ELECTRICITY AND MAGNETISM- PHYS 104

BY DR. HADI ALQAHTANI
OFFICE 2B2
PHYSICS AND ASTRONOMY
COLLEGE OF SCIENCE, BUILDING NO. 4

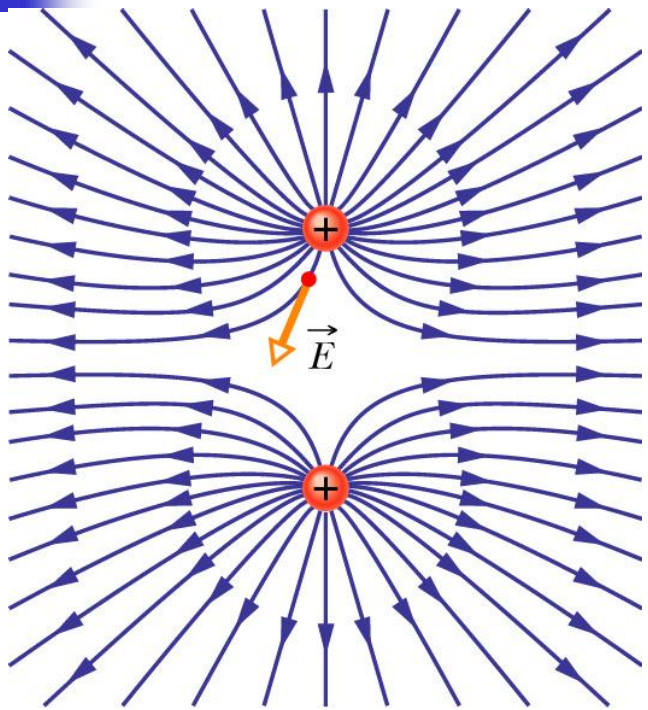
Electric Force and Electric Field

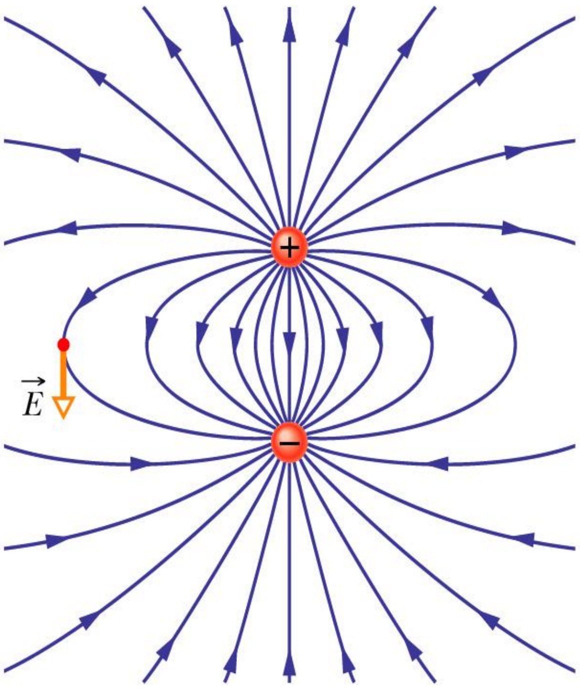
- Properties of Electric Charges
- Charging Objects by Conduction and Induction
- Electric Force (Coulomb's Law)
- Electric Field
- Electric Field Lines
- Motion of Charged Particle in a Uniform Electric Field

Properties of Electric Charges

- Two types of charges exist
  - They are called positive and negative
  - Named by Benjamin Franklin
- Like charges repel and unlike charges attract one another
- Nature's basic carrier of positive charge is the proton
  - Protons do not move from one material to another because they are held firmly in the nucleus

