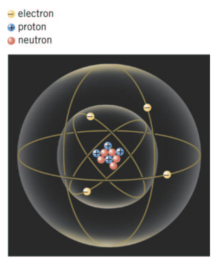
1 – Properties of Electric Charges



- Electric charge is an intrinsic property of matter, inherent in its atomic structure.

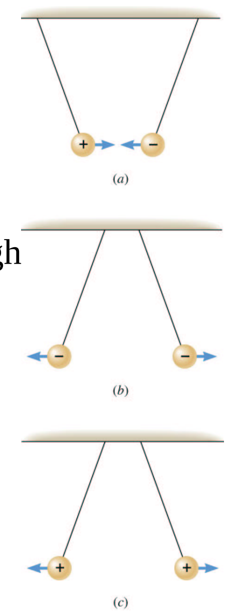
electron charge: $q = -e$
proton charge: $q = +e$
with *elementary* charge: $e = 1.60 \cdot 10^{-19}$ Coulomb

- The earliest studies of electricity were conducted by the Greeks (≈570 B.C. Thales of Milet): amber (greek: *electron*) attracts small objects after being rubbed with wool
- Experiments demonstrate that there are two kinds of electric charges:

positive and negative

(Benjamin Franklin [1706 – 1790])

Electric Forces and Electric Fields



- *like charges repel one another and unlike charges attract one another*
- objects become charged through contact with another already charged object or by induction (no contact).
- When charging an object negative charge is transferred from one object to the other.
- electric charge is conserved:
  → the sum of all electric charges in the universe does not change
  → when an electrically charged object is created the same amount of negative and positive charge is produced

2 – Conductors and Insulators

Substances are classified in terms of their ability to conduct electric charge:

- **Conductors:** materials in which electric charges move freely
  Examples: copper, aluminum, in general all metals
- **Insulators:** materials in which electric charges do not move freely
  Examples: rubber, glass

Special case: *semiconductors:* their electrical properties are between those of conductors and insulators
semiconductors are important in electronics
Examples: silicon, germanium

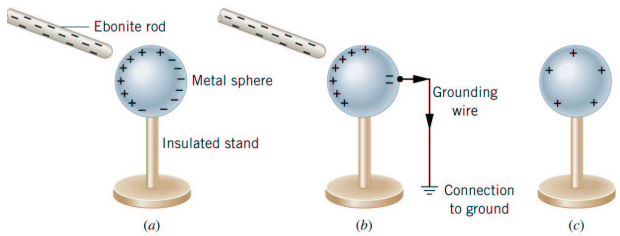
3 – Charging by Induction

A conductor connected to Earth by means of a conducting wire is said to be **grounded**

Charging by Induction:

1. bring negatively charged rubber rod near uncharged conducting sphere
2. ground sphere
3. remove wire $\rightarrow$ sphere is now positively charged

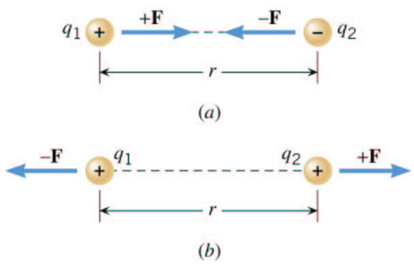
NOTE: Charging an object by induction requires no contact with the object inducing the charge



4 – Coulomb's Law

Experiments show that an electrostatic force has the following properties:

1. It is inversely proportional to the square of the separation, r, between the two charged particles and is along the line joining them



2. It is proportional to the product of the magnitudes of the charges, $|q_1|$ and $|q_2|$ on the two particles
3. It is attractive if the charges have opposite sign, and repulsive if the charges have the same sign

Fundamental law of electrostatic force between two stationary charged pointlike particles:

$$F = k\,\frac{|q_1|\,|q_2|}{r^2} \qquad (1)$$

- In the SI system, the unit of charge is the **Coulomb** (C)
- In the SI system, the Coulomb constant, k, has the value

  $k = 8.99 \times 10^9\ \mathrm{Nm}^2/\mathrm{C}^2$

  (or $k = 1/(4\pi\epsilon_0)$ where ϵ_0 denotes the *permittivity* of free space)
- all charges are multiples of the elementary charge $e = 1.6 \times 10^{-19}$ C

