Physics 126 Spring 2009
Exam 1
Name:

Time Allowed: 2 hours
Credits for numerical questions require evidence of calculation

Some Physics Constants:
- Electronic charge: \( e = 1.6 \times 10^{-19} \text{ C} \)
- Coulomb constant: \( k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2 \)
- Permittivity of free space: \( \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2 \)
- Mass of electron: \( m_e = 9.11 \times 10^{-31} \text{ kg} \)
- Mass of proton: \( m_p = 1.67 \times 10^{-27} \text{ kg} \)

PART A (70 points)

Circle the correct answer for the next 14 questions, worth 5 points each.

1. A negatively charged rod was brought near an uncharged sphere permanently connected to ground with a metal wire. The rod was never in contact with the sphere, and it was then withdrawn. Afterwards, the charge on the sphere was
   - (A) Zero
   - (B) Positive
   - (C) Negative
   - (D) Unknown, depending how close the rod was brought near the sphere

2. Two electrically neutral objects A and B are rubbed against each other. Afterwards, the charge on A is found to be \( +800 \text{nC} \). Assuming that the charging is due to transfer of electrons, how many have been transferred and from which object?
   - (A) \( 5 \times 10^{12} \), from B
   - (B) \( 5 \times 10^{12} \), from A
   - (C) \( 5 \times 10^{11} \), from B
   - (D) \( 5 \times 10^{11} \), from A

3. Three identical charge-bearing metallic spheres are brought into contact with each other and then separated. They are then found to all carry the same charge of \( +2 \mu \text{C} \). It is also known that the initial charges on A and B are \( +5 \mu \text{C} \) and \( -2 \mu \text{C} \) respectively. What is the initial charge on C?
   - (A) \( +1 \mu \text{C} \)
   - (B) \( -2 \mu \text{C} \)
   - (C) \( +3 \mu \text{C} \)
   - (D) \( -4 \mu \text{C} \)

\[ \sum Q = \sum Q \]
\[ \text{before} \quad \text{after} \]
\[ 5 + (-2) + x = 3 \times 2 \]
\[ x = 3 \]
4. If the distance apart is the same, which pair of charges would yield the greatest repulsive force?

\[
\frac{1}{r} \propto \frac{|q_1| |q_2|}{d^2}
\]

(A) +4q and -5q
(B) +2q and +8q
(C) +q and +17q
(D) -3q and -6q

5. A point charge A of 5nC near a negative point charge B is moved away so that their distance apart becomes four times as much as before. If the charge on A can change, what should it become so that the force becomes repulsive and has the same magnitude as before?

\[
\frac{q_A}{(4d)^2} = \frac{1}{d^2}
\]

\[q_A = 4^2 \times 5 = 20\ nC\]

6. An electron travels in a circular orbit of radius \(4 \times 10^{-11}\ m\) around a bare nucleus of \(^8O^{16}\). How large is the force of attraction on the electron due to the nucleus?

\[
F = \frac{9 \times 10^9 \times \frac{8 \times 1.6 \times 10^{-19}}{4 \times 10^{-11}} \times 1.6 \times 10^{-19}}{(4 \times 10^{-11})^2}
\]

\[= 1.2 \times 10^{-7}\ N\]

7. In gold (\(^{79}Au^{197}\)) metal, each atom loses two electrons to become the sea of free electrons. What would be the charge on a 5g sample of gold if all the free electrons are removed from it?

\[
\frac{5}{19.7} \times 6 \times 10^{23} \times 2 \times 1.6 \times 10^{-19} = 4.473\ C
\]
8. If it is desired to push a point charge of \(-3nC\) toward the NE direction with a force of \(240\mu\text{N}\) from an electric field, the magnitude and direction of the electric field should be

\[
\left| \vec{E} \right| = \frac{F}{q} = \frac{240 \times 10^{-6}}{3 \times 10^{-9}} = 8 \times 10^4 \text{ N/C}
\]

(A) \(7.2 \times 10^8 \text{ N/C} \) pointing NE
(B) \(7.2 \times 10^8 \text{ N/C} \) pointing SW
(C) \(8.0 \times 10^4 \text{ N/C} \) pointing NE
(D) \(8.0 \times 10^4 \text{ N/C} \) pointing SW

9. Sketch 12 electric field lines for the three point charges as shown that reflect the relative strength of the charges.

10. An electric field line is always drawn with an arrow. What information does the arrow carry?

\(\text{gives the direction of the electric field}\)

11. The diagram below shows two infinite charged sheets. The left sheet carries a charged density of \(+4 \times 10^{-7} \text{ C/m}^2\) while the right sheet carries \(-8 \times 10^{-7} \text{ C/m}^2\). What is the magnitude and direction of the electric field at a point to the right of both sheets?

\[
\left| \vec{E}_L \right| = \frac{\sigma}{2\varepsilon_0} = \frac{4 \times 10^{-7}}{2 \times 8.85 \times 10^{-12}} \text{ to the right}
\]

\[
\left| \vec{E}_R \right| = \frac{\sigma}{2\varepsilon_0} = \frac{8 \times 10^{-7}}{2 \times 8.85 \times 10^{-12}} \text{ to the left}
\]

\[
\therefore \left| \vec{E} \right| = \left| \vec{E}_R - \vec{E}_L \right| = \frac{4 \times 10^{-7}}{2 \times 8.85 \times 10^{-12}} = 2.3 \times 10^4 \text{ N/C} \text{ to the left}
\]

