Name______________________________Pd________

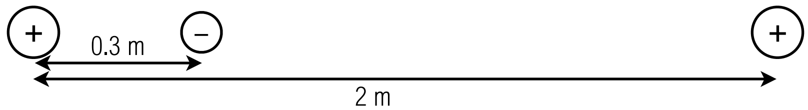
Coulomb's Revenge

Remember Charles Augustin Coulomb from the other day? Well, he's back to taunt you again! Here are a few more difficult problems dealing with Coulomb's Law. Remember to watch metric prefixes and the d^2…

$$F_E = k\frac{q_1 q_2}{d^2}$$

$k = 9 \cdot 10^9\ Nm^2/C^2$

$q_e = 1.6 \cdot 10^{-19}\ C$



1. Two protons are locked in place 2 meters apart, as shown above. An electron is placed between them 0.3 m from the leftmost proton.
   a) With what force (and in what direction) does the left proton push (or pull) the electron?

   $F_{E\text{-left}} = 9{\cdot}10^9(1.6{\cdot}10^{-19})^2/(0.3)^2$

   $F_{E\text{-left}} = 2.56{\cdot}10^{-27}$ N, to the left

   b) With what force (and in what direction) does the rightmost proton pull (or push) the electron?

   $F_{E\text{-right}} = 9{\cdot}10^9(1.6{\cdot}10^{-19})^2/(1.7)^2$

   $F_{E\text{-left}} = 7.97{\cdot}10^{-29}$ N, to the right

   c) What's the net force acting on the electron at the position shown? (Don't forget direction!)

   $F_{net} = 2.48{\cdot}10^{-27}$ N, to the left

   d) Now for the really hard one–a system of equations problem! Where would the electron have to be placed between the two protons so that it wouldn't experience any net force? Give the distance measured from the leftmost proton.
   (HINT 1: Call that distance *x*. HINT 2: What's the distance from the electron to the right proton going to be in terms of x?
   HINT 3: The forces have to be equal and opposite for equilibrium to occur!)

$F_{E\text{-left}} = F_{E\text{-right}}$ $\quad 9{\cdot}10^9(1.6{\cdot}10^{-19})^2/(x)^2 = 9{\cdot}10^9(1.6{\cdot}10^{-19})^2/(2-x)^2$ Notice how *k*, and the charges will cancel in this problem

So, $1/(x)^2 = 1/(2-x)^2$ Cross multiplying and expanding gives: $x^2 = 4-4x+x^2$

This simplifies to: $4x = 4$, so $x = 1$m (No surprise, right?)

Most times, these types of problems don't have like charges at the ends–we'll end up with a quadratic to solve with two possible answers. You might want to store the quadratic in your calculator, just in case a problem like this shows up on the AP test.

2. An aluminum Coke can (which was originally neutral) has lost $2.5{\cdot}10^{19}$ electrons. A metal-encased cell phone has given away $32{\cdot}10^{20}$ electrons to its owner's ear. When the cell phone is held 0.25 cm away from the Coke can…
   a) Will the two metal objects be attracted to or repelled from each other?

   They will both be positive (loss of e^-s), so they will repel

   b) What will be the force exerted by the cell phone on the can when they are a quarter centimeter apart?

   $Q_{can} = (2.5{\cdot}10^{19})(1.6{\cdot}10^{-19}) = +4$ C $\qquad Q_{phone} = (32{\cdot}10^{20})(1.6{\cdot}10^{-19}) = +512$ C

   $F_E = 9{\cdot}10^9(4)(512)/(.0025)^2$

   $F_E = 2.94{\cdot}10^{18}$ N

   c) Will the force be larger or smaller when the can is 1 full centimeter away from the cell phone?

   Smaller, the distance has increased

   d) How many times larger or smaller will the force be when they are 1 cm apart (compared to the force at ¼ cm)?

   At four times the distance, the force would be 1/16 as large

   e) How far apart must the Coke can and phone be so that a force of 400 N is present between them?

   $400 = 9{\cdot}10^9(4)(512)/d^2$

   $d = 2.15{\cdot}10^5$ m

3. A bullet is being fired from a gun. As the gun is fired, the bullet rubs against the inside of the barrel. The barrel ends up with a charge of +2nC.

a) What is the charge of the bullet? Explain how you know.

–2nC ; Since it's being charged by friction, it must have an equal and opposite charge

b) By what method was the bullet charged? CONTACT FRICTION INDUCTION

c) When the bullet is 30 cm from the end of the barrel, what electrical force does it experience? (Assume all the gun's charge is located at the end of the barrel…a bad assumption, but it makes your work easier!)

$F_E = 9 \cdot 10^9 (2 \cdot 10^{-9})^2/(0.3)^2$

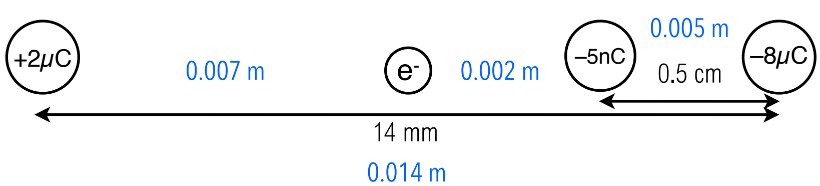
$F_E = 4 \cdot 10^{-7}$ N, to the right

d) Is that force attractive or repulsive?

Attractive

e) If the charge of the gun barrel was somehow doubled, yet the bullet's charge remained the same, what would happen to the force calculated in part c) above? (Be specific in your answer...like: two and a half times greater, or four times smaller)

It would double, as the force is proportional to the product of the charges



4. Three large stationary charges are shown above. An electron is placed exactly halfway between the two largest charges at the ends. What is the net force acting on the movable electron? (Don't forget to include a direction!)

[Need some help? Answer these questions…then add the answers, remembering that force is a vector!]

What force would the +2μC charge exert on the electron if they were alone?

What force would the –5nC charge exert on the electron if they were alone?

What force would the –8nC charge exert on the electron if they were alone?

$F_{E\text{-}2} = 9 \cdot 10^9 (1.6 \cdot 10^{-19})(2 \cdot 10^{-6})/(0.007)^2$

$F_{E\text{-}2} = 5.88 \cdot 10^{-11}$ N, to the left

$F_{E\text{-}5} = 9 \cdot 10^9 (1.6 \cdot 10^{-19})(5 \cdot 10^{-9})/(0.002)^2$

$F_{E\text{-}5} = 1.8 \cdot 10^{-12}$ N, to the left

$F_{E\text{-}8} = 9 \cdot 10^9 (1.6 \cdot 10^{-19})(8 \cdot 10^{-6})/(0.007)^2$

$F_{E\text{-}8} = 2.35 \cdot 10^{-10}$ N, to the left

Since all three forces are to the left, we can just add them:

$F_{net} = 2.956 \cdot 10^{-10}$ N to the left