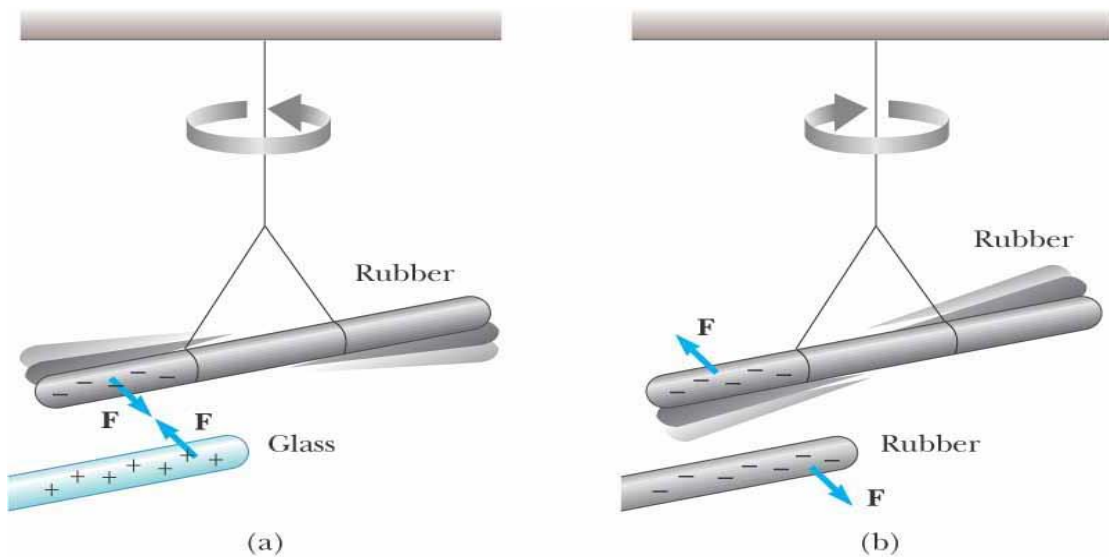


## Chapter 23

### 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



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- (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**

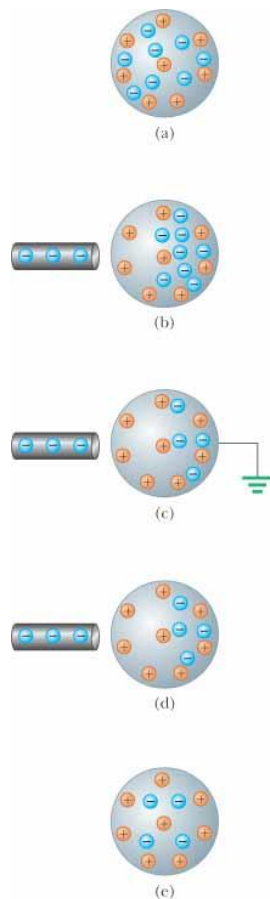
Charge and Mass of the Electron, Proton, and Neutron		
Particle	Charge (C)	Mass (kg)
Electron (e)	$-1.602\,191\,7 \times 10^{-19}$	$9.109\,5 \times 10^{-31}$
Proton (p)	$+1.602\,191\,7 \times 10^{-19}$	$1.672\,61 \times 10^{-27}$
Neutron (n)	0	$1.674\,92 \times 10^{-27}$

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- In **conductors**, electrons can move easily because the outermost electrons in conductive materials (such as metals) are loosely bound to their parent atoms.
- An **insulator** is a material that resists the flow of electrical current because its electrons are tightly bound to their atoms and cannot move freely. This property makes insulators essential for protecting us from electrical hazards and for isolating electrical components in devices.
- A **semiconductor** is a material whose electrical conductivity falls between that of a conductor (like copper) and an insulator (like glass). Semiconductors can conduct electricity under certain conditions, making them crucial in electronic devices like diodes, transistors, and integrated circuits.

