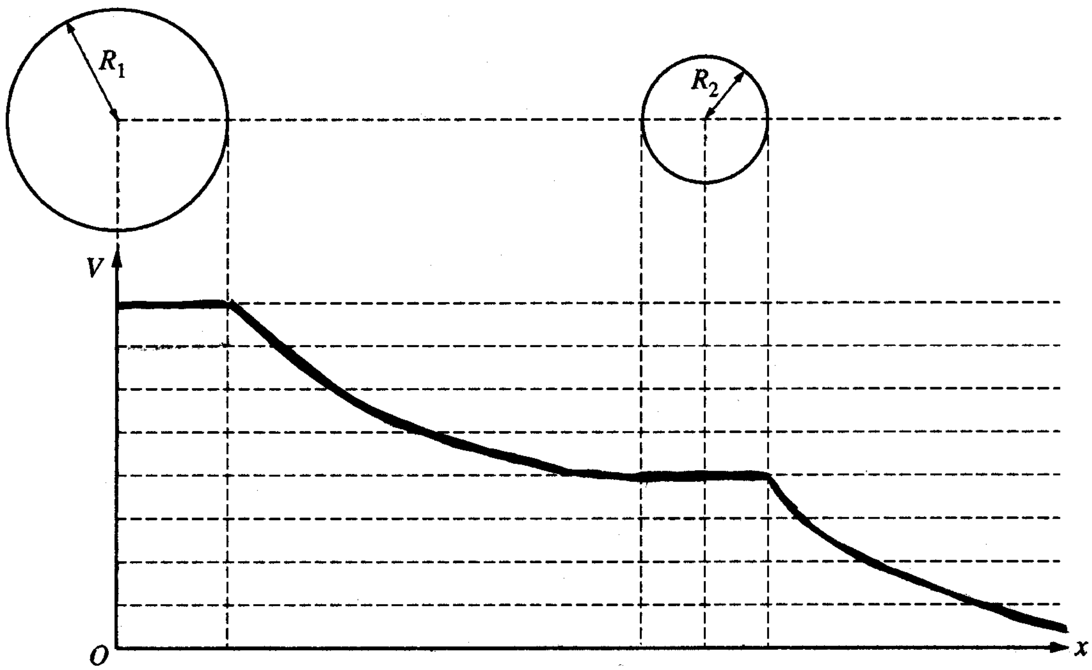
$E = 1000 \text{ N/C}$

Question 2 (continued)

Distribution of points

(d) 2 points

Sample Sketch



For a horizontal line inside the second sphere, with a nonzero value and continuous with the parts of the graph on either side — 1 point

For $1/r$ curves in the regions on either side of the second sphere, with the curve in the region to the right at lower values than the curve to the left — 1 point

Note: Except for the stipulation above for the $1/r$ curves, the relative values of the potentials of the two spheres are not scored. The sample graph shows an acceptable answer that does not include exact relative values.

Units point

For correct units in parts (a) ii and (c) ii — 1 point

2. (15 points)

An isolated, solid copper sphere of radius $R_1 = 0.12$ m has a positive charge of 6.4×10^{-9} C.

(a)

i. Calculate the electric potential at a point 0.10 m from the center of the sphere.

$V = \frac{1}{4\pi\epsilon_0}\frac{q}{d} = 9\times10^9\left(\frac{6.4\times10^{-9}}{0.12}\right) = 480$

Potential inside = potential at surface

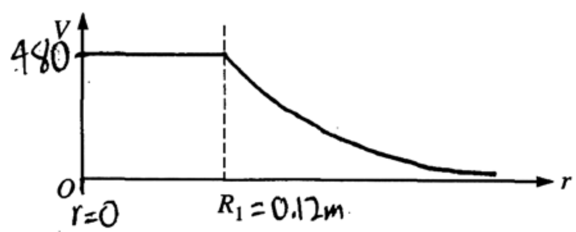
480V

ii. Calculate the electric potential at a point 0.24 m from the center of the sphere.

$V = \frac{1}{4\pi\epsilon_0}\frac{q}{d} = 9\times10^9\left(\frac{6.4\times10^{-9}}{0.24}\right) = 240$

240 V

(b) On the axes below, sketch a graph of electric potential V versus radius r from the center of the sphere. Label the value at $r = 0$ on the vertical axis.



