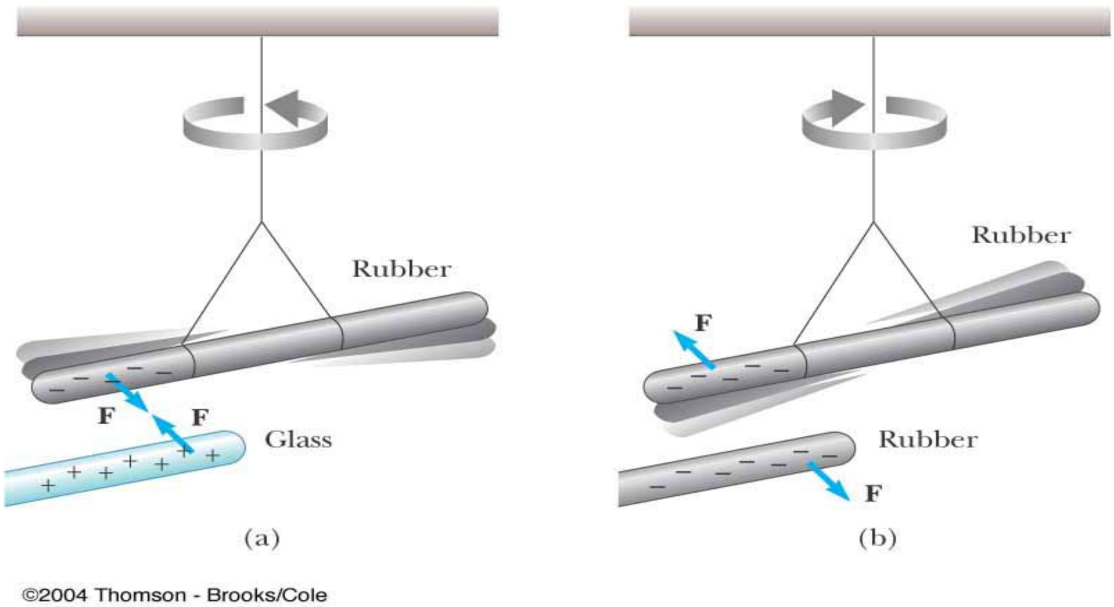
# Chapter 23

# Electric Field

## 23.1 Properties of electric charges

- Two types of charges exist in nature
    - They are called positive and negative
    - Named by Benjamin Franklin
- **Like** charges *repel* and **unlike** charges *attract* one another




(a) Negatively charged rubber rod suspended by a thread is attracted to a positively charged glass rod.

(b) A negatively charged rubber rod is repelled by another negatively charged rubber rod.

- Charge is quantized
    - All charge is a multiple of a fundamental unit of charge, symbolized by e
    - Electrons have a charge of –e
    - Protons have a charge of +e
- The SI unit of charge is the Coulomb (C)

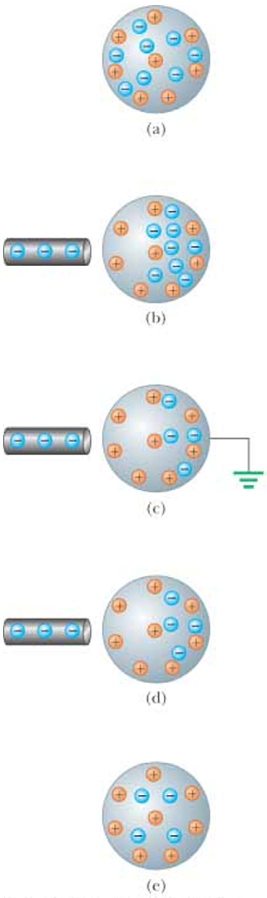
$$e = 1.6 \times 10^{-19} \text{ C}$$

## Table 23.1

| Charge and Mass of the Electron, Proton, and Neutron | | |
|---|---|---|
| **Particle** | **Charge (C)** | **Mass (kg)** |
| Electron (e) | $-1.602\,191\,7 \times 10^{-19}$ | $9.109\,5 \times 10^{-31}$ |
| Proton (p) | $+1.602\,191\,7 \times 10^{-19}$ | $1.672\,61 \times 10^{-27}$ |
| Neutron (n) | 0 | $1.674\,92 \times 10^{-27}$ |



## 23.2 Charging objects by induction:




Charging a metallic object by *induction* (that is, the two objects never touch each other).
(a) A neutral metallic sphere, with equal numbers of positive and negative charges.

