Electric charge

*Electric charge* is a fundamental property of matter, same as mass. Mass is associated to gravitational forces, charge is associated to “electromagnetic” forces.

Charge exists in two “flavors”:

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+  “positive”
-  “negative”
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How is the atom arranged? Why is it easiest to move electrons?

- Electrons arrange around the nucleus in “shells”.
- Inner electrons are tightly bound to the nucleus.
- Electrons in outer shells are less bound to the nucleus and easy to remove.
- New electrons added to the atoms, will sit in the outer shell as well.
Lithium as a cation, an anion, and a neutral atom

- Let’s study the subatomic arrangement of lithium with all charges balanced and the way only electrons move to make the atom an ion (+ or −).

**Charge is “quantized”**

Charge can only exist in “packets” formed by an integer number of “elementary or fundamental charges”, the charge of the electron (or proton)

\[ e = 1.60217653 \times 10^{-19} \text{C} \]

This number is so small, that the charge can be considered to vary continuously in practice

**The unit of charge is the “Coulomb”**

Charge is conserved
Electric charge

Glass rods, plastic tubes, silk, and fur can be used to demonstrate the movement of electrons and how their presence or absence make for powerful forces of attraction and repulsion.
Charging by conduction

- Materials that allow easy passage of charge are called **conductors**.
- Materials that resist electronic flow are called **insulators**.
- The motion of electrons through conductors and about insulators allows us to observe “**opposite charges attract**” and “**like charges repel**.”

http://www.youtube.com/watch?v=Dz_vvw_fsTo&feature=related

Electrons move freely and charges may be induced

(a) Uncharged metal ball
(b) Negative charge on rod repels electrons, creating zones of negative and positive **induced charge**.
(c) Wire lets electron buildup (induced negative charge) flow into ground.
(d) Wire removed; ball now has only an electron-deficient region of positive charge.
(e) Rod removed; electrons rearrange themselves, ball has overall electron deficiency (net positive charge).
Polarizing an insulator

• The motion of static charges about a plastic comb and light bits of paper can cause attractive forces strong enough to overcome the weight of the paper.

http://www.youtube.com/watch?v=VhWQ-r1LYXY&NR=1

Charles Coulomb determined the electrostatic force law
Coulomb’s law

\[ F = \frac{1}{4\pi\varepsilon_0} \frac{|q_1q_2|}{r^2} \]

- The force on the particles has the same magnitude but opposite direction.
- They can be attractive (charges with opposite sign), or repulsive (charges with equal sign).
- It is directly proportional to the charges, and inversely proportional to the square of the inter-charge distance.
- It does not depend on the mass!!!
Electric vs. gravitational force

Let us assume two point particles (alpha particles = nucleus of helium atom) with mass \( m = 6.64 \times 10^{-27} \text{ kg} \) and charge \( q = 3.2 \times 10^{-19} \text{ C} \)

\[
F_e = \frac{1}{4\pi\varepsilon_0} \frac{q^2}{r^2} \quad F_g = G \frac{m^2}{r^2}
\]

\[
\frac{F_e}{F_g} = \frac{1}{4\pi\varepsilon_0 G} \frac{q^2}{m^2} = 3.1 \times 10^{35}
\]

Remember: Gravity is always attractive!!!

Superposition of forces (I)

We consider the charges as point-size objects

(a) The two charges

(b) Free-body diagram for charge \( q_2 \)

(c) Free-body diagram for charge \( q_1 \)

\[
\vec{F}_{\text{Total on } q_0} = \sum_i \vec{F}_{q_i \text{ on } q_0} = \frac{q_0}{4\pi\varepsilon_0} \sum_i \frac{q_i n_{0i}}{r_{0i}^2}
\]
Superposition of forces (II)

\[ \vec{F}_2 - \vec{F}_1 \]

\[ |F_1| = \frac{1}{4\pi\varepsilon_0} \frac{|q_1 q_3|}{(2d)^2} \]

\[ |F_2| = \frac{1}{4\pi\varepsilon_0} \frac{|q_1 q_3|}{d^2} \]

\( \rightarrow \) \[ |F_2| = 4 |F_1| \]

Superposition of forces (III)

\[ F_1 = \frac{1}{4\pi\varepsilon_0} \frac{|q_1 q_3|}{(x^2 + y^2)} \]

\[ F_{1x} = F_1 \cos(\alpha) \]

\[ F_{1y} = -F_1 \sin(\alpha) \]