***Notes***

## Physics Tool box

- **Coulomb's Law** –The magnitude of the electric force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.
- $F = k\frac{|q_1 q_2|}{r^2}$.
- **k** is the Coulomb proportionality Constant
- $k = \frac{1}{4\pi \in_0} = 8.988\times 10^9 \frac{N\cdot m^2}{C^2}$.
- Coulomb's Law applies when the charges on the two spheres are very small, and the two spheres are small compared to the distance between them.
- There are similarities between Coulomb's Law and Newton's Law of universal Gravitation:
  - Both are inverse squares laws that are proportional to the product of quantities that characterize the body involved
  - The gravitational force only attracts, while the electric force and attract or repel.
  - The universal gravitational constant is very small while the Coulomb constant is very large.
  - $F_E = \frac{kq_1q_2}{r^2}$, $F_g = \frac{Gm_1m_2}{r^2}$

The electric force between two point charges also depends on the quantity of charge on each body, which is denoted at q. Coulomb found that the forces that two point charges $q_1$ and $q_2$ exert on each other are proportional to each charge and therefore proportional to the product $q_1q_2$ of the two charges.

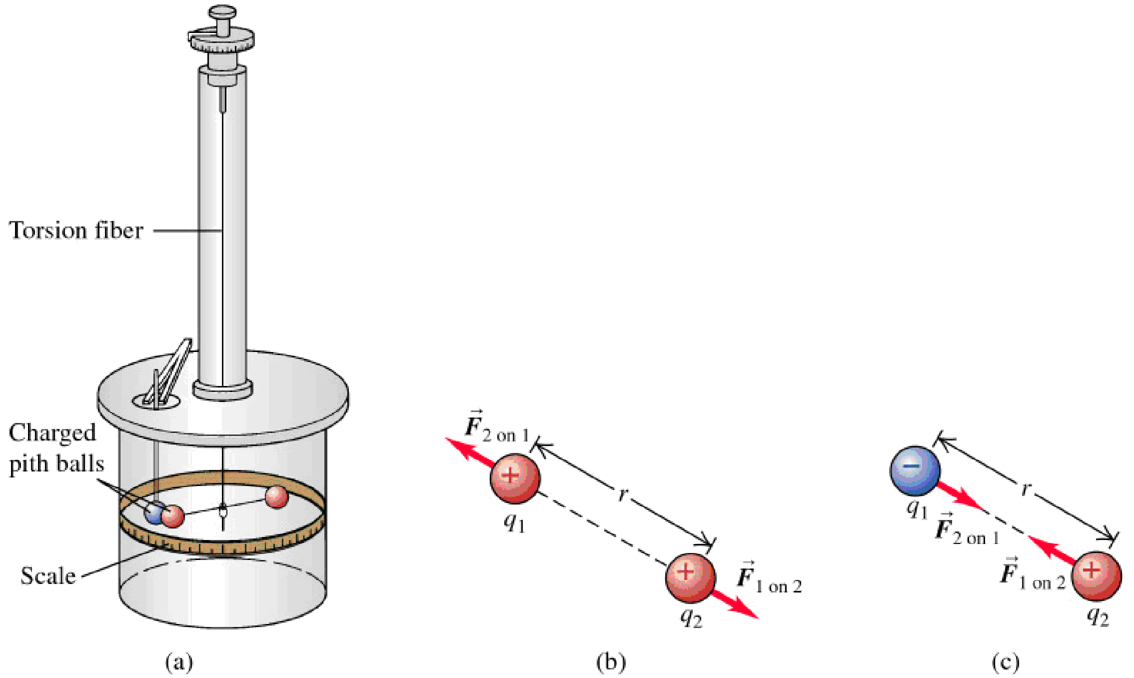
**Coulomb's Law** –The magnitude of the electric force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

$$F = k\frac{|q_1 q_2|}{r^2}$$

Where k is the Coulomb Proportionality Constant whose numerical value depends on the system of units used. The absolute value bars are used because the charges $q_1$ and $q_2$ can be either positive or negative, while the force magnitude F is always positive.

$$k = \frac{1}{4\pi \in_0} = 8.988\times 10^9 \frac{N\cdot m^2}{C^2}$$

$\in_0$ (epsilon-nought) is permittivity of free space = $8.854\times 10^{-12} \frac{C^2}{N\cdot m^2}$




Plastic rods and fur (real or fake) are typically used to demonstrate electrostatics.

We now that there are exactly two types of charges negative and positive

**The Laws of Electric Charges** – Two positive charges or two negative charges repel each other. A positive charge and a negative charge attract each other

**Example**

The magnitude of the electrostatic force between two point like charged objects is $4.0\times10^{-6}N$. Calculate the force for each of the following situations:

a) The distance between objects is doubled
b) Distance remains same but charge on one object tripled and charge on other is cut by 5.
c) Both a and b occur.

