Name ______________________
Test 1 - February 10, 2012

This test consists of three parts. Please note that in parts II and III, you can skip one question of those offered.

**Possibly useful formulas:**

<table>
<thead>
<tr>
<th>Constants</th>
<th>Charge on Surface of Conductor</th>
<th>Parallel Plate Capacitor</th>
<th>Energy in a Capacitor</th>
<th>Dipoles</th>
</tr>
</thead>
<tbody>
<tr>
<td>( e = 1.602 \times 10^{-19} \text{C} )</td>
<td>( E = \frac{\sigma}{\varepsilon_0} \hat{n} )</td>
<td>( C = \frac{Ake_0}{d} )</td>
<td>( U = \frac{1}{2} C (\Delta V)^2 )</td>
<td>( \tau = p \times E )</td>
</tr>
<tr>
<td>( k_e = 8.988 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 )</td>
<td>( \varepsilon_0 = 8.854 \times 10^{-12} \text{C}^2/\text{N} \cdot \text{m} )</td>
<td>( u = \frac{1}{2} \varepsilon_0 E^2 )</td>
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<tr>
<td>( k_e = 1/4\pi\varepsilon_0 )</td>
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**Part I: Multiple Choice [20 points]**

For each question, choose the best answer (2 points each)

1. If you place some charge on a solid conducting sphere, the charge will move to
   A) The center
   B) The surface
   C) It will be uniformly distributed throughout
   D) Wherever you put it, since charges don’t move in a conductor
   E) California

2. How do the charge of the proton and electron compare?
   A) The magnitude of the proton’s charge is greater
   B) The magnitude of the electron’s charge is greater
   C) They are equal in magnitude, and both are positively charged
   D) They are equal in magnitude, and both are negatively charged
   E) They are equal in magnitude, but opposite in sign.

3. In the sketch at right, the electric field is in the +x direction, and the rectangle drawn is in the xy-plane with a unit normal in the +z direction. The total electric flux across the rectangle will be
   A) Positive  B) Negative  C) Zero  D) Insufficient information
   E) I have no idea

4. What is the significance of the circuit symbol sketched at right?
   A) Anything attached here has potential zero
   B) Anything attached here has no charge
   C) Anything attached here is a conductor
   D) This is a switch, meaning it can either be connected or disconnected
   E) This is a capacitor, which stores charge

5. The unit of electric potential is
6. What effect does putting some sort of material between the two plates of a parallel plate capacitor generally have on the capacitance?
   A) It increases it
   B) It decreases it
   C) It leaves it unchanged
   D) It can either increase or decrease it, depending on the material
   E) It decreases it or leaves it the same, depending on the material

7. If you are just outside the surface of a conductor, which direction will the electric field point?
   A) It will always point outwards
   B) It will always point inwards
   C) It will point away from the conductor if the surface charge is positive, and toward it if the surface charge is negative
   D) It will point toward the conductor if the surface charge is positive, and away from it if the surface charge is negative
   E) It will point parallel to the surface of the conductor

8. Suppose we have two equal and opposite point charges \( +Q \) and \( -Q \). Which of the following is true of the point exactly half way between them?
   A) The electric field and electric potential will both be zero
   B) The electric field and electric potential will both not be zero.
   C) The electric field will be zero, but the potential will not
   D) The electric potential will be zero, but the electric field will not
   E) There is insufficient information to know for sure.

9. A charge \( Q \) is placed in a spherical region of unknown radius, but not necessarily at the center. What additional information is needed to determine what the total electric flux out of the region is?
   A) You need to know the radius of the sphere, and the exact position of the charge
   B) You need to know the radius of the sphere, but not the position of the charge
   C) You need to know the distance of the charge from the center of the sphere
   D) You need to know the ratio of the distance of the charge to the radius
   E) You don’t need any additional information

10. Which of the following is not true about how materials become charged?
    A) Most ordinary objects contain a very large number of positive charges
    B) Most ordinary objects contain a very large number of negative charges
    C) An object could become positively charged by removing electrons from it
    D) An object could become negatively charged by adding electrons to it
    E) When an object becomes charged, most of the electrons in it have been removed or added

**Part II: Short answer [20 points]**
Choose two of the following questions and give a short answer (2-3 sentences) or brief sketch (10 points each).

11. Sketched at right are the electric field lines from a pair of point charges A and B. What is the sign of each charge, which charge is larger, and how much bigger (approximately) is the larger charge?

12. Using the same diagram as for question 11, sketch in the approximate equipotential lines. Include 3 or more curves, and indicate which ones represent the highest potential and which the lowest potential.

13. Explain qualitatively what an electric dipole is. If a dipole is placed in a constant electric field, what will the total force on the dipole be? Will there be any sort of other forces (not net force) on it?
Part III: Calculation: [60 points]

Choose three of the following four questions and perform the indicated calculations (20 points each)

14. Four point charges are arranged in the xy-plane as sketched at right, two of magnitude $+6.00 \mu C$ and two of magnitude $-6.00 \mu C$, all a distance 5.0 cm from the origin.
   (a) Find the magnitude and direction of the electric field at the origin.
   (b) A point charge of magnitude $-1.00 \mu C$ and mass 1.00 g is placed at the origin. Find the force on the charge (magnitude and direction) and the acceleration of the point charge (magnitude and direction).
15. A long thin cylinder has a uniform charge on it. It is 1.0 cm in radius and 10.0 m in length. It is then surrounded by a neutral hollow conducting cylinder with inner radius 2.0 cm and outer radius 3.0 cm, also of length 10.0 m. It is observed that at a distance of 4.0 cm from the axis of the cylinder, the electric field is 50.0 kV/m, oriented outwards. This field is nearly constant along the entire length of the cylinder.

(a) What is the total charge of the cylinder of charge?

(b) What is the electric field \( E \) a distance \( r = 2.5 \) cm from the axis (inside the conductor)?

(c) What is the total charge on the interior surface of the hollow conducting cylinder?
16. A ring of total charge $Q = 2.00 \, \mu \text{C}$ and radius $a = 3 \, \text{cm}$ is arranged in the $xy$-plane, centered on the origin.
(a) Find a formula for the potential $V$ at a point on the $z$-axis a distance $z$ from the origin.
(b) A particle of mass $m = 3.00 \, \text{g}$ and charge $q = 1.00 \, \mu \text{C}$ is launched from $z = 4.0 \, \text{cm}$ towards the center of the ring along the $z$-axis. Find the minimum velocity $v$ such that it can reach and pass through the center of the ring.
17. Three capacitors, initially uncharged, are connected to a switch and a battery as shown at right. Two capacitors $C_1$ and $C_2$ are of known capacitance, and a third $C_3$ is of unknown capacitance. Initially, the switch is open and the capacitors are uncharged.

(a) When the switch is closed, a total of 750 $\mu$C of charges flow out of the battery and into the system of capacitors. What must be the effective capacitance of the whole combination of the three capacitors?

(b) What is the capacitance of the unknown capacitor $C_3$?

(c) What is the total amount of energy stored in the capacitors?