(b) The electrons on the neutral sphere are redistributed when a charged rubber rod is placed near the sphere.

(c) When the sphere is grounded, some of its electrons leave through the ground wire.

(d) When the ground connection is removed, the sphere has excess positive charge that is nonuniformly distributed.

(e) When the rod is removed, the remaining electrons redistribute uniformly and there is a net uniform distribution of positive charge on the sphere.



**Fig 23-4, p.710**

Check the following simulation:

http://phet.colorado.edu/en/simulation/balloons

**23.3 Coulomb's Law: (Charles Augustin de Coulomb, France, 1736)**

Coulomb shows that an electrical force has the following properties:

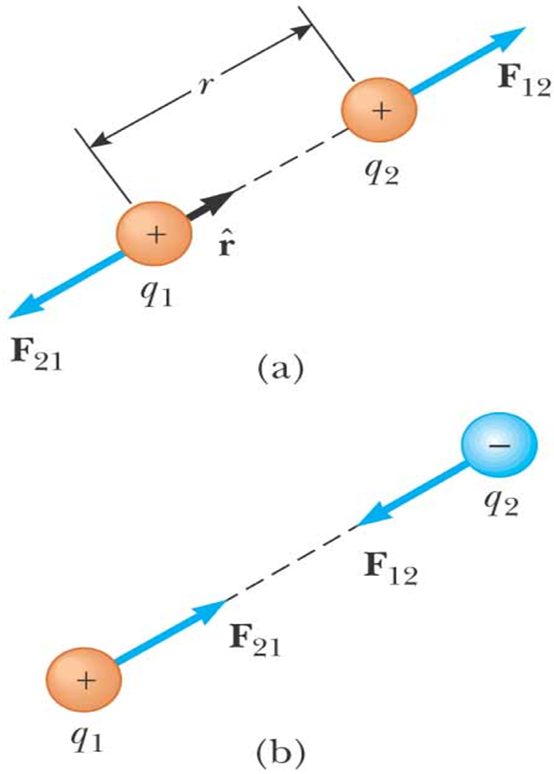
- It is along the line joining the two particles and inversely proportional to the square of the separation distance, r, between them,

  $\vec{F} \propto \frac{1}{r^2}$

- It is proportional to the product of the magnitudes of the charges, $|q_1|$and $|q_2|$on the two particles

  $\vec{F} \propto |q_1| * |q_2|$

- It is attractive if the charges are of opposite signs and repulsive if the charges have the same signs.





**Mathematically:**

$$\vec{F} = K_e \frac{|q_1||q_2|}{r^2} \hat{r}$$

- $k_e$ is called the *Coulomb Constant*

$k_e = \frac{1}{4\pi\varepsilon_0}$ =8.9875 x $10^9$ N $m^2/C^2$

$\varepsilon_0$ is the permittivity of free space

$(\varepsilon_0 = 8.854x10^{-12}C^2/N.m^2)$

- q = n e

  q is the symbol used to represent total of charge, while n is a positive or negative integer, and e is the electronic charge, 1.6 x $10^{-19}$ Coulombs (C).

**Example:** The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3 $x10^{-11}$ m.

**Find** the magnitudes of the electric force.

$$F_e = k_e \frac{|e|^2}{r^2} = \left(8.99 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right) \frac{(1.60 \times 10^{-19}\ \text{C})^2}{(5.3 \times 10^{-11}\ \text{m})^2}$$

$$= 8.2 \times 10^{-8}\ \text{N}$$