1/25/2019: Coulomb's Law

Friday, January 25, 2019 3:02 PM

$\oplus \quad \ominus$ ATTRACTIVE

$\left.\begin{matrix} \oplus & \oplus \\ \ominus & \ominus \end{matrix}\right\}$ REPULSIVE

This law comes from empirical evidence from MANY experiments. Like all fundamental laws of physics, this result has been confirmed through rigorous experiment.

Coulomb's Law:

Coulomb's Constant

$$\vec{F}_{on,\, q_1} = k \frac{q_1 q_2}{r^2} \hat{r}$$

POINT CHARGES (TEST CHARGES)
→ IGNORE SIZE OF OBJECT

DISTANCE OF SEPARATION

$q_1 \quad q_2$ <- Include the sign

DIRECTION OF FORCE IS ALONG SEPARATION VECTOR

$$\underset{q_2}{\ominus} \xrightarrow{\vec{r}} \underset{q_1}{\oplus} \xrightarrow{\hat{r}}$$

For a more practical method:

1. Determine magnitude...

$$|\vec{F}| = k \frac{|q_1|\,|q_2|}{r^2}$$

2. Determine direction through identifying the sign of the two charges

Analogy to Newtonian Gravitational Force

$$\vec{F}_g = \frac{GMm}{r^2} \hat{r}$$

The variables are all analogous here, except that the **force is always attractive!**

How much is one Coulomb?

Coulomb $\quad C \qquad 1C = 1A \cdot 1s$

$i = \frac{dq}{dt} \quad (A) \qquad \mu C$ <- Microcoulomb is the preferred unit in most cases. (Coulombs are large!)

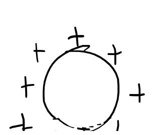
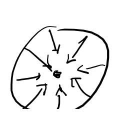
$$k = 8.99 \times 10^9 \frac{N \cdot m^2}{C^2} ; \quad \varepsilon_0 = 8.85 \times 10^{-12}\, C^2 / N \cdot m^2$$

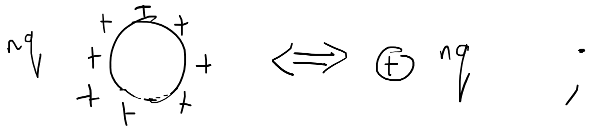
$$k = \frac{1}{4\pi \varepsilon_0}$$

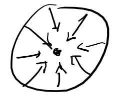
The Coulombic Force obeys the superposition law.

$$\underset{q_1}{\circ} \quad \underset{q_2}{\circ} \quad \cdots \quad \underset{q_n}{\circ} \qquad \sum \vec{F}_{net\ on\ q_1} = \vec{F}_{1\cdot 2} + \vec{F}_{1\cdot 3} + \cdots \vec{F}_{1\cdot n}$$

Shell Theorem: if we have a uniform spherical shell, and there exists an excess charge (=nq) on the shell, then the net charge will be evenly distributed along the surface such that the center of the shell will receive zero net force. From the outside, this shell behaves like a point mass of positive charge "nq"

nq  $\Longleftrightarrow \oplus\ nq$;  Net force on the center point is zero.





Net force on the center point is zero.

Let's talk more about charges now...

Mass	Charge
An intrinsic factor	An intrinsic factor
You can break a mass into smaller masses	Charge is quantized. The basic unit of charge is e=1.602*10^(-19) C Charges must take the form q = n*e $n = \pm 1, \pm 2, \ldots$ +e proton -e electron

Q: But what about Quarks? They have fractional charges.
A: Quarks do not exist alone in nature, they form larger particles. So, the charge quantization holds.

Q: How many electrons go through a 100W lightbulb?
A: Let's say that 1 Amp is going through the wire and coming out of the lightbulb. That's about 10^19 electrons coming into and out of the lightbulb, every second. (That's more electrons in one second than millimeters traveled by light per second!)

*** Charge is conserved

$$ {}^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He $$

Atomic number:
Telling you how many protons are in the atom.

$92 = 90 + 2$. So, CONSERVED!

- Annihilation process $e^- + e^+ \to 2\gamma$ (POSITRON)
- Pair process $\gamma \to e^- + e^+$