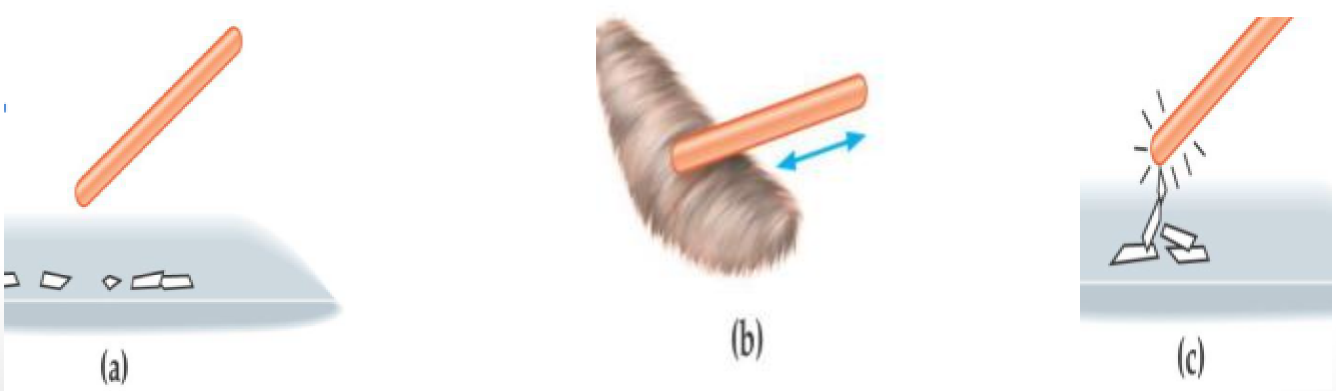
King Saud University
College of Science
Physics & Astronomy Dept.

111 PHYS (GENERAL PHYSICS 2)
CHAPTER 23: Electric Fields
LECTURE NO. 1

Presented by Nouf Alkathran

23.1 Properties of Electric Charges

- A number of simple experiments demonstrate the existence of electric forces and charges.
- What does it happen when we put a glass rod near bits of paper?
- What does it happen when we put a glass rod after being rubbed with silk or fur near bits of paper?



23.1 Properties of Electric Charges

When materials behave in this way, they are said to be electrified, or to have become **electrically charged.**

<u>Electric Charge:</u>

There are two kinds of electric

charges, which were given the names positive and negative by Benjamin Franklin(1706–1790).

1- Proton (+q)

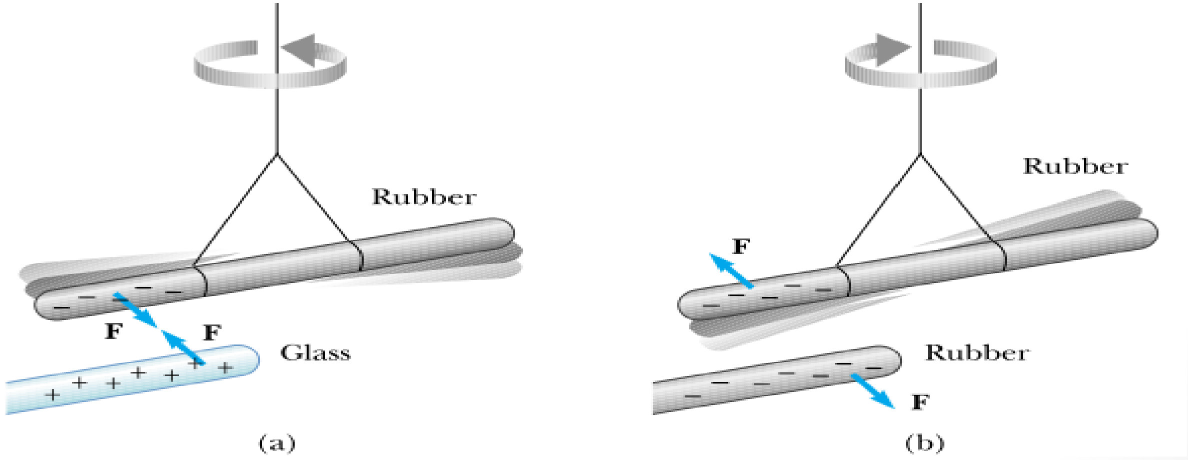
2- Electron (-q)

23.1 Properties of Electric Charges

Electric forces:

When a glass rod that has been rubbed with silk is brought near the rubber rod, the two attract each other (a). On the other hand, if two charged rubber rods (or two charged glass rods) are brought near each other, as shown in Figure 23.1b, the two repel each other.

