PHYS-115(3) (Kaldon-16406) **Name** _____
WMU - Winter 2001
Exam 1 - 100,000 points **Book Title** _____
Section: **3a** A to F **3b** G to M **3c** N to S **3d** T to Z

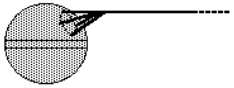
Sample Exam Rev. 1/31/01

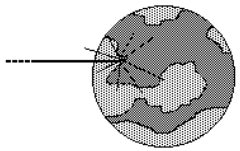
State Any Assumptions You Need To Make -- Show All Work -- Circle Any Final Answers
Use Your Time Wisely - Work on What You Can - Be Sure to Write Down Equations
BOLDFACE Variables Are Vectors - Feel Free to Ask Any Questions

"You Can't Imagine the Power of the Dark Side of the Coulomb Force!" (25,000 points)

1.) (a) In class Dr. Phil commented that it is very important the charge of the electron (-e) and the proton (+e) are exactly the same magnitude. Suppose this is not true. Suppose that the charge on the electron was slightly different than that on the proton. List three things that would be different in our universe.

(b) In the dark cold of space, Darth Vader's Death Star silently approaches a rebel planet. At 100,000 km above the center of the planet, the Death Star fires a beam of "something" at the unsuspecting planet. What could the evil Empire be using as a weapon? How about charge? (I know, it's a stretch considering the material in Physics 106.) Suppose they transferred 1.576×10^{44} electrons ($Q = -2.536 \times 10^{25}$ C) from the Death Star (mass = 2.68×10^{17} kg) to the planet. Find the acceleration of the Death Star toward the planet.



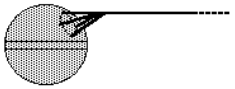


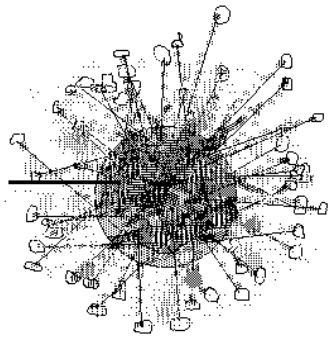
"You're Our Only *Hope*, Obi-Wan Kenobi..." (continued)

(c) As evil as they are, the Imperial scientists are not idiots. Suppose that the Death Star beam works to somehow "turn off" the charge on all the electrons. For every gram of matter, there would be one mole (6.02×10^{23}) of these electron charges suddenly made to go to a charge of zero. If the mass of the planet is 5.55×10^{24} kg, find the total number, N, of these planetary electrons; the total charge on the planet, Q; and the charge density, ρ. ($R_{planet} = 6.16 \times 10^{6}$ m; $V_{sphere} = 4/3\ \pi\ r^3$).

(d) Use Gauss' Law to find the E-field on the surface of the planet, using the new charge density ρ.

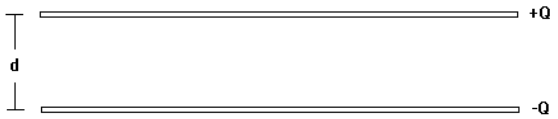
(e) Find the acceleration of a proton ($m_p = 1.67 \times 10^{-27}$ kg) that is on the planet's surface.





Just Pull Out Your Credit Card and Say, *"Charge It, Please!"* (25,000 points)

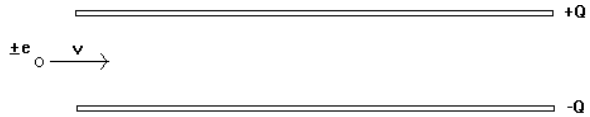
2.) (a) Two charged plates are separated by a distance of $d = 1.00$ mm $= 0.00100$ m. In the diagram below, sketch in relevant electric field lines (use *solid* lines) and equipotential lines (use *dashed* lines).



(b) If the two plates are separated by air, what is the maximum potential difference, V_{MAX} , between the plates? What is the maximum magnitude of the electric field, E?

(c) Use Gauss' Law to find the surface charge, σ, on the plates.

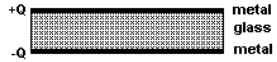
(d) First an electron ($m_e = 9.11 \times 10^{-31}$ kg) and then a proton ($m_p = 1.67 \times 10^{-27}$ kg) are shot right between the plates, at a speed of v = 1000 m/s. On the diagram below, sketch an approximate path of the electron (use *solid* lines) and the proton (use *dashed* lines).



(e) If the plates are 1.000 m long, how far is the electron deflected from its original path? How far is the proton deflected?

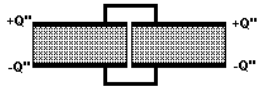
Batman Returns Forever (25,000 points)

3.) In the movie Batman Returns from a couple of years ago, Michelle Pfeiffer's character gets into trouble because she saw the plans for a building her evil boss was constructing to "steal all the power from Gotham City" and determined that these plans were for "a giant capacitor". Consider a parallel plate capacitor that is building sized: length = 100 m, width = 50.0 m, plate separation = 30.0 m. Find (a) the capacitance, C, and charge Q on the plates if the voltage difference is V = 125,000 volts, and the capacitor is filled with glass ($\kappa = 4.7$; dielectric strength = 14×10^6 V/m) acting as a dielectric between the plates.