Charge Interactions





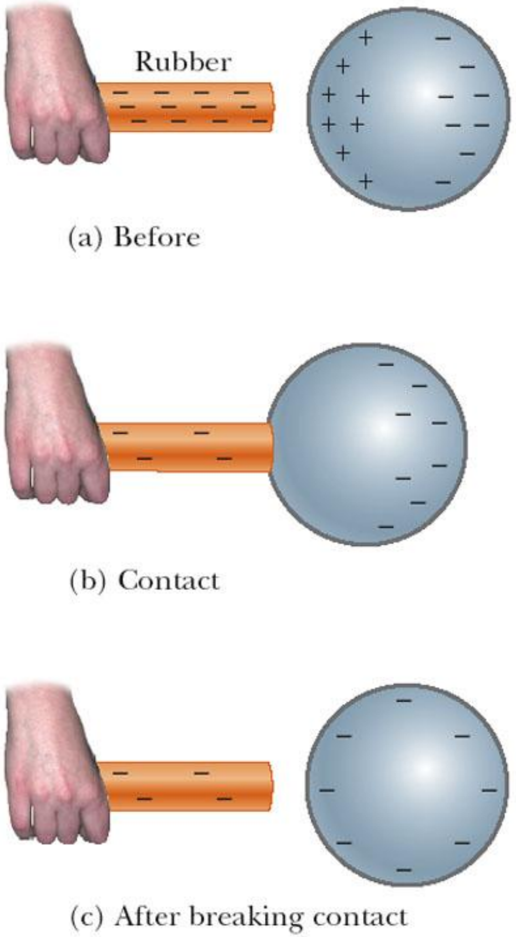
This is called an electric dipole

Properties of Charge, final

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

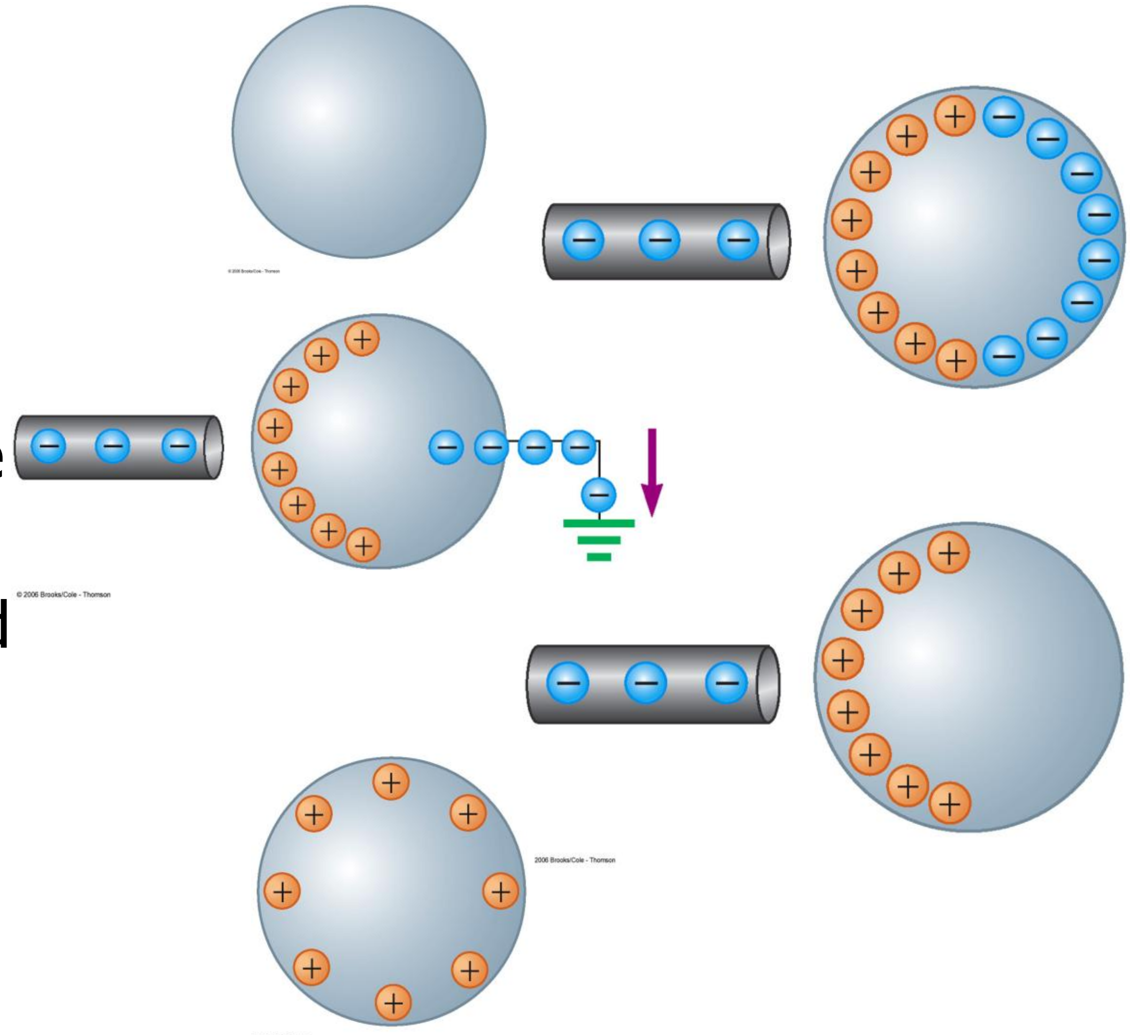
Charging by Conduction

- A charged object (the rod) is placed in contact with another object (the sphere)
- Some electrons on the rod can move to the sphere
- When the rod is removed, the sphere is left with a charge
- The object being charged is always left with a charge having the same sign as the object doing the charging



Charging by Induction

- When an object is connected to a conducting wire or pipe buried in the earth, it is said to be grounded
- A negatively charged rubber rod is brought near an uncharged sphere



Coulomb’s Law

- 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
  - It is proportional to the product of the magnitudes of the charges, $|q_1|$ and $|q_2|$ on the two particles
  - It is attractive if the charges are of opposite signs and repulsive if the charges have the same signs