- Charges of the same sign repel one another and charges with opposite signs attract one another.



23.1 Properties of Electric Charges

- When one object is rubbed against another , **charge is not created** in the process. The electrified state (+,- charges) is due to a transfer of charge from one object to the other. One object gains some amount of negative charge (silk) while the other gains an equal amount of positive charge (glass rod). So, **Electric charge is always conserved.**

- Electric charge q is said to be **quantized.** we can write:

$$q = Ne$$

N: number of charge

e : electron charge = - 1.60×10^{-19} C

Proton charge = + 1.60×10^{-19} C

SI Unit of charge is Coulomb (C)

It is convenient to classify materials in terms of the ability of electrons to move through the material:

1. **Conductors:** material with free electron as some electrons are not bound to atoms and can move relatively freely through the material. Such as, copper, aluminum, and silver (metal). These material are good conductors of electricity.

2. **Insulators:** materials in which all electrons are bound to atoms and cannot move freely through the material. Such as, glass, rubber, and wood. These material are poor conductors of electricity.

3. **Semiconductors :** materials with electrical properties between those of insulators and those of conductors. The electrical properties of semiconductors can be changed by adding impurities. Silicon and germanium are well-known examples of semicondors.

4. Superconductors: A material that is a perfect conductor with zero resistance to the flow of electric charge. Sulfur and Mercury under certain condition are used for superconductors purposes.

23.3 Coulomb's Law

- Coulomb confirmed that the electric force (F) between two small charged particles is inversely proportional to the square of the separation (r) between these particles and proportional to the product of the charges (q1 and q2)on the two particles.

$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$

where k_e is a constant called the **Coulomb constant.**

$$k_e = 8.9875 \times 10^9 \ \mathrm{N \cdot m^2/C^2}$$

$$k_e = \frac{1}{4\pi\epsilon_0}$$

where the constant ϵ_0 is known as the **permittivity of free space**

$$\epsilon_0 = 8.8542 \times 10^{-12} \ \mathrm{C^2/N \cdot m^2}$$

23.3 Coulomb's Law

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	$1.674\,92 \times 10^{-27}$

Example 23.1 The Hydrogen Atom

- The electron and proton of a hydrogen atom are separated by a distance of approximately 5.3×10^{-11} m. Find the magnitudes of the **electric force** and the **gravitational force** between the two particles.

Solution:

- From Coulomb's law, the magnitude of the electric force is

$$F_e = k_e \frac{|e||-e|}{r^2} = (8.99 \times 10^9 \ \mathrm{N \cdot m^2/C^2}) \frac{(1.60 \times 10^{-19} \ \mathrm{C})^2}{(5.3 \times 10^{-11} \ \mathrm{m})^2} = 8.2 \times 10^{-8} \ \mathrm{N}$$

- Using Newton's law of universal gravitation

$$F_g = G\frac{m_e m_p}{r^2} = (6.67 \times 10^{-11} \ \mathrm{N \cdot m^2/kg^2}) \times \frac{(9.11 \times 10^{-31} \ \mathrm{kg})(1.67 \times 10^{-27} \ \mathrm{kg})}{(5.3 \times 10^{-11} \ \mathrm{m})^2}$$

