AP® PHYSICS
2011 SCORING GUIDELINES

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 $g = 9.8 \text{ m/s}^2$, but use of 10 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 1

15 points total	**Distribution of points**

(a) 3 points

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$$

For a proper application of Gauss's Law using spherical symmetry	1 point
$E\left(4\pi r^2\right) = \dfrac{Q_{enc}}{\epsilon_0}$	
For a proper description of the correct Gaussian surface	1 point
A proper description of the Gaussian surface should indicate that it is a sphere, concentric with the charged shell, and with a radius less than the radius of the shell. Drawing a proper Gaussian surface is acceptable.	
For completing the response with an indication that $E = 0$, consistent with previous work	1 point
The enclosed charge Q is zero for all radii of the Gaussian surface; therefore, the electric field E is also zero everywhere inside the sphere.	

(b) 2 points

For selecting the correct answer of "No"	1 point
For a correct justification	1 point
Example: With a nonsymmetric distribution, the fields from individual charges no longer have the net effect of completely canceling inside the shell.	

(c) 5 points

For correctly selecting face *ABCD*	1 point
For correctly selecting face *ABGH*	1 point
For correctly selecting face *ADEH*	1 point
One earned point is deducted for each incorrect face selected.	
For a correct and complete justification of the correctly checked choices	2 points

Examples:

The electric field from the sphere is radial, so it is parallel to the three correct faces.

The electric field vector does not penetrate the area of any of the three correct faces.

Note: One point can be earned for a partial explanation or an explanation with a minor factual error.

Question 1 (continued)

Distribution of points

(d) 1 point

For correctly identifying corner A as having the smallest magnitude of electric field. — 1 point

Corner A is inside the small conducting sphere, so the electric field there is zero. All other corners have a nonzero electric field.

(e) 1 point

For correctly determining the electric field strength at the position indicated in part (d). — 1 point

As explained above, the electric field at point A is zero. A correct calculation for whatever point is indicated in part (d) also receives full credit.

(f) 3 points

For proper use of Gauss's Law that recognizes that the flux is a constant — 1 point

Total electric flux $= \phi_{\text{total}} = \dfrac{Q_{\text{enc}}}{\epsilon_0}$. The cube encloses $\dfrac{1}{8}$ of the charge, i.e. $Q_{\text{enc}} = \dfrac{Q}{8}$.

For recognizing that the flux is the same through each of the three nonzero flux sides of the cube and is equal to $1/3$ of the total flux through the cube. — 1 point

For proper reasoning leading to the final correct answer — 1 point

$$\phi_{\text{total}} = 3\phi_{CDEF} = \frac{Q/8}{\epsilon_0}$$

$$\phi_{CDEF} = \frac{Q}{24\epsilon_0}$$

PHYSICS C: ELECTRICITY AND MAGNETISM
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.

E&M. 1.

A nonconducting, thin, spherical shell has a uniform surface charge density σ on its outside surface and no charge anywhere else inside.

(a) Use Gauss's law to prove that the electric field inside the shell is zero everywhere. Describe the Gaussian surface that you use.

surface - a sphere centered at the center of the shell w/ radius r less than that of the shell and greater than zero

Gauss' Law $\oint E \cdot dA = \frac{Q_{enc}}{\varepsilon_0}$. $E \cdot 4\pi r^2 = \frac{Q_{enc}}{\varepsilon_0}$

$E = \frac{Q_{enc}}{4\pi r^2 \varepsilon_0}$ since $Q_{enc} = 0$, $E = 0$ for all points inside of the shell

(b) The charges are now redistributed so that the surface charge density is no longer uniform. Is the electric field still zero everywhere inside the shell?

____ Yes __✓__ No ____ It cannot be determined from the information given.

Justify your answer.

Gaussian surface no longer applies because E is not equal at all points

Since charge density is no longer uniform, the electric field from various points of charge on the shell does not perfectly cancel out

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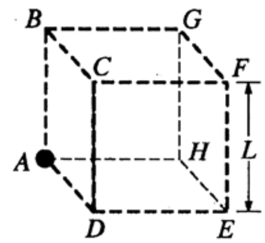
Now consider a small conducting sphere with charge $+Q$ whose center is at corner A of a cubical surface, as shown below.



(c) For which faces of the surface, if any, is the electric flux through that face equal to zero?

_✓_ *ABCD* ____ *CDEF* ____ *EFGH* _✓_ *ABGH* ____ *BCFG* _✓_ *ADEH*

Explain your reasoning.