(c)

i. Determine the magnitude of the electric field at a point 0.10 m from the center of the sphere.

The magnitude of the electric field at a point 0.01m from the center of the sphere is 0 because no static electrical field can exist inside a conductor.

ii. Determine the magnitude of the electric field at a point 0.24 m from the center of the sphere.

$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} = 9\times10^9\left(\frac{6.4\times10^{-9}}{0.24^2}\right) = 1000$

1000 N/C

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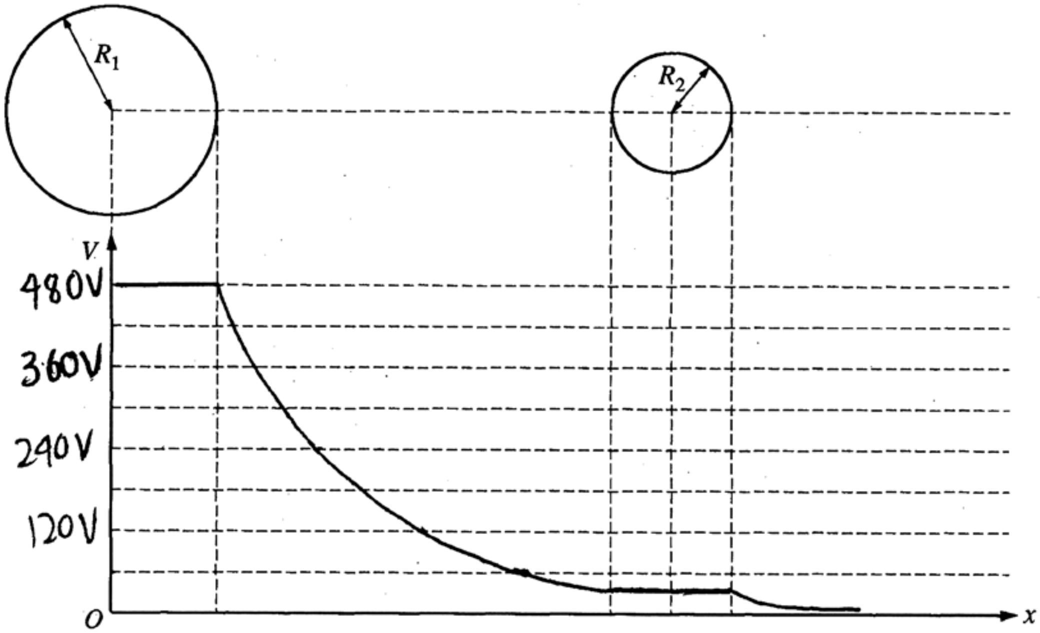
(d) A second copper sphere of radius R_2 that is uncharged is placed near the first sphere, as represented in the figure below. On the axes below, sketch a graph of electric potential V versus distance along the x-axis shown, where the center of the first sphere is at $x = 0$.



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2. (15 points)

An isolated, solid copper sphere of radius $R_1 = 0.12$ m has a positive charge of 6.4×10^{-9} C.

(a)

i. Calculate the electric potential at a point 0.10 m from the center of the sphere.

$V = \frac{kq}{r}$

$V = \frac{(9\times10^{9})(6.4\times10^{-9}c)}{(0.10\ m)}$

$V = 576$ V

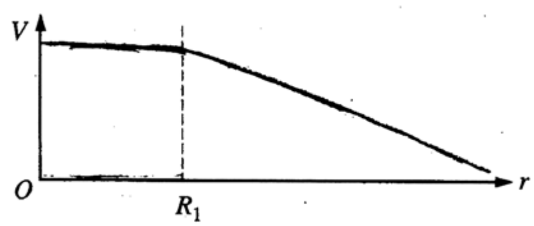
ii. Calculate the electric potential at a point 0.24 m from the center of the sphere.

$V = \frac{kq}{r}$

$V = \frac{(9\times10^{9}\ \frac{N\cdot m^2}{c^2})(6.4\times10^{-9}\ c)}{(0.24\ m)}$

$V = 240$ V

(b) On the axes below, sketch a graph of electric potential V versus radius r from the center of the sphere. Label the value at $r = 0$ on the vertical axis.