5 – The Principle of Superposition

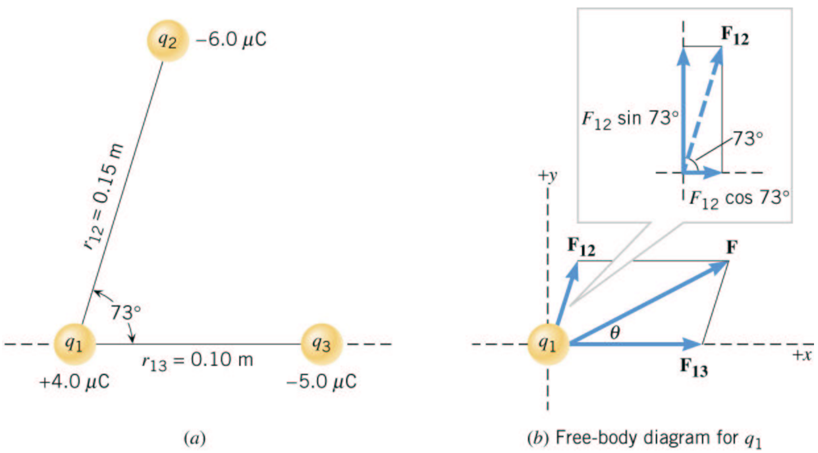
Frequently more than two charges are present. The net force is given by the **vector** sum of the forces exerted by the individual charges that are present.

Reminder: Forces are **vectors**!

$$\mathbf{F}_{net} = \sum_{ij} \mathbf{F}_{ij}$$

$\mathbf{F}_{ij}$: force between charges i and j

Example:



Electric Forces and Electric Fields

6 – The Electric Field

- The electrostatic force is capable of acting through space, producing an effect even when there is no physical contact between the objects involved.
- An **electric field** is said to exist in the region of space around a charged object.
- When another charged object is brought into the electric field it feels the electrostatic force.
- The strength of the electric field, E, of a point charge, q, at a distance r from the charge is

$$E = k\,\frac{|q|}{r^2} \qquad (2)$$

- If q is positive, the field is directed **radially outward**. If q is negative, the field is directed **radially inward**.

- Force on a (small) test charge q_0 exerted by an electric field:

$$\mathbf{F} = q_0 \mathbf{E} \quad (3)$$

- The electric field at a point P exists regardless whether a charge is present in P.
- The principle of superposition holds in the same way as for the electric force when the net electric field due to a group of point charges is calculated.
- The strength of an electric field of a parallel plate capacitor with charge density $\sigma = q/A$, where q is the electric charge and A the area of the plates:

$$E = \frac{q}{A\epsilon_0} = \frac{\sigma}{\epsilon_0} \quad (4)$$

7 – Electric Field Lines

A convenient aid for visualizing electric field patterns is to draw lines pointing in the direction of the electric field at any point (**electric field lines**).

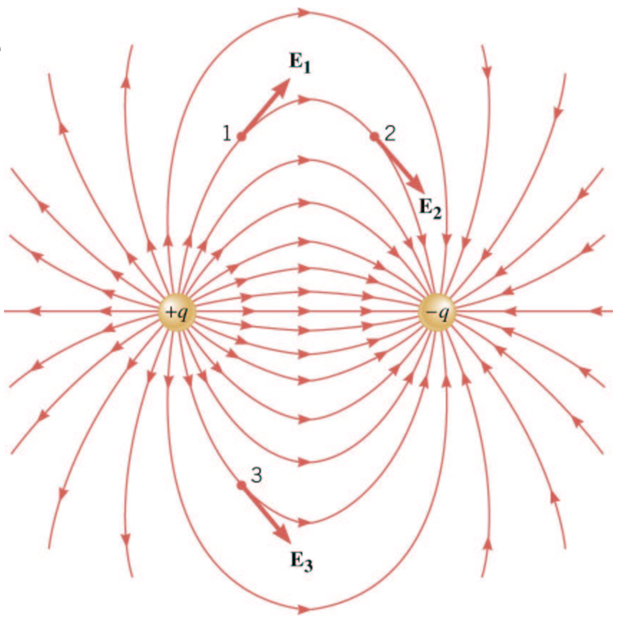
Properties:

1. The electric field vector, $\mathbf{E}$, is tangent to the electric field lines at any point
2. The number of lines per unit area through a surface perpendicular to the lines is proportional to the strength of the electric field in a given region

Rules for drawing electric field lines:

1. Lines begin at positive charges and end at negative charges or infinity
2. The number of lines drawn leaving (approaching) a positive (negative) charge is proportional to the magnitude of the charge
3. No two field lines can cross each other

Example



8 – Conductors in Electrostatic Equilibrium

In good electric conductors charges (=electrons) are able to move freely.

Electrostatic Equilibrium: no net motion of charge occurs within a conductor.

Properties of an isolated conductor:

1. The electric field is **ZERO** everywhere inside the conductor (why?)
2. Any excess charge on an isolated conductor resides on its surface (consequence of Coulomb's law)
3. The electric field just outside a charged conductor is perpendicular to its surface (why?)
4. On a conductor, charge tends to accumulate at sharp points