Physics 2: Advanced
PHYC10002

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Semester 2, 2025

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Definition 1. *Electrostatics* concerns forces between charges at rest.

Law 1 (Coulomb's law)**.** *The electrostatic force experienced by a charge q_1 in the vicinity of another charge q_2 is equal to*

$$\mathbf{F}_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{|\mathbf{r}_{12}|^2}\hat{\mathbf{r}}_{12},$$

where $\varepsilon_0 \approx 8.85 \times 10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$.

Definition 2 (Coulomb's constant)**.** Define *Coulomb's constant* to be $k_e = \frac{1}{4\pi\varepsilon_0} \approx 8.99 \times 10^9\,\mathrm{N\,m^2/C^2}$. We can then write Coulomb's law as

$$\mathbf{F}_1 = k_e\frac{q_1 q_2}{|\mathbf{r}_{12}|^2}\hat{\mathbf{r}}_{12}.$$

Remark 1. The electromagnetic force at an atomic scale is far stronger than the gravitational force. Consider an electron and a proton about $10^{-10}\,\mathrm{m}$ apart. Given that $8.99 \times 10^9\,\mathrm{N\,m^2/C^2}$, $G \approx 6.67 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$, $m_e \approx 9.1 \times 10^{-31}\,\mathrm{kg}$, $m_p \approx 1.6 \times 10^{-27}\,\mathrm{kg}$, and $e \approx 1.6 \times 10^{-19}\,\mathrm{C}$, we would have

$$|\mathbf{F}_E| = k_e\frac{q_1 q_2}{r^2} \approx 2.3 \times 10^{-8} \gg 9.7 \times 10^{-48} \approx G\frac{m_1 m_2}{r^2} = |\mathbf{F}_g|.$$

It should also be noted that the strong nuclear force, the force of the gluons binding the quarks together within nucleons, is far stronger than the electromagnetic force.