(c)

i. Determine the magnitude of the electric field at a point 0.10 m from the center of the sphere.

The magnitude of the electric field at a point 0.10 m from the center of the sphere is zero because it is a point inside the sphere.

ii. Determine the magnitude of the electric field at a point 0.24 m from the center of the sphere.

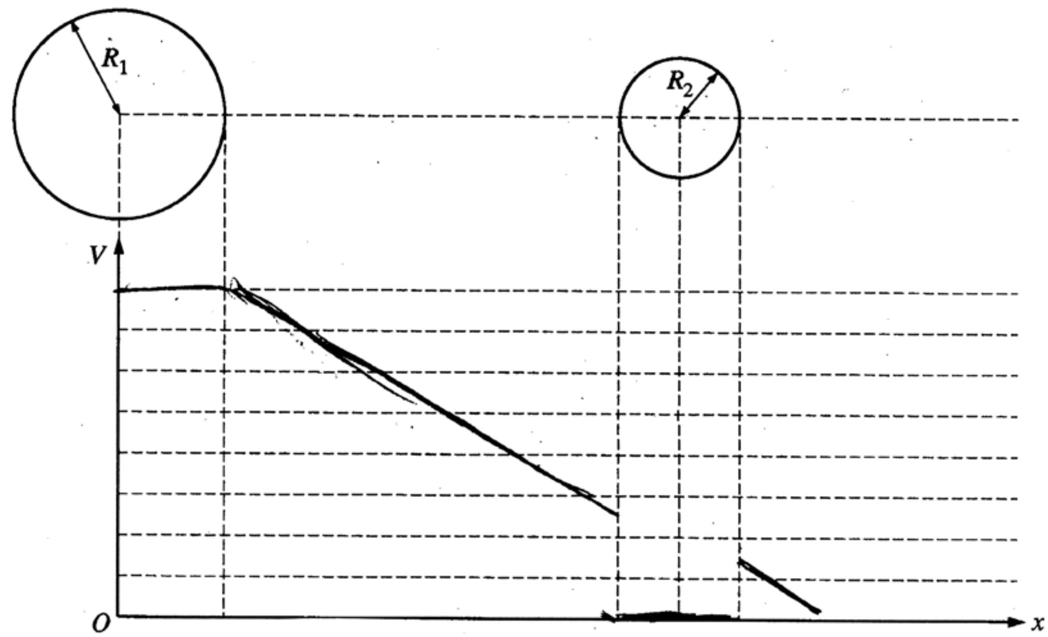
$E = \frac{kq}{r^2}$

$E = \frac{(9\times10^{9}\ \frac{N\cdot m^2}{c^2})(6.4\times10^{-9}c)}{(0.24 m)^2}$

$E = 1000\ \frac{N}{C}$

GO ON TO THE NEXT PAGE.

(d) A second copper sphere of radius R_2 that is uncharged is placed near the first sphere, as represented in the figure below. On the axes below, sketch a graph of electric potential V versus distance along the x-axis shown, where the center of the first sphere is at $x = 0$.



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2. (15 points)

An isolated, solid copper sphere of radius $R_1 = 0.12$ m has a positive charge of 6.4×10^{-9} C.

(a)

i. Calculate the electric potential at a point 0.10 m from the center of the sphere.

$V = \frac{KQ}{r}$

$V = \frac{(9\times10^9 N\cdot m^2/c^2)(6.4\times10^{-9} c)}{.1m}$ $\boxed{V = 576 v}$

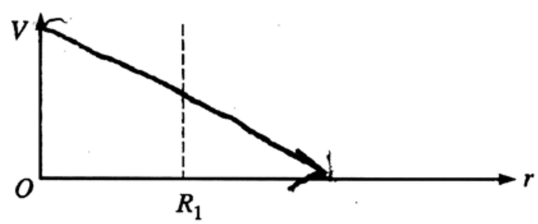
ii. Calculate the electric potential at a point 0.24 m from the center of the sphere.

$V = \frac{KQ}{r}$

$V = \frac{(9\times10^9 N\cdot m^2/c^2)(6.4\times10^{-9} c)}{.24m}$

$\boxed{V = 240v}$

(b) On the axes below, sketch a graph of electric potential V versus radius r from the center of the sphere. Label the value at $r = 0$ on the vertical axis.