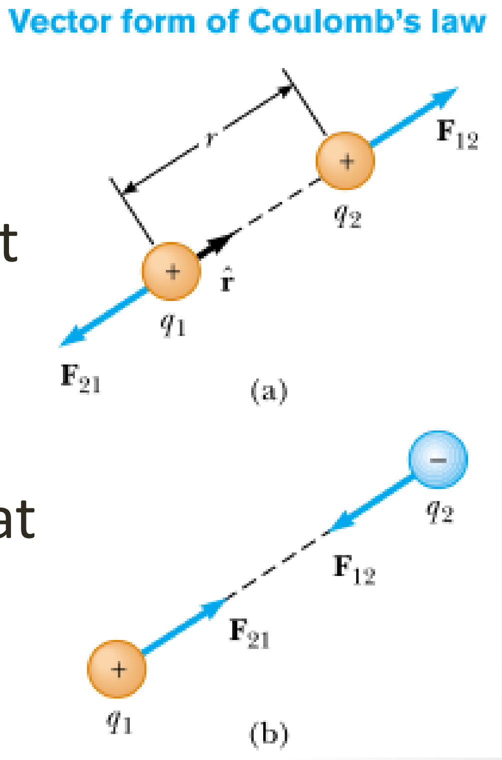
$$= 3.6 \times 10^{-47} \ \mathrm{N}$$

The ratio $F_e/F_g \approx 2 \times 10^{39}$

23.3 Coulomb's Law

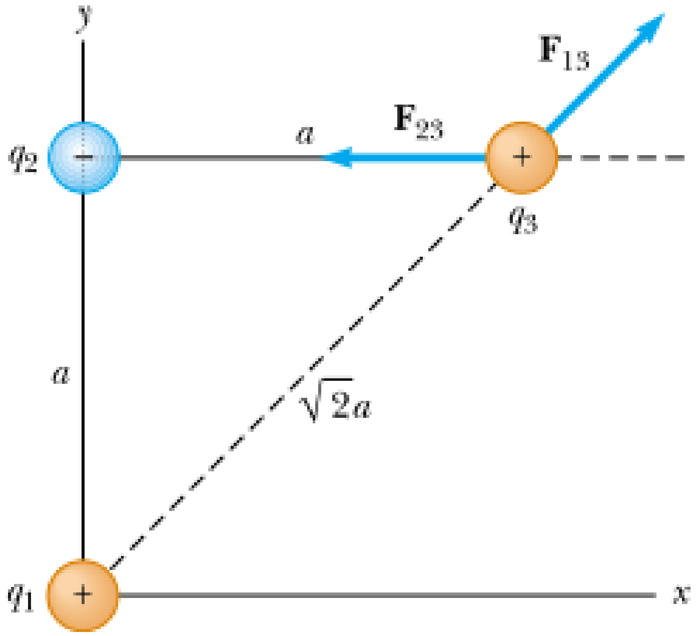
$$\mathbf{F}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}$$

- you must remember that force is a vector quantity and must be treated accordingly.
- If q1 and q2 have the same sign, the product q1q2 is positive. This indicates that the electric force is a repulsive force.
- If q1 and q2 are of opposite sign, the product q1q2 is negative. This indicates that the force is an attractive force.



Example 23.2 Find the Resultant Force

- **Consider three point charges located at the corners of a right triangle, where $q_1 = q_3 = 5.0\ \mu C, q_2 = -2\mu C, and$ $a = 0.10\ m. Find\ the\ resultant\ force\ act\ on\ q_3$.**



Solution 23.2

$$F_{23} = k_e \frac{|q_2||q_3|}{a^2}$$

$$= (8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}) \frac{(2.0 \times 10^{-6}\ \mathrm{C})(5.0 \times 10^{-6}\ \mathrm{C})}{(0.10\ \mathrm{m})^2}$$

$$= 9.0\ \mathrm{N}$$ the attractive force $\mathbf{F}_{23}$ is to the left (in the negative x direction).

$$F_{13} = k_e \frac{|q_1||q_3|}{(\sqrt{2}a)^2}$$

$$= (8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}) \frac{(5.0 \times 10^{-6}\ \mathrm{C})(5.0 \times 10^{-6}\ \mathrm{C})}{2(0.10\ \mathrm{m})^2}$$

$$= 11\ \mathrm{N}$$

The repulsive force $\mathbf{F}_{13}$ makes an angle of 45° with the x axis. Therefore, the x and y components of $\mathbf{F}_{13}$ are equal, with magnitude given by $F_{13} \cos 45° = 7.9\ \mathrm{N}$.

