Flipping Physics Lecture Notes:
AP Physics 1 Review of *Electrostatics*
https://www.flippingphysics.com/ap1-electrostatics-review.html

Elementary Charge: The smallest charge of an isolated particle. $e = 1.6 \times 10^{=19} C$

- Two examples: $q_{electron} = -e = -1.6 \times 10^{=19} C$ & $q_{proton} = +e = +1.6 \times 10^{=19} C$

The electron is a fundamental particle, however, the proton is not a fundamental particle.

Protons and neutrons are composed of "up" and "down" quarks: $q_{up\ quark} = +\frac{2}{3}e$ & $q_{down\ quark} = -\frac{1}{3}e$

- Proton is composed of 2 "up" quarks and 1 "down" quark.
  - $q_{proton} = 2q_{up\ quark} + 1q_{down\ quark} = 2\left(+\frac{2}{3}e\right) + \left(-\frac{1}{3}e\right) = +\frac{4}{3}e - \frac{1}{3}e = +e$
- Neutron is composed of 1 "up" quark and 2 "down" quarks.
  - $q_{neutron} = 1q_{up\ quark} + 2q_{down\ quark} = \left(+\frac{2}{3}e\right) + 2\left(-\frac{1}{3}e\right) = +\frac{2}{3}e - \frac{2}{3}e = 0$
- A quark can have a charge less than the Elementary Charge because a single quark has never been isolated; quarks are always found in groups like they are in the proton and neutron.

The Law of Charges: Unlike charges attract and like charges repel. For example:

- Two positive charges repel one another & two negative charges repel one another.
- A positive and a negative charge attract one another.

The force they repel or attract one another with is determine using Coulomb's Law: $F_e = \frac{kq_1q_2}{r^2}$

- This is called the Electrostatic Force. (Also sometimes called a Coulomb Force)
- Coulomb's Constant, $k = 8.99 \times 10^9 \frac{N \cdot m^2}{C^2}$
- q_1 & q_2 are the charges on the two charged particles.
- r is not the radius, it is the distance between the centers of charge of the two charges. (Sometimes r actually is the radius, however, that is not its definition.)
- Note the similarity to Newton's Universal Law of Gravitation: $F_g = \frac{Gm_1m_2}{r^2}$
  - However, comparing Coulomb's Constant to $G = 6.77 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$ shows that Coulomb's Constant is about 10^{20} times greater than the Gravitational Constant. In general, the electrostatic force is much, much, much greater than the gravitational force.

Conservation of Charge: In an isolated system the total charge stays constant. For example, if we start with two electrically isolated spheres, $q_{1i} = +4C$ & $q_{2i} = -2C$, we touch them together and pull them apart:

$$q_t = q_{1i} + q_{2i} = +4C + (-2C) = +2C \ \& \ q_{1f} = q_{2f} = q_f \Rightarrow q_t = q_{1f} + q_{2f} = q_f + q_f = 2q_f \Rightarrow q_f = \frac{q_t}{2} = \frac{+2C}{2} = +1C$$

Each sphere ends up with 6.24 x 10^{18} *excess* protons on it:

$$q_1 = n_1 e \Rightarrow n_1 = \frac{q_1}{e} = \frac{+1C}{1.6022 \times 10^{-19} C / proton} \approx 6.24 \times 10^{18}\ protons$$