LECTURE 6

Recall your knowledge about gravitational forces. We have

$$\vec{F}_{12} = \frac{Gm_1m_2}{r^2}\vec{r}_{12} = \vec{F}_{21}$$; direction of $r_{12} = r_2 - r_1$

One very important consequence of this particular law is that there is no force on an object inside a closed spherical shell. (this result is easy to understand if the object is in the center – no matter what the 1/rn dependence is - however it is rigorously true even when the object is not in the center for $1 / r^2$ laws.)

Experimentally it was observed that there was no force on a pith ball placed inside a charged metal sphere. So analogy with Newtons theory of gravitation (which had already been proposed) it was therefore argued that The electrical force between two charges is:

$$F_{el} \propto 1/r^2.$$

This was further substantiated by Coulomb’s direct experiments which showed that in addition

$$F_{el} \propto q_1 q_2.$$

We can combine the above two facts to obtain:

$$F_{el} = \frac{kq_1q_2}{r^2} \text{ or } \vec{F}_{el} = \frac{kq_1q_2}{r^2}\vec{r}_{12}$$ where $k = 8.99 \times 10^9$ N m^2 / C^2

The constant k can also be expressed as $k= (1/4\pi\varepsilon_0)$ in terms of the fundamental parameter ε_0 which is the permittivity of space.

Note: Coulomb’s law assumes that the charged objects being considered are point like. Spherically symmetric objects even though extended act point like in nature.

Q: Just how strong is this electric force? For example the gravitational force between the electron and proton in the hydrogen atom.

Radius = 5×10^{-11} m

$M_e = 9.2 \times 10^{-31}$ kg

$M_p = 1.7 \times 10^{-27}$ kg and $G = 6.67 \times 10^{-11}$ N m2/kg2

Therefore $F_g = 4 \times 10^{-47}$ N.

The electric force is: $F_{el} = 9 \times 10^{-8}$ N !!!

SUPERPOSITION PRINCIPLE: Again taking the analogy with gravity – since we have the earth, moon and sun plus other planets:

$F_{1,total} = F_{12} + F_{13} + F_{14} + ...$

Here we have pay proper attention to the sign of the force. Like charges repel and unlike charges attract.

CONTINOUS CHARGES: Instead of discrete charges in the examples we worked – what if there is a continuous distribution ?

If there are a lot of electrons, say 106 or higher then we can pretend the charge is continuos. We then have force between such a continuous charge and another continuous charge.

Examples:

Parallel plates

Parallel Lines
ε_0