These faces are parallel to the electric field created by the sphere at A therefore it does not pass through them and flux is zero

(d) At which corner(s) of the surface does the electric field have the least magnitude?

corner F because it is farthest away

(e) Determine the electric field strength at the position(s) you have indicated in part (d) in terms of Q, L, and fundamental constants, as appropriate.

$E = K\frac{Q}{r^2}$ $\quad r =$ space diagonal $= L\sqrt{3}$

$= K\frac{Q}{(L\sqrt{3})^2} = K\frac{Q}{3L^2} = E$ at F

(f) Given that one-eighth of the sphere at point A is inside the surface, calculate the electric flux through face *CDEF*.

flux is $\frac{Q_{enc}}{\varepsilon_0}$ $\quad \frac{Q_{enc}}{A_{enc}} = \frac{Q_T}{A_T}$ $\quad Q_{enc} = \frac{A_{enc}}{A_T} Q_T = +\frac{Q}{8}$

so net flux through the cube is $\frac{Q}{8\varepsilon_0}$

flux through face CDEF, because there are three faces w/ nonzero flux positioned equivalently

is $\left(\frac{Q}{8\varepsilon_0}\right)/3 = \frac{Q}{24\varepsilon_0}$

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E&M. 1.

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(a) Use Gauss's law to prove that the electric field inside the shell is zero everywhere. Describe the Gaussian surface that you use.

$$\int \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon}$$

$$EA = \frac{q_{enc}}{\varepsilon}$$

q=0 inside shell

$$E(4\pi r^2) = \frac{q_{enc}}{\varepsilon} = \frac{0}{\varepsilon}, \quad \text{so} \quad EA = 0. \quad \boxed{\therefore E = 0.}$$

Gaussian surface: a sphere, with charge uniformly distributed over surface

(b) The charges are now redistributed so that the surface charge density is no longer uniform. Is the electric field still zero everywhere inside the shell?

✓ Yes ✓ No ____ It cannot be determined from the information given.

Justify your answer.

$$E(4\pi r^2) = \frac{q_{enc}}{\varepsilon}$$

$$q_{enc} = \sigma \cdot A$$

$$\cancel{E(4\pi r^2)} = \frac{\sigma \cancel{(4\pi r^2)}}{\varepsilon}$$

$$\sigma \neq 0$$

The charges no longer cancel out due to the symmetrical nature of the sphere since the charges are not uniformly distributed. Therefore $q_{enc} \neq 0$.

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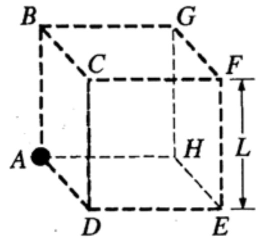
Now consider a small conducting sphere with charge $+Q$ whose center is at corner A of a cubical surface, as shown below.



(c) For which faces of the surface, if any, is the electric flux through that face equal to zero?

✓ $ABCD$ ____ $CDEF$ ____ $EFGH$ ✓ $ABGH$ ____ $BCFG$ ✓ $ADEH$

Explain your reasoning.

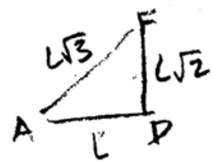
The electric field from the conducting sphere radiates perpendicular to its surface, but parallel to those 3 faces. Therefore $\Phi = 0$

(d) At which corner(s) of the surface does the electric field have the least magnitude?

$E = \frac{kQ}{r^2}$ E is minimum when r is largest, so @ $\boxed{F}$

(e) Determine the electric field strength at the position(s) you have indicated in part (d) in terms of Q, L, and fundamental constants, as appropriate.

$$E = \frac{kQ}{(\sqrt{3L^2})^2} = \boxed{\frac{kq}{3L^2}}$$



$\sqrt{L^2 + 2L^2}$

$= \sqrt{3L^2}$

(f) Given that one-eighth of the sphere at point A is inside the surface, calculate the electric flux through face $CDEF$.

