Homework Set 8: Solutions
Due: Tuesday, November 2, 2010

Chapter 12

(Q6) 8 points If you charge an electroscope with a plastic rod that has been rubbed with car fur, will the metal leaves of the electroscope move farther apart or come closer together when you bring the cat fur near the ball of the electroscope? Explain.

By charging the electroscope with the plastic rod, the electroscope will pick up some net charge (say, negative). As a result, the metal leaves will tend to move farther apart (since both are negatively charged). However, by bringing the cat fur (which is positively charge) close to the ball of the electroscope, the leaves will come closer together. This is because as the cat fur moves closer, it attracts the negative charges in the metal leaves of the electroscope. As a result, these negative charges move out of the metal leaves (to get closer to the positive cat fur), thus reducing the negative charge of the leaves and thus reducing the repulsive interaction between them.

(Q10) 10 points If you touch the ball of a charged electroscope with your finger, will it discharge? What does this suggest about the conducting properties of people? Explain.

By touching the ball of a charged electroscope with your finger, the electroscope will most definitely discharge. As a result, we can conclude that people are also conductors of electricity.

(Q18) 8 points If two charges are both doubled in magnitude without changing the distance between them, will the force that one charge exerts on the other also be doubled? Explain.

Using Coulomb’s law, the magnitude of the electrostatic force exerted between two charges \(q_1\) and \(q_2\) separated by a distance \(r\) is \(F = k_e|q_1||q_2|/r^2\). As a result, if we double both \(q_1\) and \(q_2\) without changing \(r\), we expect that the magnitude of the force between the two charges will increase by a factor of four.

(Q20) 12 points Two charges, of equal magnitude but opposite sign, lie along a line as shown in the diagram. Using arrows, indicate the directions of the electric field at points A, B, C, and D as shown on the diagram.

The direction of the electric field at point A is to the left.
The direction of the electric field at point B is to the right.
The direction of the electric field at point C is to the right.
The direction of the electric field at point D is to the left.

(Q24) 10 points Is the electric field produced by a single positive charge a uniform field? Explain.

A single positive charge does not produce a uniform electric field. A uniform electric field is one that is the same everywhere. The electric field produced by a single positive charge, however, becomes weaker with distance: it is strong near the charge, while weak a great distance from the charge. Therefore, the field is not uniform.

(Q30) 10 points In the drawing for question 20, which point, B or C, will have the higher electric potential? Explain.

Point B has the higher electric potential. As one rule of thumb, we found in class that the electric potential near a positive charge is large (positive), while the electric potential the same distance from a (same magnitude) negative charge is low (negative).
Two charged particles exert an electrostatic force of 8 N on each other. What will the magnitude of the electrostatic force be if the distance between the two charges is reduced to one-half of the original distance?

Using Coulomb’s law \( F = k \frac{|q_1| |q_2|}{r^2} \), we find that decreasing the distance separating the charges by a factor of two increases the electrostatic force by a factor of four.

An electron and a proton have charges of an equal magnitude but opposite sign of \( 1.6 \times 10^{-19} \) C. If the electron and proton in a hydrogen atom are separated by a distance of \( 5 \times 10^{-11} \) m, what are the magnitude and direction of the electrostatic force exerted on the electron by the proton?

The magnitude of the electrostatic force exerted between these two charges is

\[
F = k \frac{|q_1| |q_2|}{r^2} = \frac{(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(1.6 \times 10^{-19} \text{ C})(1.6 \times 10^{-19} \text{ C})}{(5 \times 10^{-11} \text{ m})^2} = 9.2 \times 10^{-8} \text{ N}.
\]

As these two charges have the opposite sign charge, this force is an attractive one.

A charge of \( -3 \times 10^{-6} \) C is placed at a point in space where the electric field is directed toward the right and has a magnitude of \( 8.5 \times 10^4 \) N/C. What are the magnitude and direction of the electrostatic force on this charge?

Using \( \vec{F} = q \vec{E} \) we find that

\[
\vec{F} = (-3 \times 10^{-6} \text{ C})(+8.5 \times 10^4 \text{ N/C}) = -0.255 \text{ N}.
\]

Because this force has the opposite sign as the electric field (the electric field I chose to have a positive sign, while the force has a negative sign), these two vectors are pointing in opposite directions. As a result, the force is directed toward the left.

The electric potential increases from 100 V to 500 V from the bottom plate to the top plate of a parallel-plate capacitor.

a. What is the magnitude of the change in potential energy of a \( -5 \times 10^{-4} \) C charge that is moved from the bottom plate to the top plate?

Using \( \Delta V = \Delta U/q \) and solving for \( \Delta U \) we find that

\[
\Delta U = q \Delta V = (-5 \times 10^{-4} \text{ C})(+400 \text{ V}) = -0.2 \text{ J}.
\]

Therefore, the magnitude of the change in potential energy is 0.2 J.

b. Does the potential energy increase or decrease in this process?

Due to the minus sign in part a, we conclude that the potential energy decreases by 0.2 J.