Flipping Physics Lecture Notes:
Introduction to Coulomb's Law or the Electric Force
https://www.flippingphysics.com/coulombs-law.html

We have already learned about the Law of Charges which governs the directions of the forces on pairs of charges.[1] Today we learn about the magnitude of that force.

The electric force is described by Coulomb's Law: $F_e = \frac{kq_1q_2}{r^2}$

- This is the electric force which exists between any two charged particles.
- It is sometimes called the Coulomb Force or Electrostatic Force. I will call it the Electric Force.
- k is the Coulomb Constant: $k = 8.99\times10^{9}\frac{N\cdot m^2}{C^2}$
- q_1 and q_2 are the two electric charges.
- r is the distance between the centers of *charge* of the two charges.
- Note the similarities to Newton's Universal Law of Gravitation: $F_g = \frac{Gm_1m_2}{r^2}$
- k, the Coulomb Constant is much larger than, G, the Universal Gravitational Constant.

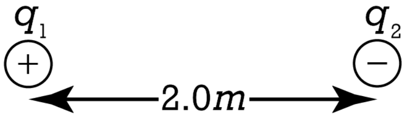
$$\frac{k}{G} = \frac{8.99\times10^{9}\frac{N\cdot m^2}{C^2}}{6.67\times10^{-11}\frac{N\cdot m^2}{kg^2}} = 1.347826087\times10^{20} \approx 1.35\times10^{20}\frac{kg^2}{C^2}$$

A point charge is are just like a point mass, only the description has to do with charge rather than mass. In other words, a point charge is an object which has zero size and carries an electric charge. A point charge is an object whose mass is small enough that its mass is negligible when compared to its charge.

Three prefixes you should be familiar with when using coulombs:

- μ means micro or 1 millionth or $\times10^{-6}$ *so* 1 microcoulomb $= 1\mu C = 1\times10^{-6}C$
- n means nano or 1 billionth or $\times10^{-9}$ *so* 1 nanocoulomb $= 1nC = 1\times10^{-9}C$
- p means pico or 1 trillionth or $\times10^{-12}$ *so* 1 picoulomb $= 1pC = 1\times10^{-12}C$

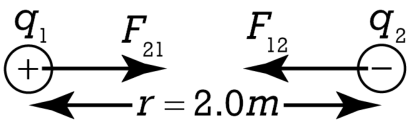
Example #1: Two equal magnitude point charges are located 2.0 meters apart. If the magnitudes of their charges are both 5.0 μC and one is positive and one is negative, what is the electric force acting on each charge caused by the other charge?



Knowns: $q_1 = +5.0\mu C \times \frac{1C}{1\times10^{6}\mu C} = 5\times10^{-6}C;\ q_2 = -5.0\mu C = -5\times10^{-6}C;\ r = 2.0m;\ F_e = ?$

$$F_e = \frac{kq_1q_2}{r^2} = \frac{\left(8.99\times10^{9}\right)\left(5\times10^{-6}\right)\left(-5\times10^{-6}\right)}{2^2} = -0.0561875 \approx -0.056N$$

$$\boxed{F_{\text{each charge}} \approx 0.056N \text{ toward the other charge}}$$



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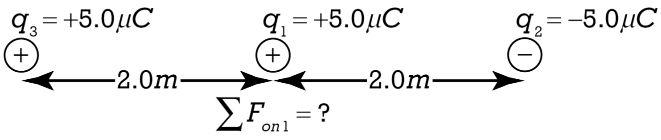
[1] See video "Electric Charge, Law of Charges, and Quantization of Charge" at https://www.flippingphysics.com/charge.html

But what does the negative on $F_e \approx -0.056N$ mean?

I have seen three different versions of Coulomb's Law:

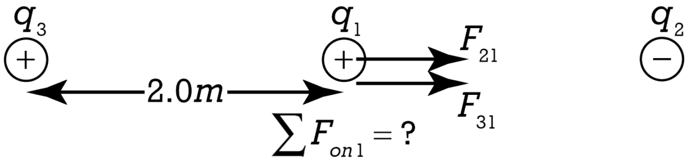
- The one we have been working with: $F_e = \frac{kq_1q_2}{r^2}$
- The magnitude of the electric force: $\left|\vec{F}_e\right| = k\left|\frac{q_1q_2}{r^2}\right|$
    - This ignores direction information, so we are not going to use it.
- And the unit vector version: $\vec{F}_{12} = \frac{kq_1q_2}{{r_{12}}^2}\hat{r}_{12}$
    - $\vec{F}_{12}$ is the electric force by charge 1 on charge 2
    - $\hat{r}_{12}$ is the unit vector directed from charge 1 toward charge 2
    - We have not worked with unit vectors in this algebra based class yet, so we are not going to use this verson of Coulomb's Law.
- Therefore we will use the first one: $F_e = \frac{kq_1q_2}{r^2}$
    - A negative force means an attractive force.
    - A positive force means a repulsive force.
- Note: $F_e = \frac{kq_1q_2}{r^2}$ can be attractive or repulsive however, $F_g = \frac{Gm_1m_2}{r^2}$ is always attractive.

Building on Example #1, Example #2 is .. If we place a third charge, q 3, with the same charge as the positively charged object, q 1, only now 2.0 meters on the opposite side from the other negative charge, q 2, what is the net force acting on q 1, the positive charge in the middle?



Adding the third charge does not affect the electric force of 0.056 newtons which is from q_2 on q_1 and acting to the right. We just need to add the electric force from q_3 on q_1. Because both q_1 and q_3 are positive, force 3-1 will be a positive, repulsive force, on q_1 that would be to the right.

$$F_{31} = \frac{kq_1q_3}{{r_{31}}^2} = \frac{\left(8.99\times10^9\right)\left(+5\times10^{-6}\right)\left(+5\times10^{-6}\right)}{2^2} = 0.0561875N \text{ to the right}$$



$$\sum F_{on1} = F_{21} + F_{31} = 0.0561875 + 0.0561875 = 0.112375 \approx \boxed{0.11\text{N to the right}}$$