Principle of Conservation of Electric Charge

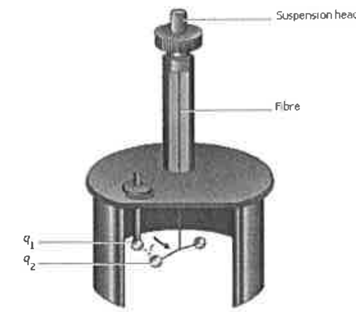
IB 11

The total electric charge of an isolated system remains constant.

The Electrostatic Force

Coulomb's torsion balance was used to establish the relationship for the electric force between two charged spheres.

Charles Coulomb
(1736 – 1806)

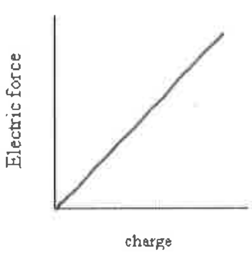


$F_g = \frac{G m_1 m_2}{r^2}$

The charged spheres act as if they were *point charges.*

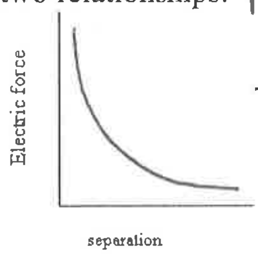
Point charge: an object whose charge is concentrated at a single point where $r = \emptyset$

Experimental data showed the following two relationships:

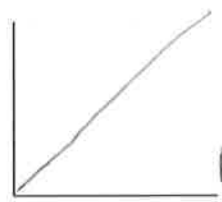


$F \propto q_1$

$F \propto q_2$



$\rightarrow$



$\frac{1}{r^2}$

linearizing the graph

$F \propto \frac{1}{r^2}$

Relationship:

Formula: $F_e = \frac{K q_1 q_2}{r^2}$ or $\frac{K Q_1 Q_2}{r^2}$

electro-static force

Electrostatic Constant (Coulomb's constant):

$K = 8.99 \times 10^9 \, N \frac{m^2}{C^2}$

Coulomb's Law: The electrostatic force between two charged objects is directly proportional to the product of the two charges and inversely proportional to the square of the distance between their centers and acts along a line joining their centers.

Hydrogen atom

1. A proton and an electron are placed 1.0×10^{-10} meter apart.

1 Å

a) Calculate the Coulomb force of attraction between them.

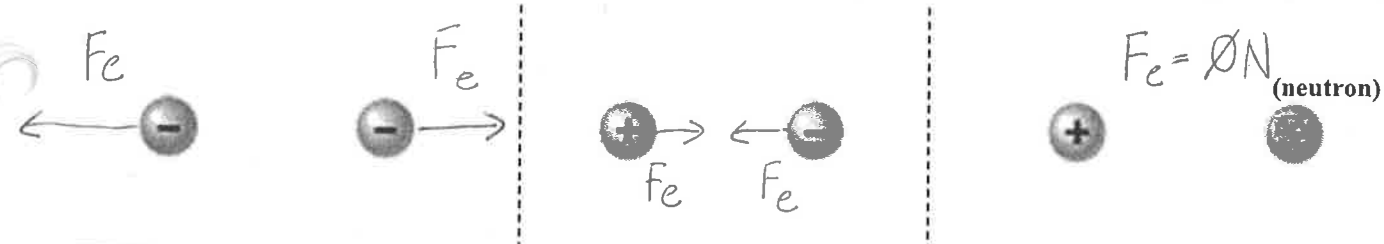
$F_e = \frac{K|q_1||q_2|}{r^2} = \frac{8.99 \times 10^9 N \frac{m^2}{C^2} (1.6 \times 10^{-19} C)^2}{(1.0 \times 10^{-10} m)^2} = \boxed{2.3 \times 10^{-8} N}$

NOTE:

b) Calculate the gravitational force of attraction between them.

