Print your name clearly:____

Signature:____

"I agree to abide by the Duke Community Standard and will neither give nor receive aid during this quiz."

Physics 162: Quiz 1

Professor Greenside
Friday, January 16, 2015

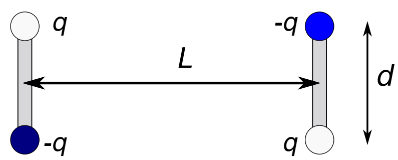
This 30-minute quiz is closed book and nothing is allowed on your desk except items to write with. If you have any questions about the wording of the quiz, please don't hesitate to ask during the quiz.

Please write *all* answers (including true-false) on the blank pages handed out in class. You need to write your name and problem number on each page and staple all of your pages together at the end of the quiz.

Unless stated otherwise, you need to justify your reasoning, e.g., with brief phrases and drawings; a correct answer without some explanation will get zero credit. If your answers are not *easily* readable and understandable by the grader, you will lose credit and possibly get no credit.

Quantitative Problems

1. Neutral diatomic molecules that contain different kinds of atoms (e.g., hydrogen chloride HCl) usually have nonuniform charge distributions and so act as electric dipoles because some atoms attract electrons more strongly (are more electronegative) than others. Consider two identical electric dipoles that are antiparallel and whose centers are separated by a distance L as shown here:



The molecules are idealized as consisting of a thin insulating non-polarizable rigid rod of length d that has point charges of $q > 0$ at one end and charge $-q$ at the other end as indicated.

(a) **(3 points)** Briefly and qualitatively explain whether the two dipoles are attracted or repelled from one another.

(b) **(3 points)** Briefly and qualitatively explain whether the dipoles will start to rotate about their centers and, if so, which way (clockwise or counterclockwise).

(c) (**6 points**) Obtain and give an explicit expression for the total force vector $\mathbf{F}$ (magnitude and direction) acting on the right dipole in terms of the parameters K, q, d, and L, where K is Coulomb's constant.

(d) **(8 points)** Assuming that the dipoles are far apart compared to their size, $L \gg d$, use the generalized binomial theorem

$$(1+\epsilon)^\alpha \approx 1 + \frac{\alpha}{1} \cdot \epsilon + \frac{\alpha}{1} \cdot \frac{\alpha - 1}{2} \cdot \epsilon^2, \quad \text{for } |\epsilon| \ll 1, \tag{1}$$

i. to deduce mathematically whether the force acting on dipole 2 is attractive or repulsive,

ii. to show that the magnitude F of the total force acting on the right dipole can be written in the form

$$F \approx \frac{C}{L^\beta}, \tag{2}$$

where you need to give explicit expressions for the constant C and exponent β.

2. **(8 points)** To a rather good approximation, the entire Earth acts as a negatively charged spherical conductor of radius $R \approx 6,400\,\mathrm{km}$. Using a force sensor, an experiment shows that a negatively charged insulating rod with total charge $q \approx 1\,\mathrm{nC}$ that is near the Earth's surface is repelled upwards with an electric force of magnitude $F \approx 2 \times 10^{-7}\,\mathrm{N}$. From these data,

   (a) estimate to the nearest power of ten (without using any multiplication or division of digits) the number N of electrons per square meter on the Earth's surface and discuss briefly whether this is a large or small value.

   (b) estimate to the nearest power of ten the total charge on the Earth's surface in coulombs.

   Some hints: ignore polarization of the Earth by the rod, and assume that, because of its approximate spherical symmetry, the entire Earth acts as a point charge at its center, with the point charge having a charge equal to all the charge on the Earth's surface. It can be helpful to first obtain a simplified symbolic answer in terms of given quantities before substituting any numerical values.

True or False Questions (3 points each)

For each question, indicate whether it is true or false and briefly explain your reasoning.

1. **T / F** If you touch one end of a charged rod to a grounded wire, the rod will become neutral.

2. **T / F** You can charge a conducting copper rod by rubbing it with a conducting aluminum cloth.

3. **T / F** It is possible for some object to repel an electron and for the same object to repel a proton.

4. **T / F** When charging a neutral metal ball by induction with a charged rod, the final charge on the ball will depend on the distance of the rod to the ball at the time when the ball is grounded.

5. **T / F** Four spheres of equal size, two made of glass and two made of metal, are individually sprayed uniformly with electrons so that each is uniformly coated with the same total amount of negative electrical charge. If F_{metal} is the magnitude of the force between the two metals spheres when their centers are placed a distance d apart, and if F_{glass} is the magnitude of the force between the two glass spheres when their centers are placed the same distance d apart, then $F_{\mathrm{metal}} = F_{\mathrm{glass}}$.

6. **T / F** Ignoring gravitational forces, for any fixed arrangement of three electrons in empty space, there must always be a location, not on an electron, where a proton can be placed so that it is in mechanical equilibrium.