Coulomb's Law, cont.

- Mathematically, $F = k_e \frac{|q_1||q_2|}{r^2}$
- k_e is called the *Coulomb Constant*
  - $k_e = 8.9875 \times 10^9$ N m^2/C^2
- Typical charges can be in the µC range
  - Remember, Coulombs must be used in the equation
- Remember that force is a *vector* quantity
- Applies only to point charges

Characteristics of Particles

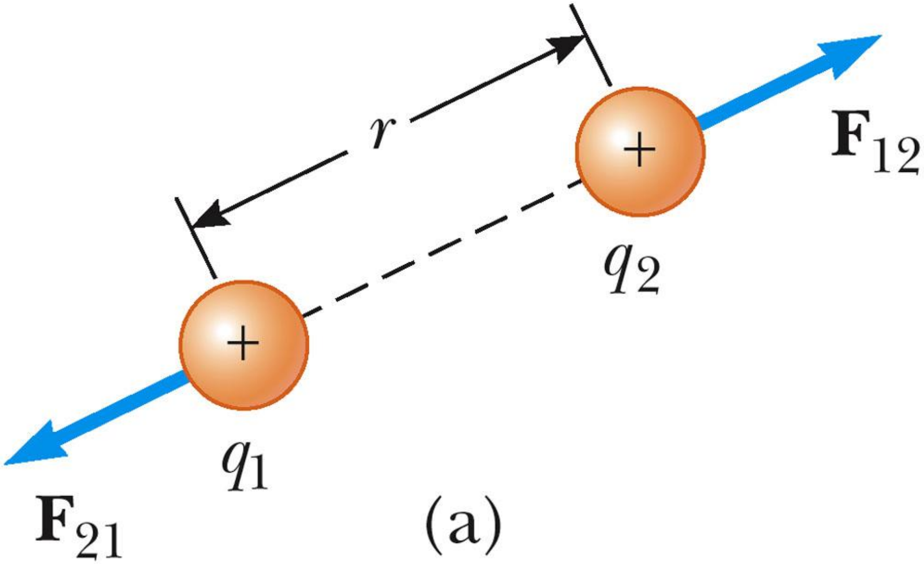
TABLE 15.1

Charge and Mass of the Electron, Proton, and Neutron

Particle	Charge (C)	Mass (kg)
Electron	-1.60×10^{-19}	9.11×10^{-31}
Proton	$+1.60 \times 10^{-19}$	1.67×10^{-27}
Neutron	0	1.67×10^{-27}

Vector Nature of Electric Forces

- Two point charges are separated by a distance *r*
- The like charges produce a repulsive force between them
- The force on q_1 is equal in magnitude and opposite in direction to the force on q_2



Example

- 23.1 The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 0.053 nm. Find the magnitudes of the electric force and the gravitational force between the two particles.

