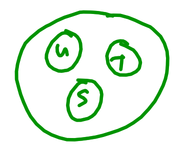
Electrostatics

Measuring Electric Charge: The Coulomb

- The Coulomb is to electricity as Kilogram is to gravity
- The unit used to measure electric charge is the coulomb, C.

  > Named after French scientist Charles-Augustin de Coulomb
  > Made pivotal discovery about the forces that electric charges exert on each other

- The charge of one electron, q_e, is -1.602×10^{-19} C.



- The charge of one proton, q_p, is $+1.602 \times 10^{-19}$ C.
- q is referred to as the "elementary charge" because nothing can have a lower charge than this value (quarks maybe?)
- The definition came many years after his death. Had no knowledge of atomic particles and so when deciding on how to define 1 C they didn't know it's connection to elementary charge

An object is charged if gains or loses electrons.

The total charge acquired is calculated as

$$Q = n q_e \quad \text{or} \quad Q = n q_p$$

where n = number of unpaired protons or electrons,
$q = q_e$ or q_p, and
Q = the total net charge, in coulombs.

Coulomb's Law

The law states that the electrostatic force exerted between two charged point charges is ...

directly proportional to the sizes of the charges and

inversely proportional to the square of the distance of separation.

dim.

↓

$r^{n-1} \rightarrow n = 3$

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

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

F_Q

this looks familiar....

no sig figs used

where
k = proportionality constant = 9.0×10^9 N m^2/C^2,
r = distance of separation from centre to centre in metres, m,
q_1 = size of charge on first object, in C, and
q_2 = size of charge on second object, in C.

p. 955 k = 8.988 x 10^9 Nm^2/C^2

If q_1 and q_2 are like charges, the force is positive
If they are opposite charges, the force is negative
This will affect the direction of the force vector.... we will deal with that later

Examples

Ex. 1 attractive

What is the electrostatic force acting between a positive 1.1×10^{-5} C charge and a negative 2.2×10^{-6} C charge that are placed 100 cm apart?

Ex. 2

An attractive force of 4.21×10^{-3} N exists between a $+ 6.3 \times 10^{-4}$ C charge and a $- 4.7 \times 10^{-5}$ C charge. How far apart are the charges?

Ex. 3

An electron is placed 132 cm from a positive charge such that the force of attraction is 4.12×10^{-3} N. What is the size of the positive charge?

Do Practice Problems 1-5 on Page 638

Ex 1

$q_1 = 1.1 \times 10^{-5} C$

$q_2 = -2.2 \times 10^{-6} C$

$r = 100 \text{ cm}$

$F_e = ?$

$$F_e = \frac{K q_1 q_2}{r^2}$$

$$= \frac{(9.0 \times 10^9 Nm^2/C^2)(1.1 \times 10^{-5} C)(-2.2 \times 10^{-6} C)}{(1 m)^2}$$

$$= -0.2178 N = \boxed{-0.2 N}$$

Ex 2

$F_e = -4.21 \times 10^{-3} N$

$q_1 = 6.3 \times 10^{-4} C$

$q_2 = -4.7 \times 10^{-5} C$

$r = ?$

$$F_e = \frac{Kq_1q_2}{r^2}$$

$$r = \sqrt{\frac{Kq_1q_2}{F_e}}$$

$$= \sqrt{\frac{(9.0 \times 10^9 Nm^2/c^2)(6.3 \times 10^{-4} C)(-4.7 \times 10^{-5} c)}{(-4.21 \times 10^{-3} N)}}$$

$$= 251.59\,m = \boxed{250\,m}$$

Ex 3

$r = 132\ cm$

$F_e = -4.12 \times 10^{-3} N$

$q_1 = -1.602 \times 10^{-19} C$

$q_2 = ?$

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

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

$$= \frac{(-4.12 \times 10^{-3} N)(1.32\ m)^2}{(9.0 \times 10^9 Nm^2/C^2)(-1.602 \times 10^{-19} C)}$$

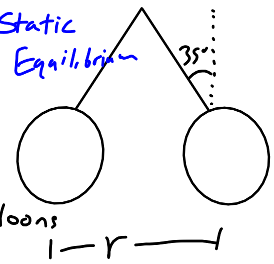
$= 4978976.28\ C$

$= 4.98 \times 10^6 C = 4.98\ MC$

2 Balloons of equal mass and equal charge are supported be strings. The strings make an angle of 35^0 with the vertical. The balloons are separated by a distance of 0.42m and each has a mass of 6.038g.

What is the ~~Tension in the string~~ Charge on balloons

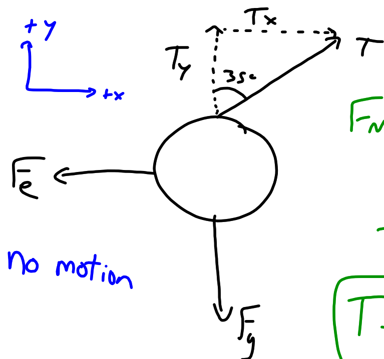
Static Equilibrium



$m = 6.038\,g$ $\quad \vec{g} = 9.81\,m/s^2$ [down]

$\theta = 35°$ $\quad \vec{a}_x = 0\,m/s^2$

$r = 0.42\,m$ $\quad \vec{a}_y = 0\,m/s^2$



no motion

$$F_{Net,x} = T_x - F_e = ma_x = 0N$$

$$T_x = F_e$$

$$\boxed{T\sin\theta = \frac{Kq_1q_2}{r^2}}$$

$$F_{Net,y} = T_y - F_g = ma_y = 0\,N$$

$$T_y = F_g \rightarrow \boxed{T\cos\theta = mg}$$

$$\frac{\cancel{T}\sin\theta}{\cancel{T}\cos\theta} = \frac{Kq_1q_2/r^2}{mg}$$

$$\tan\theta = \frac{Kq_1q_2}{r^2mg} = \frac{Kq^2}{mgr^2}$$

$$q = \sqrt{\frac{mgr^2\tan\theta}{K}}$$

$$= \sqrt{\frac{((0.006038\,kg)(9.81\,m/s^2)(0.42\,m)^2\tan(35°))}{9.0\times10^9\,Nm^2/C^2}}$$

$$= \pm 9.016\times10^{-7}\,C$$

$$\boxed{= \pm 9.0\times10^{-7}\,C}$$