Solution 23.2

$$F_{3x} = F_{13x} + F_{23x} = 7.9 \text{ N} + (-9.0 \text{ N}) = -1.1 \text{ N}$$

$$F_{3y} = F_{13y} + F_{23y} = 7.9 \text{ N} + 0 = 7.9 \text{ N}$$

$$\mathbf{F}_3 = (-1.1\hat{\mathbf{i}} + 7.9\hat{\mathbf{j}}) \text{ N}$$

The magnitude of the resultant Force

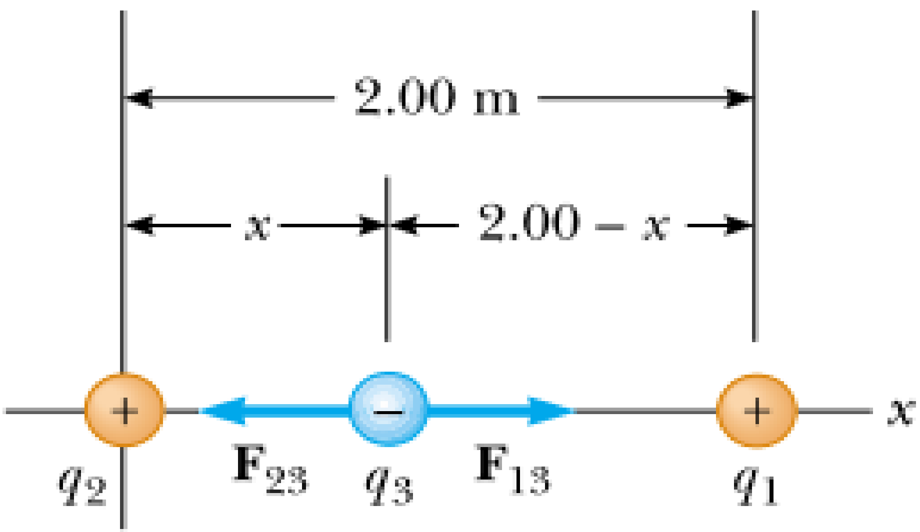
$$F_3 = \sqrt{fx^2 + fy^2} = \sqrt{(-1.1^2) + (7.9^2)} = 7.976\ N$$

The direction of the resultant force

$$\theta = \tan^{-1}\frac{\text{fy}}{\text{f}x} = \tan^{-1}\frac{7.9}{-1.1} = \text{-}82°$$

Example 23.3

Three point charges lie along the x axis as shown in Figure 23.9. The positive charge $q_1 = 15.0\ \mu C$ is at $x = 2.00$ m, the positive charge $q_2 = 6.00\ \mu C$ is at the origin, and the resultant force acting on q_3 is zero. What is the x coordinate of q_3?



Solution 23.3

$$F_{13} = k_e \frac{|q_1||q_3|}{(2.00 - x)^2} \qquad F_{23} = k_e \frac{|q_2||q_3|}{x^2}$$

For the resultant force on q_3 to be zero, $\mathbf{F}_{23}$ must be equal in magnitude and opposite in direction to $\mathbf{F}_{13}$. Setting the magnitudes of the two forces equal, we have

$$k_e \frac{|q_2||q_3|}{x^2} = k_e \frac{|q_1||q_3|}{(2.00 - x)^2}$$

$$(2.00 - x)^2 |q_2| = x^2 |q_1|$$

$$(4.00 - 4.00x + x^2)(6.00 \times 10^{-6}\ \mathrm{C}) = x^2(15.0 \times 10^{-6}\ \mathrm{C})$$

$$3.00x^2 + 8.00x - 8.00 = 0$$

$x = 0.775$ m. **OR X= -3.44 m**