(A) \(2.3 \times 10^4 \text{ N/C} \) to the right
(B) \(2.3 \times 10^4 \text{ N/C} \) to the left
(C) \(4.6 \times 10^4 \text{ N/C} \) to the right
(D) \(4.6 \times 10^4 \text{ N/C} \) to the left
12. An oil drop of mass 2.5 ng captures two electrons from air ionized by X-ray. What is the direction and magnitude of an electric field that will cause it to suspend in air?

\[ 2.5 \text{ ng} = 2.5 \times 10^{-9} \text{ g} = 2.5 \times 10^{-12} \text{ kg} \]

\[ (2e)E = mg \]

\[ E = \frac{mg}{2e} = \frac{2.5 \times 10^{-12} \times 9.8}{2 \times 1.6 \times 10^{-19}} \]

\[ = 7.7 \times 10^{7} \ \text{N/C} \]

(A) \( 3.9 \times 10^{6} \ \text{N/C} \) upward
(B) \( 3.9 \times 10^{6} \ \text{N/C} \) downward
(C) \( 7.7 \times 10^{7} \ \text{N/C} \) upward
(D) \( 7.7 \times 10^{7} \ \text{N/C} \) downward

13. The diagram shows three point charges in space, and a spherical surface enclosing two of them. What is the electric flux through the surface?

\[ \Phi = \frac{q \cos \theta}{\varepsilon_0} \]

(A) \( \frac{q}{\varepsilon_0} \)
(B) \( \frac{2q}{\varepsilon_0} \)
(C) \( \frac{3q}{\varepsilon_0} \)
(D) 0

14. The figure shows four point charges at the corners of a square.

Sketch the electric field vector at the center of the square.
PART B (30 points)

15. The diagram below shows a point charge \( A +20nC \) at the point \( x = 4m, y = 0 \) and another \( B \) of \(-2nC \) at \( x = -2m, y = 0 \).

(a) Find the magnitude and direction of the electric field at the origin. (5 points)

\[
\begin{align*}
E_A &= 9 \times 10^9 \times \frac{20 \times 10^{-9}}{4^2} = 11.25 \text{ N/C to the left} \\
E_B &= 9 \times 10^9 \times \frac{2 \times 10^{-9}}{2^2} = 4.5 \text{ N/C to the left} \\
\end{align*}
\]

(b) Find the magnitude of the electric field at the point \( x = -2m, y = 2m \). (7 points)

\[
\begin{align*}
|E_A| &= 9 \times 10^9 \times \frac{20 \times 10^{-9}}{(\sqrt{40})^2} = 4.5 \text{ N/C} \\
|E_B| &= 9 \times 10^9 \times \frac{2 \times 10^{-9}}{2^2} = 4.5 \text{ N/C} \\
\end{align*}
\]

\[
\begin{array}{c|c|c}
\text{x < 2m} & \text{y < 2m} & \text{4 - x > 5} \\
\text{E}_A & -4.5 \cos \theta = -4.5 \frac{6}{\sqrt{40}} = -4.27 & -4.5 \sin \theta = -4.5 \frac{2}{\sqrt{40}} = -1.42 \\
\text{E}_B & 0 & 4.5 \\
\text{E} & -4.27 & 3.09 \\
\text{E} & \sqrt{(-4.27)^2 + 3.09^2} = 5.26 \text{ N/C} \\
\end{array}
\]

(c) Choose one of the following answers (3 points): The electric field can be zero at a point in

(1) Region I where \( x < -2m \)
(2) Region II where \(-2m < x < 4m\)
(3) Region III where \( 4m < x \)
(4) Nowhere
16. The diagram below shows two charged sheets separated by a distance of 5 mm. Each sheet is 30 cm × 30 cm in area. They carry charges of equal magnitude but opposite signs. It is found that the electric field between the sheets is 8000 N/C directed from right to left. Neglect gravity in the following problems.

(a) What is the total charge on the left sheet? (5 points)

\[ |\mathbf{E}| = \frac{|q|}{\varepsilon_0} \]

\[ |\mathbf{E}| = 8.85 \times 10^{-12} \times 8000 = 7.1 \times 10^{-8} \text{ C/m}^2 \]

\[ |q| = |\mathbf{E}| A = 7.1 \times 10^{-8} \times 0.3 \times 0.3 = 6.4 \times 10^{-9} \text{ C} \]

\[ q = -6.4 \times 10^{-9} \text{ C} \]

(b) If an electron is introduced at rest at a point midway between the sheets, what is the direction of its acceleration? What is the velocity of the electron when it reaches one of the sheets? (5 points)

\[ \text{Accel. is to the right} \]

\[ a = \frac{F}{m} = \frac{eE}{m} = \frac{1.6 \times 10^{-19} \times 8000}{9.1 \times 10^{-31}} = 1.4 \times 10^{-15} \text{ m/s}^2 \]

\[ v^2 = u^2 + 2ax = 2ax \]

\[ v = \sqrt{2ax} = \sqrt{2 \times 1.4 \times 10^{-15} \times 2.5 \times 10^{-3}} = 2.7 \times 10^{-6} \text{ m/s} \]

(c) If a third sheet is placed to the right of both sheets, what charge should it carry so that when the electron is introduced at rest anywhere between the first two sheets, it will remain stationary? (5 points)

\[ \text{Electric field due to third sheet} = 8000 \text{ N/C to the right.} \]

\[ |\mathbf{E}| = 2 \times 8.85 \times 10^{-12} \times 8000 = 1.4 \times 10^{-7} \text{ C/m}^2 \]

\[ |q_3| = |\mathbf{E}| A = 1.4 \times 10^{-7} \times 0.3 \times 0.3 = 1.3 \times 10^{-8} \text{ C} \]

\[ q_3 = -1.3 \times 10^{-8} \text{ C} \]