Solution

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

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

$$F_g = G\frac{m_e m_p}{r^2}$$

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

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

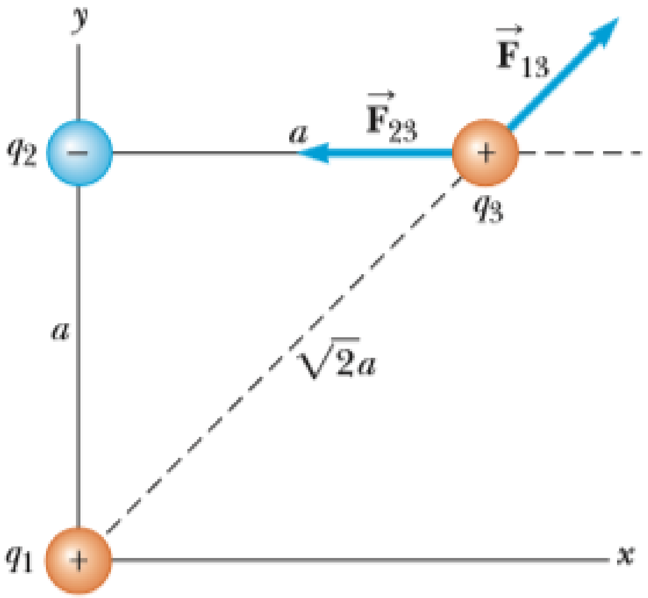
- Fe/Fg≈10^{39} this means that gravitational force is negligible when dealing with charges atomic particles

Example 23.2

EXAMPLE 23.2 Find the Resultant Force

Consider three point charges located at the corners of a right triangle as shown in Figure 23.7, where $q_1 = q_3 = 5.0\ \mu C$, $q_2 = -2.0\ \mu C$, and $a = 0.10$ m. Find the resultant force exerted on q_3.

Solution- schematic



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

$$= (8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}) \frac{(2.0 \times 10^{-6}\ \mathrm{C})(5.0 \times 10^{-6}\ \mathrm{C})}{(0.10\ \mathrm{m})^2} = 9.0\ \mathrm{N}$$

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

$$= (8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}) \frac{(5.0 \times 10^{-6}\ \mathrm{C})(5.0 \times 10^{-6}\ \mathrm{C})}{2(0.10\ \mathrm{m})^2} = 11\ \mathrm{N}$$

$$F_{13x} = F_{13}\cos 45° = 7.9\text{ N}$$

$$F_{13y} = F_{13}\sin 45° = 7.9\text{ N}$$

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

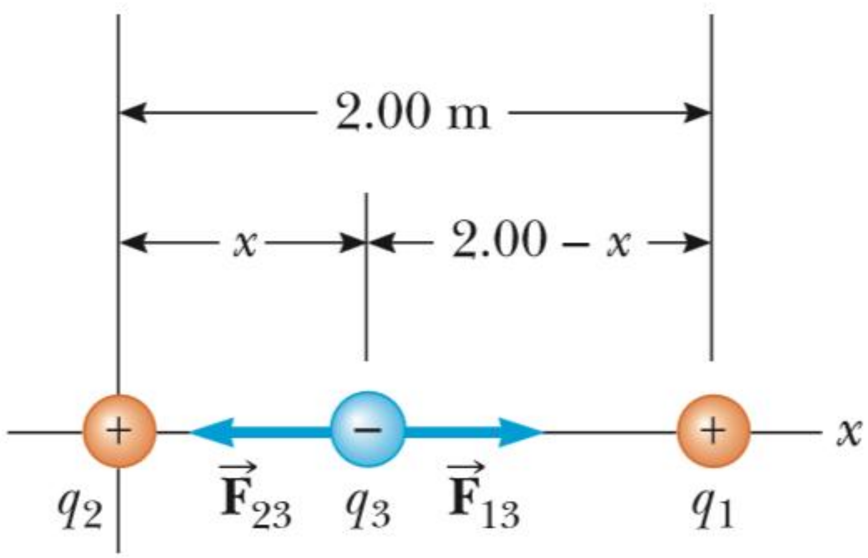
$$F_{3y} = F_{13y} + F_{23y} = 7.9\text{ N} + 0 = 7.9\text{ N}$$

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

Example 23.3

EXAMPLE 23.3 **Where Is the Net Force Zero?**

Three point charges lie along the x axis as shown in Figure 23.8. 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 net force acting on q_3 is zero. What is the x coordinate of q_3?



Solution

$$\vec{\mathbf{F}}_3 = \vec{\mathbf{F}}_{23} + \vec{\mathbf{F}}_{13} = -k_e \frac{|q_2||q_3|}{x^2}\,\hat{\mathbf{i}} + k_e \frac{|q_1||q_3|}{(2.00 - x)^2}\,\hat{\mathbf{i}} = 0$$

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

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

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

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

$$x = \boxed{0.775\text{ m}}$$