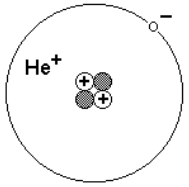
(b) Rather than making just one big capacitor to fill a building, suppose we stack a two identical capacitors in the building. Find the capacitance of just one of these capacitors. Use the length and width of the building from above. (c) Determine whether this arrangement is parallel or series, then find Q′ and V′ for each capacitor, and C_{eq} for the pair of capacitors.

(d) On the other hand, suppose we set two identical capacitors side by side in the building. Find the capacitance of just one of these capacitors. Use the length and width of the building from above. (e) Determine whether this arrangement is parallel or series, then find Q′′ and V′′ for each capacitor, and C_{eq} for the pair of capacitors.



The Atoms Family (25,000 points)

4.) A helium ion, He^+, consists of two protons and two neutrons in the nucleus, and a single electron orbiting around outside. (a) Find the electric field, E, at a point 1.00 m from this ion.



The two protons are about 1 fermi apart. This is 1 femtometer or 1.00×10^{-15} m. (b) Find the electric force between the two protons, and (c) find the initial acceleration of one of the protons assuming that there was no strong nuclear force from the neutrons holding the nucleus together.

(d) If we take a classical view of the atom, then the electron in orbit ($r = 1$ Å $= 1.00 \times 10^{-10}$ m) is in Uniform Circular Motion: $a_c = v^2/r$. Find the centripetal force on the electron.

(e) Find the speed of the electron.

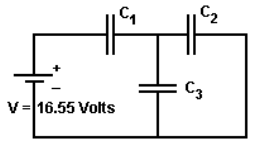
Star Trek Science (40,000 points)

5.) As pointed out in class, not everything in science fiction is scientifically accurate. Take *Star Trek,* for example. The *USS Enterprise* (right) can apply a *tractor beam* on the Klingon warship (left), which applies an attractive force. We can actually make something like a tractor beam, if the *Enterprise* transfers some electrons to the Klingon. (a) If both ships started out as charge neutral, each has a mass of 20,000 metric tons (20×10^6 kg) and are one kilometer (1000 m) apart, find the acceleration between them after -5.00 C of electrons are transferred.

(b) The electrons are accelerated through a potential difference of 2.20×10^6 V. Find the speed of the electrons, using $K = \frac{1}{2} mv^2$. Determine if the final speed of the electrons is relativistic (more than 42% the speed of light).

"We Hold These Truths To Be Self-Evident, That All Q's Are Created Equal" (25,000 points)

6.) If $C_1 = 125$ pF, $C_2 = 175$ pF, $C_3 = 225$ pF, then (a) find the equivalent capacitance of this circuit, (b) the potential difference across each capacitor (V_1, V_2, V_3) and (c) the charge stored on each capacitor (Q_1, Q_2, Q_3).



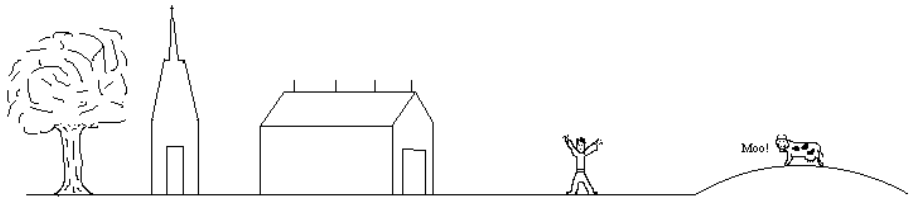
Shocking (50,000 points)

7.) A spark will jump a gap in air, if the electric field exceeds $E = 3 \times 10^6$ V/m. If lightning jumped in a *straight* path between the cloud and the ground, then we could figure out the potential difference between a cloud that is 1.00 km (1000 m) above the ground. (a) Find V (or we could call it ΔV).

(b) Real lightning actually only travels over shorter distances which link together to form the ragged pattern we normally associate with lightning. If the voltage difference over a segment of a lightning bolt is 1,000,000 volts, how long is the segment?

(c) This cloud had -5.00 C of charge along its bottom, 1000 m above the ground. Suppose a charge +Q is induced in the surface of the earth directly below the cloud, that is equal and opposite to the charge of the cloud. Find the strength of the electric force, F_E, between the earth and the cloud, and explain whether the force is attractive or repulsive. *Treat the cloud and charge on the ground as if they were point charges.*

(d) One of the consequences of Gauss' Law is that charge tends to accumulate on sharp tips, rather than on long sides of things. The E-field is a maximum at the tip, too. Why would this make it more likely for lightning to hit trees, church steeples, people standing out in fields, lightning rods on the roof of a barn and cows grazing on a hilltop?



***"Hot Dogs! Getcher Red Hot, Hot Dogs! Rightchere!"* (50,000 points)**

8.) (a) Consider a hot dog that has been in its package long enough so that it is roughly rectangular in shape (length = 13.0 cm, ends 2.50 cm × 2.50 cm). It is filled with the usual assortment of stuff that makes up a hot dog, and has a dielectric constant, $\kappa = 35.5$. The capacitance of this hot dog is $C_1 = 1.51$ *pF*, if we go from left to right. (a) Find the capacitance, C_2 of this hot dog if we go from top to bottom.

(b) There are typically eight hot dogs in a pack. Draw a circuit diagram which has a 12.0 volt battery, then four capacitors all in series, and then four capacitors in parallel, in series with the first four. Find the equivalent capacitance of the hot dogs and the charge *Q* stored on this equivalent capacitor. *All the hot dogs have C = 1.51 pF.*

(c) How much energy is stored in this hog dog capacitor? *If you did not get an answer to (b), use* $C_{eq} = 1.51$ *pF.*