

# Chapter 22 Electric Charges and Forces

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## 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.

$$\tilde{\mathbf{F}}_g = G \frac{Mm}{r_{12}^2} \hat{r}$$

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

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

where:

$$k = (4\pi\epsilon_0)^{-1} = 9.0 * 10^9 \text{ Nm}^2/\text{C}^2$$

$$\epsilon_0 = \text{permittivity of free space} = 8.86 * 10^{-12} \text{ C}^2/\text{Nm}^2$$

## Electric Field

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

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

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  $\mathbf{E}$  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,  $\mathbf{F} = q_t \mathbf{E}(\mathbf{r})$