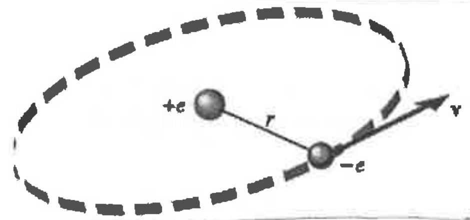
$F_g = \frac{G m_1 m_2}{r^2} = \frac{6.67 \times 10^{-11} N \frac{m^2}{Kg^2} (1.67 \times 10^{-27} Kg)(9.11 \times 10^{-31} Kg)}{(1.0 \times 10^{-10} m)^2} = \boxed{1.0 \times 10^{-47} N}$

2. Sketch the directions of the electrostatic forces and the gravitational forces in each pairing below:



3. In the Bohr model of the hydrogen atom, the electron ($-e$) is in orbit about the nuclear proton ($+e$) at a radius of $r = 5.29\times10^{-11}$ m. Determine the speed of the electron, assuming the orbit to be circular.

$\boxed{V = 2.2\times10^{6}\ \frac{m}{s}}$



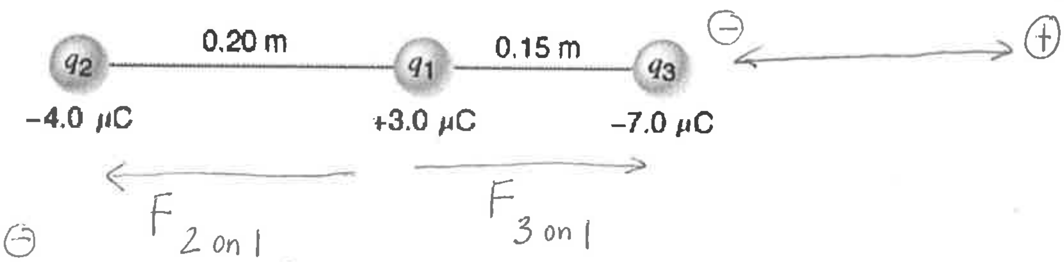
$\Sigma F_{in} = ma_c = \frac{mv^2}{r}$ $\quad m = $ mass of electron

$F_e = \frac{Kq_1q_2}{r^{\cancel{2}}} = \frac{mv^2}{\cancel{r}}$ $\quad V = \sqrt{\frac{Kq_1q_2}{mr}} = \sqrt{\frac{8.99\times10^{9}\frac{Nm^2}{C^2}(1.6\times10^{-19}C)^2}{(9.11\times10^{-31}Kg)(5.29\times10^{-11}m)}}$

$m_e = 9.11\times10^{-31}$ Kg

4. Three charges are placed along a line at the positions indicated. What is the net force on charge q_1?

$\mu C = 1\times10^{-6}\ C$

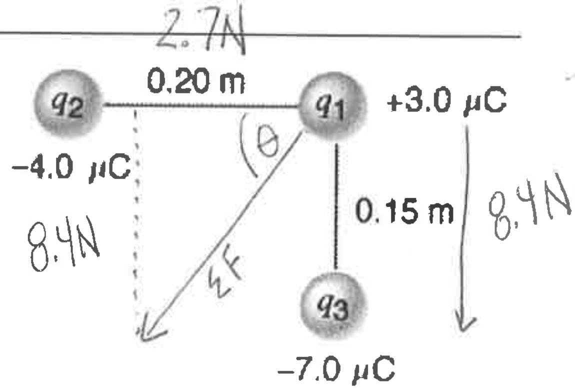


$\Sigma F_{on\ q_1} = F_{2,1} + F_{3,1}$

$\Sigma F_{on\ q_1} = \frac{Kq_2q_1}{r^2} + \frac{Kq_3q_1}{r^2} =$

$-2.7N + 8.4N = \boxed{5.7N}$

5. The three charges are now placed at right angles, as shown. What is the net force on charge q_1?



$\Sigma F_{e\ on\ q_1} = \sqrt{F_{2,1}^2 + F_{3,1}^2}$

$\boxed{\Sigma F_e = 8.8N}$

$\tan\theta = \frac{8.4N}{2.7N}$

$\theta = \tan^{-1}\left(\frac{8.4N}{2.7N}\right) = \boxed{72^{\circ}}$