Electricity and Magnetism

Two fundamental properties of matter determine interactions between objects in classical physics **mass** and **electric charge**.

1. **Gravitational force** attracts objects together and is proportional to masses of the objects.
$$\tilde{\mathbf{F}}_{\mathbf{g}} = G\frac{Mm}{r_{12}^2}\hat{r}$$
2. **Electromagnetic interaction** causes like charges to repel while opposite charges attract to each other, keeps electrons bound to nuclei, and causes chemical binding to keep atoms together in molecules or solid materials.

Electric Charge

- Electric charge can't be created from nothing and can't be destroyed.
- The process of removing an electron from the electron cloud of an atom, or adding an electron to it, is called **ionization**.
- The electrons in an **insulator** (glass, ceramic, plastic) are all tightly bound to the positive nuclei and do not move around so they are immobile.
- The outer electrons in a **conductor** (copper, silver, aluminum) are only weakly bound to the nuclei so they can easily become detached.

Type	Charge	Mass	Mass in SI
electron	$-e$	1	$9.11 * 10^{-31}$ kg
proton	$+e$	1836	$1.673 * 10^{-27}$ kg
neutron	0	1839	$1.675 * 10^{-27}$ kg
positron	$+e$	1	$9.11 * 10^{-31}$ kg

One elementary charge, e is equal to $1.602 * 10^{-19}\ C$.

Electrostatics

- If a charge is moving, it creates a magnetic field that exerts forces on other moving charges.
- If a charge is moving with acceleration, it emits electro-magnetic waves which also exert forces on other charges.

If charges move slow with small acceleration the effects of magnetic field and electromagnetic waves can be neglected.

Coulomb's Law

$$\boldsymbol{F_{12}} = k\frac{q_1 q_2}{r_{12}^2}\boldsymbol{\hat{r}_{12}}$$

where:
$k = (4\pi\varepsilon_0)^{-1} = 9.0 * 10^9\ Nm^2/C^2$
$\varepsilon_0 =$ permittivity of free space $= 8.86 * 10^{-12}\ C^2/Nm^2$

Electric Field

Electric field is the force exerted by source charges on a positive unit test charge

$$\boldsymbol{E(r)} = k\frac{Q}{r^2}\boldsymbol{\hat{r}}$$

If the source charge Q is positive, the direction of electric field vector is away from Q, otherwise the electric field vector is directed toward Q. Direction of E is the same as direction of force acting on positive charge.

If we know strength of the electric field, E, and the test charge value q_t, we can obtain the force acting on q_t with the formula, $\boldsymbol{F} = q_t\boldsymbol{E(r)}$