AP® Physics C: Electricity & Magnetism
1999 Sample Student Responses

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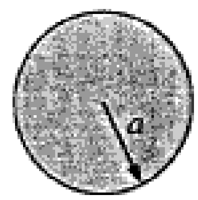
PHYSICS C

SECTION II, ELECTRICITY AND MAGNETISM

Time—45 minutes

3 Questions

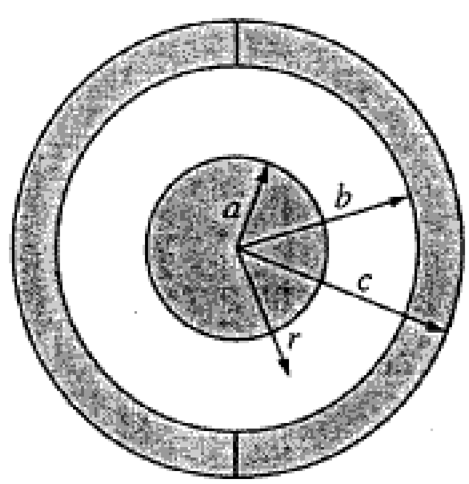
Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



E&M 1. An isolated conducting sphere of radius $a = 0.20\text{ m}$ is at a potential of $-2{,}000\text{ V}$.

(a) Determine the charge Q_0 on the sphere.

$-2000 = \frac{KQ_0}{a}$ $\quad Q_0 = -4.44 \times 10^{-8}\ C$



The charged sphere is then concentrically surrounded by two uncharged conducting hemispheres of inner radius $b = 0.40\text{ m}$ and outer radius $c = 0.50\text{ m}$, which are joined together as shown above, forming a spherical capacitor. A wire is connected from the outer sphere to ground, and then removed.

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(b) Determine the magnitude of the electric field in the following regions as a function of the distance r from the center of the inner sphere.

i. $r < a$ $\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0}$

$E = 0$ inside a conductor

ii. $a < r < b$

$$E_r(4\pi r^2) = \frac{Q_0}{\varepsilon_0}$$

$$E_r = \frac{Q_0}{4\pi\varepsilon_0 r^2} = \frac{4.44\times10^{-8}}{4\pi\varepsilon_0 r^2}$$

iii. $b < r < c$

$E = 0$ inside conductor

iv. $r > c$

$$E_r(4\pi r^2) = \frac{0}{\varepsilon_0}$$

$$E = 0$$

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(c) Determine the magnitude of the potential difference between the sphere and the conducting shell.

$$V_a - V_b = \int_a^b E_r\,dr = \frac{Q_o}{4\pi\varepsilon_o}\int_a^b \frac{1}{r^2}\,dr = \left(\frac{1}{a} - \frac{1}{b}\right)\frac{Q_o}{4\pi\varepsilon_o}$$

$$= \boxed{-999\text{ V}}$$

(d) Determine the capacitance of the spherical capacitor.

$$C = \frac{Q}{V} = \frac{4.44\times10^{-8}}{999} \Rightarrow 4.44\times10^{-11}\text{ F}$$

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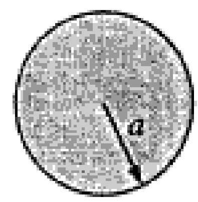


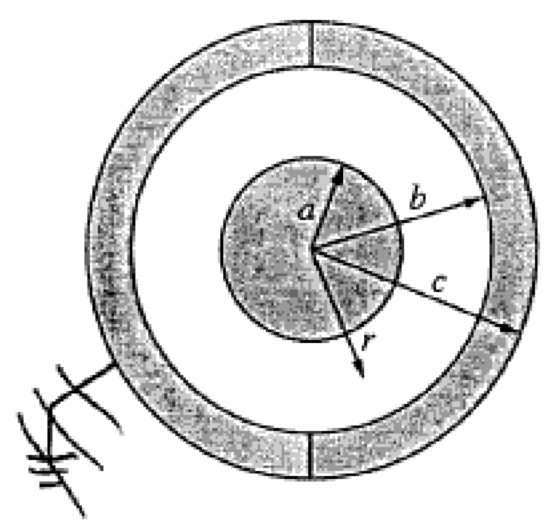
E&M 1. An isolated conducting sphere of radius $a = 0.20$ m is at a potential of $-2{,}000$ V.

(a) Determine the charge Q_0 on the sphere.

$$\left(\frac{1}{4\pi\epsilon_0}\right)\frac{q}{(.20)} = -2000$$

$$\frac{1}{4\pi\epsilon_0} q = -400$$

$$q = -4.45\times10^{-8}\,C = \boxed{-44.5\,nC}$$



The charged sphere is then concentrically surrounded by two uncharged conducting hemispheres of inner radius $b = 0.40$ m and outer radius $c = 0.50$ m, which are joined together as shown above, forming a spherical capacitor. A wire is connected from the outer sphere to ground, and then removed.