**Solution:**

a) $\dfrac{F_2}{F_1}=\dfrac{\dfrac{kq_1q_2}{r_2^2}}{\dfrac{kq_1q_2}{r_1^2}}=\left(\dfrac{r_1}{r_2}\right)^2$

$$F_2=F_1\left(\frac{r_1}{r_2}\right)^2$$

$$=\left(4.0\times10^{-6}N\right)\left(\frac{1}{2}\right)^2$$

$$=1.0\times10^{-6}N$$

The magnitude of the force is now $1.0\times10^{-6}N$

b) $$\frac{F_2}{F_1}=\frac{\dfrac{k3q_1\frac{1}{5}q_2}{r_2^2}}{\dfrac{kq_1q_2}{r_1^2}}=\frac{3}{5}$$

$$\begin{aligned}F_2&=F_1\frac{3}{5}\\&=\left(4.0\times10^{-6}N\right)\left(\frac{3}{5}\right)\\&=2.4\times10^{-7}N\end{aligned}$$

The magnitude of the force is now $2.4\times10^{-7}N$

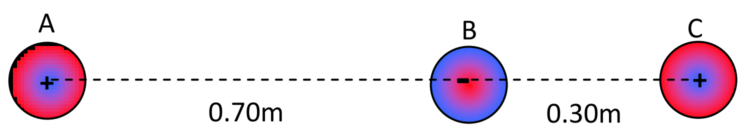
c) $$\frac{F_2}{F_1}=\frac{\dfrac{k3q_1\frac{1}{5}q_2}{r_2^2}}{\dfrac{kq_1q_2}{r_1^2}}=\frac{3}{5}\left(\frac{1}{2}\right)^2$$

$$\begin{aligned}F_2&=F_1\frac{3}{20}\\&=\left(4.0\times10^{-6}N\right)\left(\frac{3}{20}\right)\\&=6.0\times10^{-7}N\end{aligned}$$

The magnitude of the force is now $6.0\times10^{-7}N$

## Example

Three objects with charges A: $+6.0\mu C$, B: $-5.0\mu C$, and C: $+4.0\mu C$ are placed in a line. Determine the net electric force on charge A.




## Solution:

### The magnitude of the force exerted on A by C

$$\begin{aligned}F_{AC}&=\frac{kq_Aq_C}{r_{AC}^2}\\&=\frac{\left(9.0\times10^9N\cdot\frac{m^2}{C^2}\right)\left(6.0\times10^{-6}C\right)\left(4.0\times10^{-6}C\right)}{\left(\left(0.70+0.30\right)m\right)^2}\\&=0.216N\end{aligned}$$

Charges are same sign so the forces

Therefore the force on A by C is 0.216 N [left]

**The magnitude of the force exerted on A by B**

$$F_{AB} = \frac{kq_A q_B}{r_{AB}^2}$$

$$= \frac{\left(9.0\times10^9 N\cdot\frac{m^2}{C^2}\right)\left(6.0\times10^{-6}C\right)\left(5.0\times10^{-6}C\right)}{\left(0.7m\right)^2}$$

$$= 0.5510N$$

Charges are different sign so the forces

Therefore the force on A by B is 0.551N [right]

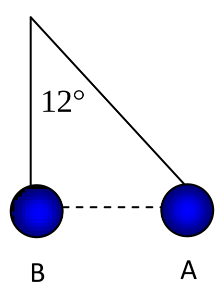
So the net force on A is : $\sum\vec{F} = \vec{F}_{AC} + \vec{F}_{AB}$

$$= 0.216N[left] + 0.551N[right]$$

$$= 0.33N\ [right]$$

**Example**

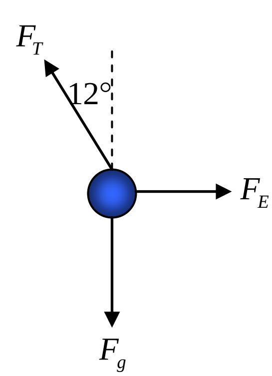
A neutral metal sphere A (0.10kg), hangs from an 2.0 m insulating wire. An identical sphere B, with charge –q, is brought into contact with sphere A. The spheres repel each other so that the angle of the wire is $12°$. What was the initial charge on B




**Solution:**

First we must determine what the forces are that holds a 0.10 kg sphere at an angle of $12°$.

So let's draw a force diagram




Now $T\cos(12°) = mg$

$T\sin(12°) = F_E$

So we can solve for $F_E$

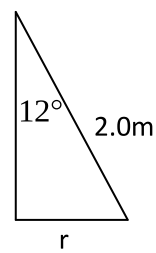
$$\frac{F_E}{mg} = \frac{\sin(12°)}{\cos(12°)}$$

$$\begin{aligned} F_E &= mg\tan(12°) \\ &= (0.10kg)\left(9.8\frac{N}{kg}\right)(\tan(12°)) \\ &= 2.08\times10^{-1}N \end{aligned}$$

Before we can apply $F = k\frac{|q_1q_2|}{r^2}$, we need the distance (r value)

$$\frac{r}{2.0m} = \sin(12°)$$

$$\begin{aligned} r &= 2.0m\sin(12°) \\ &= 0.416m \end{aligned}$$




The charge on each sphere after touching are now identical so $q_1 = q_2$, therefore half of the original charge q on B

Now,

$$F_E = k\frac{\left(\frac{1}{2}q\right)\left(\frac{1}{2}q\right)}{r^2}$$

$$q^2 = \frac{4F_Er^2}{k}$$

$$\begin{aligned} q &= \sqrt{\frac{4F_Er^2}{k}} \\ &= \sqrt{\frac{4\left(2.0\times10^{-1}N\right)(0.416m)^2}{9.0\times10^9 N\cdot\frac{m^2}{C^2}}} \\ &= 3.9\times10^{-6}C \end{aligned}$$

The initial charge on B is $3.9\times10^{-6}C$

***Extra Notes and Comments***