Chapter 22

Electrostatics

(Electricity at rest.)

The Electric Force

Electrical Forces…

- Underlie most of the forces with that we are familiar (except gravity).
  - Normal force
  - Tension
  - Friction
- MUCH stronger than gravity.
- Can be attractive or repulsive.

Electric Charge

To describe and understand electrical phenomena, we must first introduce a new concept:

ELECTRIC CHARGE (or just CHARGE).

Charge is a property of matter (just like *mass* is a property of matter) rather than an object itself. So when we lazily speak of "an electric charge," we are really referring to an object that has an excess of this new property. We should say, "I have a charged object..." rather than, " I have a charge..."

Properties of Electric Charge

- Charge comes in two types:

  "Positive" (+) and "negative" (–) and is measured in units called "Coulombs" (abbr. "C").

  The symbol for charge is Q or q.

- Charge is conserved:

  (Net) charge is neither created nor destroyed.

- Charge is quantized:

  Charge comes in discrete units or "quanta."

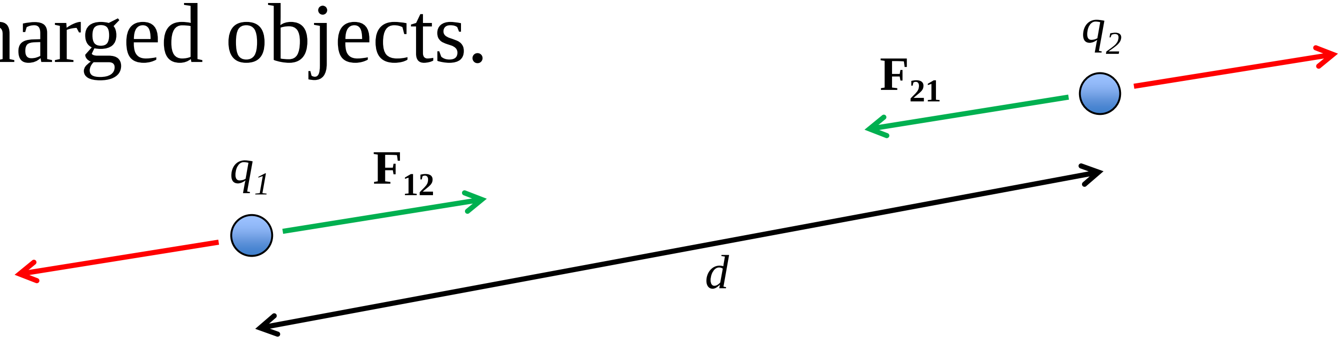
  The smallest unit of charge is that of the electron and proton: The elementary charge has a value of

$$e = 1.602 \times 10^{-19}\ \mathrm{C}$$

The charge of the electron is $-e$ and that of the proton is $+e$.

Coulomb's Law

Describes the strength of the electric force between two charged objects.



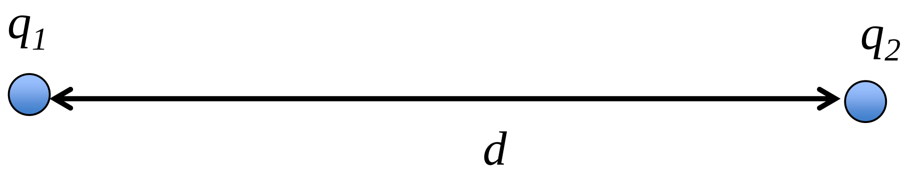
$$|F_{12}| = |F_{12}| = \frac{k|q_1||q_2|}{d^2}$$

k = 9.00 x 10^9 N·m^2/C^2 and is called the "electrostatic constant."

F_{12} and F_{21} are attractive for (q1, q2) = (+, –) or (–, +), and F_{12} and F_{21} are repulsive for (q1, q2) = (+, +) or (–, –).

(Note that F_{12} and F_{21} constitute an Newton's 3rd law pair!)

Example Using Coulomb's Law



Calculate the magnitude of the electric force between two charged objects, q_1 = +5 μC and q_2 = +4 μC separated by a distance 0.2 m. (The prefix "μ" means "micro" which is 10^{-6}.)

$$F_{12} = F_{21} = \frac{k|q_1||q_2|}{d^2} = \frac{\left(9 \times 10^9 \frac{\mathrm{N\,m^2}}{\mathrm{C^2}}\right) |5 \times 10^{-6}\ \mathrm{C}|| + 4 \times 10^{-6}\ \mathrm{C}|}{(0.5\ \mathrm{m})^2} = 4.5\ \mathrm{N}$$

Note that the force $\vec{F}_{12}$ points to the left and that $\vec{F}_{12}$ points to the right since charges of same sign repel.

That is, $\vec{F}_{12}$ = –4.5 N and $\vec{F}_{21}$= 4.5 N.

Conductors vs. Insulators

Conductor: Outer shell electrons are "loose." Charge can flow freely through a conductor.

Insulator: Electrons are tightly bound to the atoms and are not free to roam through the material.

Semiconductor: Fair insulator in pure crystalline form, but becomes good conductor when "doped" with certain impurities.

Superconductor: Material that exhibit ZERO resistance to the flow of electric charge.

“Charging”

- Charging by friction.

  Transfer of charge by contact and rubbing.

- Charging by induction.

  Transfer of charge by bring another charged object nearby.

- Polarization

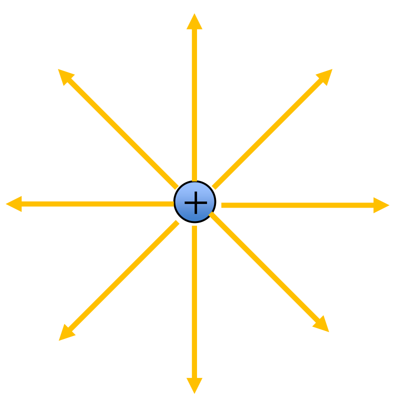
  Rearrangement of charge without adding or taking away charge.

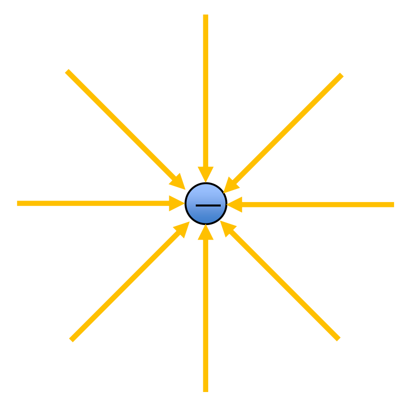
The Electric Field

The *electric field* is the “aura” that exists in space due to the presence of electric charge.

E = “Force per unit charge” = F/q (unit: N/C)

Electric fields originate at (+) charges and terminate at (–) charges.





Electric Potential

The electric potential = "The electrical potential energy per unit charge" (unit: Joule/Coulomb)

Define the "Volt:" 1 V = 1 J/C

Electric potential plays the same role for electric charge as pressure does for fluids. To push a fluid through a pipe, you need to maintain a pressure difference. Similarly, to push electric charge through a wire, you maintain an electric potential difference (a.k.a. voltage).

For example a 9-Volt battery gives 9 Joules of energy to every Coulomb of charge that passes through it.

Electrical Potential Energy Storage

"EPE" can be stored using a device called a *capacitor*.

Simplest form consists of two conductors with equal and opposite charge. (For example, two metal plates connected to the terminals of a battery.)

Like a raised mass or a compressed spring, a "charged" capacitor stores (potential) energy that can be released.

Like dropping the mass and relaxing the spring to do useful work, the capacitor can be discharged to do work (like lighting a light bulb, for example).