GO ON TO THE NEXT PAGE

(b) Determine the magnitude of the electric field in the following regions as a function of the distance r from the center of the inner sphere.

i. $r < a$

INSIDE CONDUCTOR $\therefore$ $\boxed{E = 0}$

ii. $a < r < b$

GO TO PART C

$\epsilon_0 \Phi = q$

$\epsilon_0 \oint E \cdot dA = q$

$\epsilon_0 (E)(4\pi r^2) = q$

$E = \frac{q}{4\pi \epsilon_0 r^2}$

$E = \frac{1}{4\pi\epsilon_0}\left(\frac{-44.5 \times 10^{-9}}{.4}\right) = \boxed{-1000.14\ N/C}$

$E = \frac{-dV}{dr} \therefore \quad E = -\frac{q}{4\pi\epsilon_0}\int_a^b \frac{dr}{r^2} = \cancel{-}\frac{q}{4\pi\epsilon_0}\left[-\frac{1}{r}\right]_a^b = \boxed{\frac{q}{4\pi\epsilon_0}\left[\frac{1}{b} - \frac{1}{a}\right]}$

iii. $b < r < c$

INSIDE CONDUCTOR $\therefore$ $\boxed{E = 0}$

iv. $r > c$

$E = \frac{1}{4\pi\epsilon_0}\left(\frac{-44.5 \times 10^{-9}}{.5}\right) = \boxed{-800.11\ N/C}$

(c) Determine the magnitude of the potential difference between the sphere and the conducting shell.

SEE b(ii)

$$\boxed{\frac{q}{4\pi\epsilon_0}\left[\frac{1}{b}-\frac{1}{a}\right]}$$

(d) Determine the capacitance of the spherical capacitor.

$$C = \frac{q}{V}$$

$$= \frac{\cancel{q}}{1}\cdot\frac{4\pi\epsilon_0}{\cancel{q}\left[\frac{1}{b}-\frac{1}{a}\right]} = \boxed{\frac{4\pi\epsilon_0}{\left[\frac{1}{b}-\frac{1}{a}\right]}}$$

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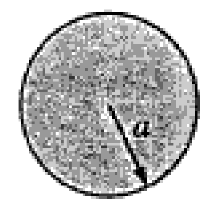
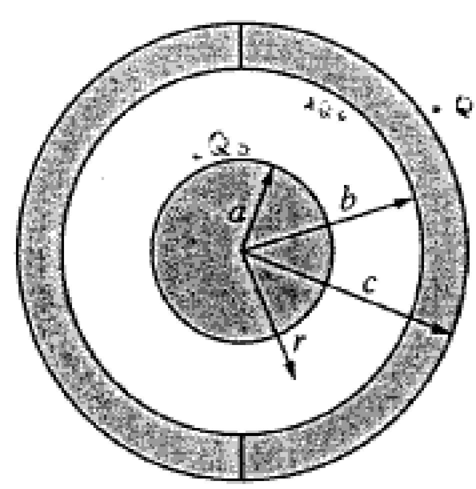


E&M 1. An isolated conducting sphere of radius $a = 0.20\text{ m}$ is at a potential of $-2{,}000\text{ V}$.

(a) Determine the charge Q_0 on the sphere.

$Ea = V = -2000 = 0.2E,\ E = -10{,}000\text{ N/C}$

$-10{,}000 = \frac{Q_0}{4\pi\epsilon_0 a^2},\ Q_0 = -4.448 \times 10^{-8}\text{ C}$



The charged sphere is then concentrically surrounded by two uncharged conducting hemispheres of inner radius $b = 0.40\text{ m}$ and outer radius $c = 0.50\text{ m}$, which are joined together as shown above, forming a spherical capacitor. A wire is connected from the outer sphere to ground, and then removed.

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(b) Determine the magnitude of the electric field in the following regions as a function of the distance r from the center of the inner sphere.

i. $r < a$

$E = 0$, because of it being inside a conductor.

ii. $a < r < b$

$E \cdot 4\pi r^2 = \frac{Q_0}{\epsilon_0}$, $E = \frac{Q_0}{4\pi\epsilon_0 r^2}$

iii. $b < r < c$

$E = 0$, becouse of it being inside a conductor.

iv. $r > c$

$E = \frac{Q_0}{4\pi\epsilon_0 r^2}$

(c) Determine the magnitude of the potential difference between the sphere and the conducting shell.

$$\Delta V = -\int_a^b E\,dr = -\int_a^b \frac{Q_0}{4\pi\epsilon_0 r^2}dr$$

$$\Delta V = -\frac{Q_0}{4\pi\epsilon_0}\int_a^b \frac{dr}{r^2}$$

$$\Delta V = \frac{Q_0}{4\pi\epsilon_0 r}\Big|_a^b$$

$$\Delta V = \frac{Q_0}{4\pi\epsilon_0}\left(\frac{1}{b}-\frac{1}{a}\right)$$

(d) Determine the capacitance of the spherical capacitor.

$$Q_0 = CV, \quad C = \frac{Q_0}{V} = \frac{-4.448\times10^{-8}\,C}{-2000\ V}$$

$$C = 2.224\times10^{-11}\ \text{Farads}$$