The Coulomb Force

- If two particles have charge, there is a static electric force acting between the particles
- This Coulomb force law was "discovered" in the late 1700s
- Interestingly, it has the same mathematical form as the universal gravitational force

$$\vec{F}_{\mathrm{e}} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|^2}\hat{r}$$

- q_1 and q_2 are the charges on the particles in Coulombs (C) which can be positive or negative. The (positive) charge on a proton is

$$1e = +1.6 \times 10^{-19}\ \mathrm{C}$$

- The prefactor is a universal constant called the electric constant k_e

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \ \ \mathrm{Nm^2/C^2} = k_\mathrm{e}$$

- Note that the electric force can be attractive or repulsive, depending on the charge signs of the particles

- The electric force vectors are computed with the same procedure as for gravitational forces

- For two protons, the ratio of forces is

$$\frac{|\vec{F}_\mathrm{e}|}{|\vec{F}_\mathrm{g}|} = 1.2 \times 10^{36}$$

Problem P38 (Chap. 3)

- A proton is located at $\langle 0,0,-2 \rangle \times 10^{-9}$ m and an alpha particle is located at $\langle 1.5,0,2 \rangle \times 10^{-9}$ m. (a) calculate the force the proton exerts on the alpha particle. (b) Calculate the force the alpha particle exerts on the proton.

Nuclear Forces (Interactions)

- At the scale of the nucleus, 10^{-15} m (= 1 femtometer = 1 fermi), the Coulomb force is enormous
- Between two protons ~ 100 N
- How can the helium nucleus (alpha particle) remain stable? Or any nucleus larger than hydrogen?
- Another force, the Strong Nuclear Interaction, provides an attractive interaction between objects made of quarks (protons, neutrons, mesons, …), but has no effect on leptons (electrons, …)

- The force is effective inside the nucleus, but is zero outside the nucleus - a short-range force

- Except for hydrogen, the nucleus of all elements have the same number of neutrons (or more) as protons (for stable isotopes) - line or valley of stability

- In addition to the Coulomb force, another interaction acts to break apart the nucleus, but of unstable isotopes

$$^{11}\mathrm{C} \rightarrow \ ^{11}\mathrm{B} + e^{+} + \nu_e$$

- This is the Weak Nuclear Interaction

- There are no known functional forms for the Strong and Weak forces