(c)

i. Determine the magnitude of the electric field at a point 0.10 m from the center of the sphere.

$E = \frac{F}{q} = \frac{\frac{KQ_1q}{r^2}}{q} = \frac{KQ_1}{r^2} = \frac{(9\times10^9 N\cdot m^2/c^2)(6.4\times10^{-9} c)}{(.1m)^2}$

$\boxed{E = 5760 N/c}$

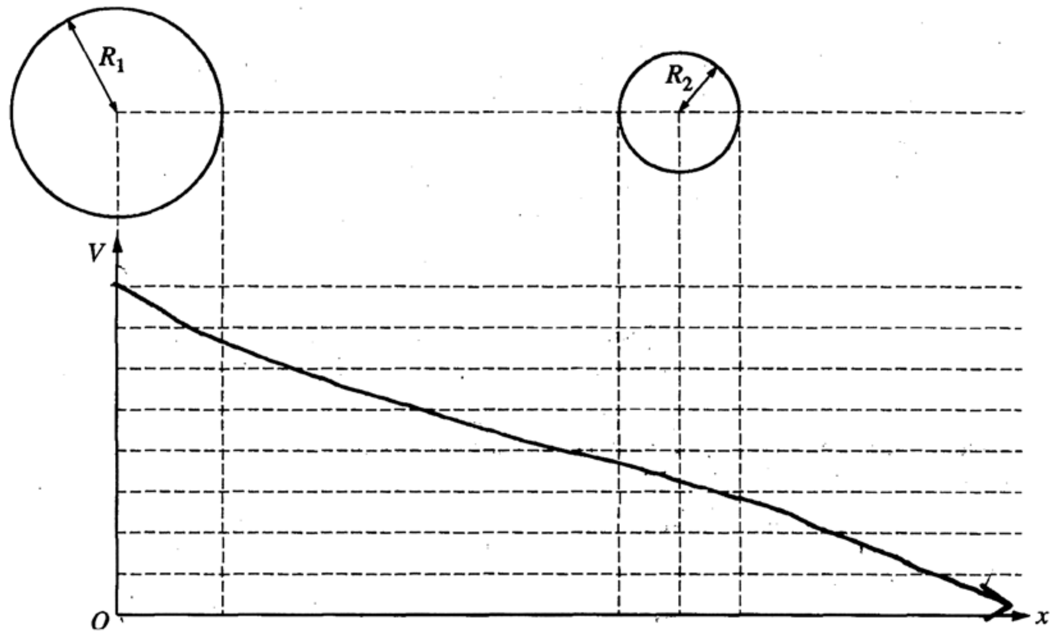
ii. Determine the magnitude of the electric field at a point 0.24 m from the center of the sphere.

$E = \frac{KQ_1}{r^2} = \frac{(9\times10^9 Nm^2/c^2)(6.4\times10^{-9} c)}{(.24m)^2}$

$\boxed{E = 1000 N/c}$

GO ON TO THE NEXT PAGE.

(d) A second copper sphere of radius R_2 that is uncharged is placed near the first sphere, as represented in the figure below. On the axes below, sketch a graph of electric potential V versus distance along the x-axis shown, where the center of the first sphere is at $x = 0$.



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Question 2

Overview

This question assessed students' understanding of the electric field resulting from a continuous charge distribution on a conducting sphere

Sample: B2A
Score: 15

This is a clear response with straightforward work. Note the explicit statement in part (a) i regarding the potential inside the sphere.

Sample: B2B
Score: 9

In part (a) i the student incorrectly substitutes the radius inside the surface of the sphere and earned only 1 point. Part (a) ii earned full credit. Part (b) has the constant value inside the sphere continuous with the other segment, but it does not have a $1/r$ curve after that and therefore earned only 1 point. Part (c) earned full credit. The graph in part (d) earned no points. The units point was earned.

Sample: B2C
Score: 6

In part (a) i the student incorrectly substitutes the radius inside the surface of the sphere and earned only 1 point. Part (a) ii earned full credit. Part (b) earned no credit because the student incorrectly makes the graph a straight line. Part (c) i earned no credit, but part (c) ii earned full credit. The graph in part (d) did not earn points. The units point was earned.