Homework 1

Electric charge

We started discussing electricity.

Experiment shows that certain objects being prepared by rubbing or other surface interactions become able to attract or repel each other. We will call these "electrically prepared" objects as charged objects. Typical examples of the materials which easily show electrical properties are amber / wool and glass / silk.

- It was established experimentally that there are two kinds of electrical charge. Historically they are called as "positive" and "negative" (it could have been A and B, for example…). We will also use the term "sign" to show the type of charge: "+" is the positive charge "_" is the negative one. If there are equal quantities of positive and negative charge in the object, then total net charge of the object is zero. We will call these objects "neutral".

- Charged objects attract objects with the charge of opposite sign and repel objects which bear the charge of the same sign.

What happens with the objects after we charged them by rubbing? It is natural to assume that some small particles which carry the electrical charge are transferred from one object to another. Latter we will talk a lot about these particles. Now we can ask: what makes these particles charged? What is the charge?

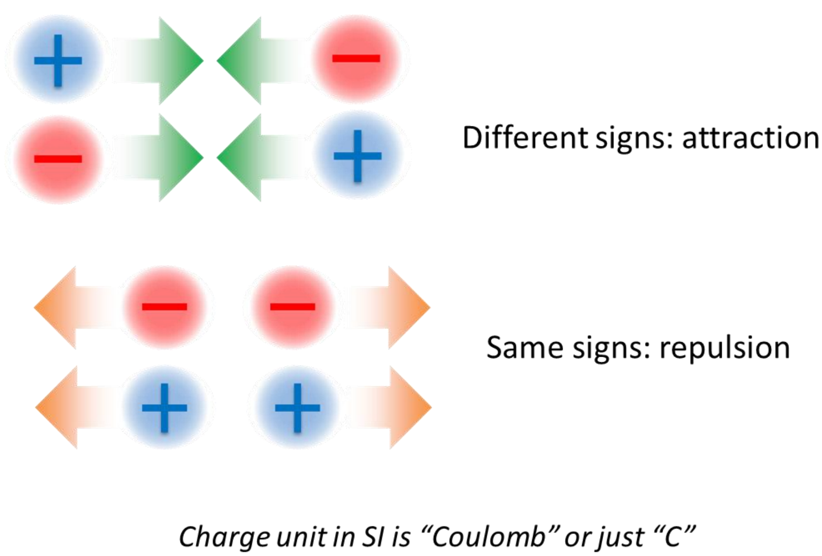


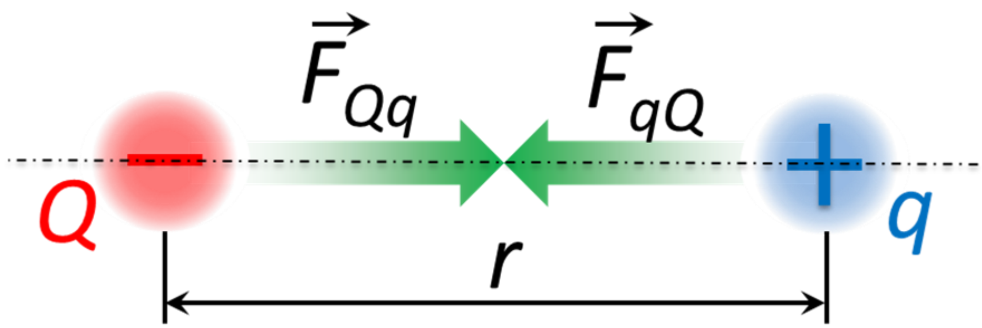
Figure 1. Interaction of point charges. Point charges is small charged objects. "Small" means that size of the objects is much less than the distance between them

I believe that the best way to think about charge is as of *property* of matter. This property is closely related to the symmetry. Like there are "right" and "left", there are "positive" and "negative" charges.

- Another important property of the charge is its conservation. There is not possible to create an isolated, say, positive charge like there is not possible to create an object with only left side. By rubbing the objects or doing other work to charge objects we can only *separate* the charges.

We have learned how to calculate the magnitude of the electrostatic force between to point electric charges. Point charges are electrically charged objects whose size is much less than the distance between them. The magnitude of the force is:

$$F = k\frac{Q\cdot q}{r^2} \quad (1)$$



Here *Q* and *q* are the charges of the objects; *r* is the distance between them. The charge is measured in Coulombs (C). This name is given after a French physicist Charles Augustin de Coulomb (1736-1806).

Charles Augustin de Coulomb

The coefficient k is 8.99 x 10^9 Nm^2/C^2. Here is a "dangerous point" – some people believe that two charges of 1 C each separated by the distance of 1m will interact with the electrostatic force of 1 N. This is not correct. In fact, the interaction force in this case is much more - 8.99 x 10^9 N!

Looking at the Coulomb's law (Formula1) we see that if the charges will have same sign, that the force will be positive; in the case the charges are of opposite signs, the force is negative. We remember that since the force is vector, changing the sign just means changing the direction of the force for the opposite – repulsion is changed for attraction.

The expression for the electrostatic force between two point charges is similar to the expression of gravitational attraction of two masses:

$$F = G\frac{m_1 \cdot m_2}{r^2} \qquad (2)$$

Here m_1 and m_2 are masses in kilograms, r is the distance between two masses in meters and G is the gravitational constant which is 6.673 x 10^{-11} $m^3/(kg\ s^2)$.

Problems:

1. Why do we have to perform work to separate the charges?
2. Would it be correct to say that there are two types of charge: “attractive” and “repulsive”?
3. Three charged particles 1,2 and 3 lie on a straight line. The particle number 2 is between the particles 1 and 3. The charges on the particles are $Q_1=5.0x10^{-6}C$, $Q_2= 3.0x10^{-6}\ C$, and $Q_3= 2.0x10^{-6}\ C$ they are of the same type (positive). The distance r_{12} between particle *1* and *2* is *10.0cm*. The positions of particles *1* and *3* are kept fixed. What must be the distance r_{23} between particles 2 and 3 for the net electrostatic force on the particle *2* to be zero? Is this equilibrium stable?
4. What must be the distance *r* between two point charges $Q_1=7.0x10^{-6}\ C$ and $Q_2=5.0x10^{-5}C$ for the electrostatic force between them to have magnitude *3.0 N*?
5. Hydrogen atom is the simplest atom, consisting of one positively charge particle -proton and one negatively charged particle – electron, separated from the proton by ~5x10^{-11}m. What is the magnitude of the electrostatic force between proton and electron in a hydrogen atom? (the charge of a proton equals to this of electron and is 1.6x10^{-19}C).