Phys212 Test I, Fall 2004

For #3-#7, circle the best answer. (4 pts each, no partial credit)

1. Two electric charges of $-Q$ and $+Q$ are arranged as shown in the figure. What is the direction of the electric field at point P?

   answer:
   
   A: ← E: ←
   B: ↑ F: ↑
   C: → G: →
   D: ↓ H: ↓

2. Eight coulombs of charge is spread uniformly throughout a box measuring 2m x 1m x 2m. What is the most appropriate charge density to describe this cube?

   answer:
   
   A: $\lambda = 2 \text{ C/m}^3$ D: $\lambda = 8 \text{ C}$ G: $\lambda = 32 \text{ C/m}^3$
   B: $\sigma = 2 \text{ C/m}^3$ E: $\sigma = 8 \text{ C}$ H: $\sigma = 32 \text{ C/m}^3$
   C: $\rho = 2 \text{ C/m}^3$ F: $\rho = 8 \text{ C}$ I: $\rho = 32 \text{ C/m}^3$

3. Within the volume of a conductor, which of the following is true about the electric field (E), electric potential (V), and charge density within the conductor ($\rho$)?

   answer:
   
   A: $E=0$, $V=0$, $\rho=0$ E: $E=\text{constant}$, $V=0$, $\rho=0$
   B: $E=0$, $V=0$, $\rho=\text{constant}$ F: $E=\text{constant}$, $V=0$, $\rho=\text{constant}$
   C: $E=0$, $V=\text{constant}$, $\rho=0$ G: $E=\text{constant}$, $V=\text{constant}$, $\rho=0$
   D: $E=0$, $V=\text{constant}$, $\rho=\text{constant}$ H: $E=\text{constant}$, $V=\text{constant}$, $\rho=\text{constant}$

4. Two charges are fixed in the positions shown. Where could a third charge be placed so that it has no net force acting on it?

   answer:
   
   A B C D E
5. In the figure below a positive charge of Q lies at the center of an uncharged conductor. Rank the electric fields in each of the three locations in order of increasing E-field magnitude.

answer:
A: $E_1 > E_{II} > E_{III}$
B: $E_1 > E_{III} > E_{II}$
C: $E_{II} > E_1 > E_{III}$
D: $E_{II} > E_{III} > E_1$
E: $E_{III} > E_1 > E_{II}$
F: $E_{III} > E_{II} > E_1$

6. Consider a hollow conducting sphere which has a total charge of $-Q$. Where is the electric potential equal to zero?

A: directly at the center
B: between the center and the inside surface
C: at the inside surface
D: inside the conductor (between the inside and outside surfaces)
E: at the outside surface
F: beyond the outside surface
G: infinitely far away from the sphere

7. Two charged conducting spheres of different size are attached using a thin conducting wire. Compare the electric potential of the two spheres:

answer:
A: $V_A = 4V_B$
B: $V_A = 2V_B$
C: $V_A = V_B$
D: $V_A = (1/2)V_B$
E: $V_A = (1/4)V_B$
F: Cannot be compared without knowing the amount of charge on each sphere
Show your work and/or explain your answers.
You should draw a meaningful figure for ALL problems.
Make sure you answer the question and use appropriate units if needed!!!

(11pts) (similar to example #9)
8. A charge is uniformly distributed along a line of length \( L \) such that the charge density is \( \lambda \). What is the \( x \)-component of the electric field at the point indicated below? Express your answer in terms of \( \lambda, L, s \) and any needed constants.

\[
\begin{align*}
dy &= \lambda \, dx \\
\frac{r_x}{F} &= \frac{-x}{\sqrt{x^2 + s^2}} \\
r^2 &= x^2 + s^2
\end{align*}
\]

\[
E = \int_{-L}^{0} k_e \frac{\lambda \, dx}{(x^2 + s^2)^{3/2}}
\]

\[
= k_e \lambda \left[ \frac{1}{\sqrt{x^2 + s^2}} \right]_{-L}^{0}
\]

\[
\vec{E} = k_e \lambda \left[ \frac{1}{s} - \frac{1}{\sqrt{L^2 + s^2}} \right] x
\]
Electric charge is distributed uniformly along two sides of a square. One side has a linear charge density of $\lambda$ and the other side has a charge density of $-\lambda$. The square has sides of length $w$. Find the $x$- and $y$-components of the electric field at the center of the square.

\[ E = 2k\varepsilon \frac{A}{d \sqrt{4d^2 + L^2}} \]

\[ d = \frac{w}{2} \]

\[ A = \lambda L \]

\[ E = 2k\varepsilon \frac{\lambda L}{\frac{w}{2} \sqrt{4 \left(\frac{w}{2}\right)^2 + L^2}} = \frac{4k\varepsilon \lambda}{L \sqrt{L^2}} \]

\[ = \frac{2\sqrt{2} k\varepsilon \lambda}{L} \]

\[ E_x = -\frac{2\sqrt{2} k\varepsilon \lambda}{L} \]

\[ E_y = -\frac{2\sqrt{2} k\varepsilon \lambda}{L} \]
10. A line charge of -2 nC/m lies along the axis of an infinite conducting hollow cylinder shell of inner radius 2 cm and outer radius 3 cm. A charge density of +4 nC/m lies on the conducting hollow cylinder. Find the electric field at a distance of 5 cm from the axis.

\[
E = \frac{\sigma_{\text{coul}}}{\varepsilon_0}
\]

\[
E(2\pi r) = \frac{q_{\text{int}} + q_{\text{ext}}}{\varepsilon_0}
\]

\[
E = \frac{2q_{\text{int}}}{2\pi \varepsilon_0 d}
\]

\[
E = \frac{-2 \times 2 \times 10^{-9}}{2 \pi \times 10^{-6} \times 0.05} = -720 \text{ N/C}
\]

The electric field is directed inward.
An object with a charge of $3 \, \mu C$ and a mass of $7 \, g$ is initially located on the axis of a ring but very far from the center of the ring. The ring is fixed in space and has a charge of $12 \, mC$ and a radius of $11 \, cm$. If the object is given an initial speed toward the center of the ring of $900 \, m/s$, how close to the center of the ring will the object get?

\begin{align*}
\frac{1}{2} m v_f^2 &= \frac{1}{2} m v_i^2 + q \left( \frac{keQ^2}{(d^2 + R^2)^{3/2}} \right) \\
\sqrt{d^2 + R^2} &= \frac{2keQ^2}{m v_i^2} \\
d &= \sqrt{\left(\frac{2keQ^2}{m v_i^2}\right)^2 - R^2} \\
&= 0.031 \, m
\end{align*}

$3.1 \, cm = d_f$