$q_{\text{inside surface}} = \frac{Q}{8}$

$\Phi = \int \vec{E} \cdot d\vec{A}$

$\Phi = E(L^2)$

$\Phi = \frac{kQ}{18L^{\cancel{4}}{}_2}(\cancel{L^2})$

$$\boxed{\Phi = \frac{kQ}{18L^2}}$$

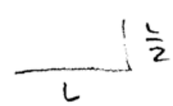
$E = \frac{k(Q/8)}{\frac{9L^4}{4}}$

$\frac{kQ}{\cancel{8}_2} \cdot \frac{\cancel{4}}{9L^4}$

$= \frac{kQ}{18L^4}$

$\frac{3L^2}{2}$ $\frac{L}{2}$

$\sqrt{\frac{5L^2}{4}}$



$\sqrt{L^2 + \frac{L^2}{4}}$

$\sqrt{\frac{5L^2}{4}}$

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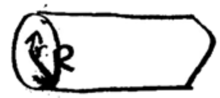
A nonconducting, thin, spherical shell has a uniform surface charge density σ on its outside surface and no charge anywhere else inside.

(a) Use Gauss's law to prove that the electric field inside the shell is zero everywhere. Describe the Gaussian surface that you use.

$\oint E \cdot dA = \frac{Q_{enc}}{\epsilon_0}$



$E(2\pi r) = \frac{0}{\epsilon_0}$

$E = 0$

using a cylinder, with radius R, the area enclosed is within the shell with radius r

(b) The charges are now redistributed so that the surface charge density is no longer uniform. Is the electric field still zero everywhere inside the shell?

X Yes ____ No ____ It cannot be determined from the information given.

Justify your answer.

Because there is only charge on the surface, so because $Q_{enc} = 0$, then $E = 0$

GO ON TO THE NEXT PAGE.

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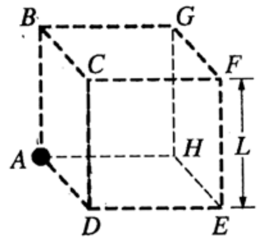


(c) For which faces of the surface, if any, is the electric flux through that face equal to zero?

X *ABCD* ____ *CDEF* ____ *EFGH* X *ABGH* ____ *BCFG* X *ADEH*

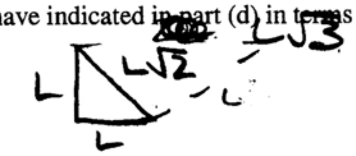
Explain your reasoning.

[redacted] because the electric field goes radially out from the sphere, it does not penetrate the cube on the 3 sides Xed through the face.

(d) At which corner(s) of the surface does the electric field have the least magnitude?

F

(e) Determine the electric field strength at the position(s) you have indicated in part (d) in terms of Q, L, and fundamental constants, as appropriate.



$$\oint E \cdot dA = \frac{Q_{enc}}{\epsilon_0}$$

$$E\left(2\pi\left(L\sqrt{3}\right)\right) = \frac{+Q}{\epsilon_0}$$

$$\boxed{E = \frac{Q}{2\sqrt{3}\pi\epsilon_0 L}}$$

(f) Given that one-eighth of the sphere at point A is inside the surface, calculate the electric flux through face *CDEF*.

$$\Phi_E = \frac{Q_{enc}}{\epsilon_0}$$

$$\boxed{\Phi_E = \frac{Q}{8\epsilon_0}}$$

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Question 1

Overview

This question assessed students' understanding of Gauss's law, the concept of electric flux, and the nature of electric fields due to charge distributions. A large part of the question concerned the idea of flux and the fact that the total flux through a closed surface is proportional to the charge enclosed by the surface.

Sample: E1A
Score: 14

The response earned all points except for 1 point in part (d) where the wrong corner is chosen (corner F). Part (e) received credit for correctly calculating the field at that point.

Sample: E1B
Score: 9

In part (a) the Gaussian surface is not correctly specified because no size is given, and it is described as charged, so only 2 points were earned. In part (b) the correct answer is selected, but the justification is not sufficient, so only 1 point was earned. Part (c) earned full credit. In part (d) the incorrect corner is chosen so no points were earned. Part (e) correctly determines the field at corner F and earned 1 point. Part (f) uses the incorrect approach of trying to evaluate the flux integral and earned no credit.

Sample: E1C
Score: 6

In part (a) the student tries to apply a cylindrical Gaussian surface. The spherical nature of the problem means that the evaluation of the flux integral is incorrect and cannot correctly be used to lead to the conclusion. Therefore no points were earned for part (a). Part (b) is incorrect and earned no credit. Part (c) is correct and earned full credit. In part (d) the wrong corner is chosen, and in part (e) the field at corner F is incorrectly calculated. No credit was earned for either part. Part (f) correctly uses the flux idea but does not try to integrate the flux integral and earned 1 point.