## 23.2 Charging objects by induction:

**Remember !** charges are conservative, which means that electric charge cannot be created or destroyed; it can only be transferred from one object to another.



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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:

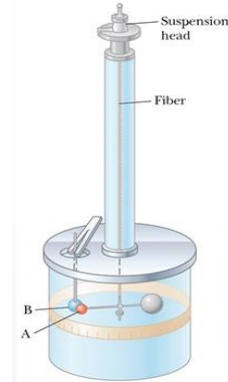
<http://phet.colorado.edu/en/simulation/balloons>

- **Here are some various materials and their tendency to lose or gain electrons:**

<b>Material</b>	<b>Tendency to Lose Electrons</b>	<b>Tendency to Gain Electrons</b>
<b>Rubber</b>	High	Low
<b>Glass</b>	High	Low
<b>Human Hair</b>	High	Low
<b>Silk</b>	High	Low
<b>Nylon</b>	High	Low
<b>Wool</b>	High	Low
<b>Cotton</b>	High	Low
<b>Wood</b>	Moderate	Moderate
<b>Steel</b>	Moderate	Moderate
<b>Copper</b>	Moderate	Moderate
<b>Aluminum</b>	Moderate	Moderate
<b>Plastic (e.g., PVC)</b>	Low	Moderate
<b>Polyester</b>	Low	Moderate
<b>Ebonite (hard rubber)</b>	Low	High
<b>Teflon</b>	Low	High
<b>Fur</b>	Low	High
<b>Polythene</b>	Low	High

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

#You can read about the experiment Charles Augustin de Coulomb performed to demonstrate that the force between two electric charges is affected by factors such as the magnitude of the charges, the distance between them, and the medium through which they interact.



#### 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.

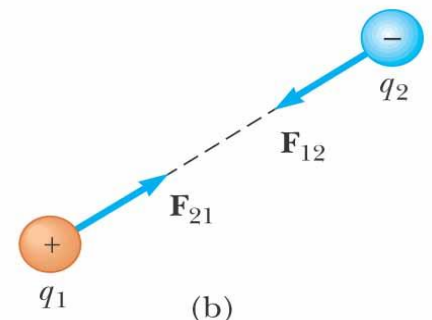
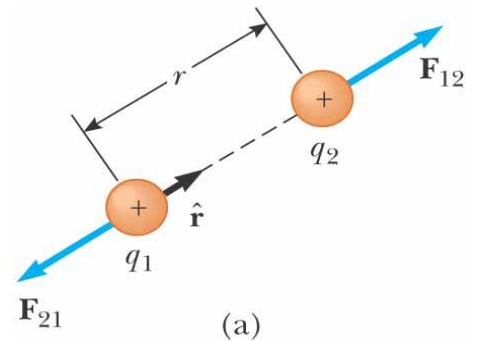
#### Mathematically:

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

- $k_e$  is called the *Coulomb Constant*

$$k_e = \frac{1}{4\pi\epsilon_0} = 8.9875 \times 10^9 \text{ N m}^2/\text{C}^2$$

$\epsilon_0$  is the permittivity of free space ( $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 / \text{N} \cdot \text{m}^2$ )



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■  $q = n e$

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

**Example-1:** The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately  $5.3 \times 10^{-11}$  m.

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

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

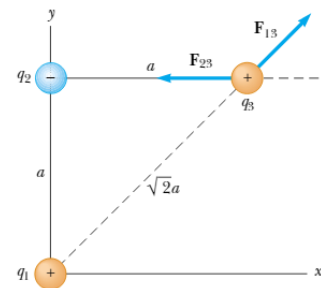
$$= 8.2 \times 10^{-8} \text{ N}$$

**Example-2 :**

$$q_1 = q_3 = 5 \mu\text{C}$$

$$q_2 = -2 \mu\text{C}$$

$$a = 0.10 \text{ m}$$



**Find** the resultant force exerted on  $q_3$ ?