Electrostatics Notes

1 – Charges and Coulomb's Law

Ancient Greeks discovered that if amber (fossilized sap) is rubbed it will attract small objects. This is similar to when you run a comb through your hair…it will then attract bits of lint or dust. WHY?!?

Clearly this attraction is due to some FORCE at work. In this case it is electrostatic force which exists between electrically charged objects.

Conductors are materials that…allow electrons to flow.

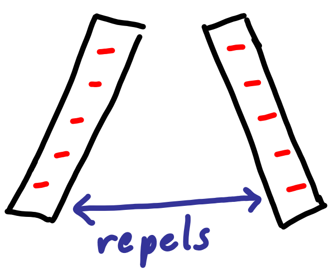
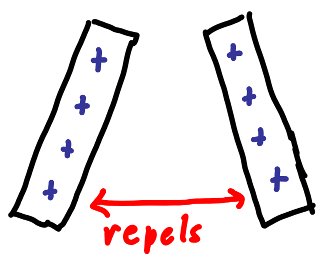
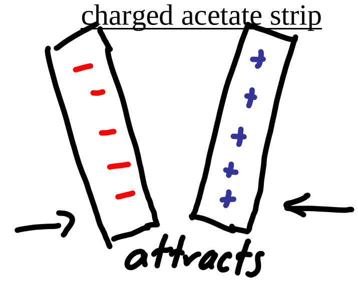
Insulators are materials that…impede electron flow.

A negative charge is caused by…an excess of electrons.

A positive charge is caused by…a lack of electrons.

It is possible to build up a charge on insulators because electrons cannot… easily flow off of (–) or onto (+) an insulator.

When a vinyl strip is rubbed with fur or wool the rod gains an excess of electrons and therefore is negative. If an acetate strip is rubbed with silk then it will lose electrons and become positive.

Two charged vinyl strips	Two charged acetate strips	One charged vinyl and one charged acetate strip
		

The Law of Charges states:

(1) Like charges repel.

(2) Opposite charges attract.

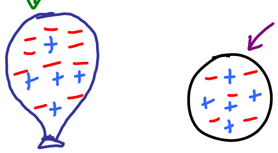
(3) Neutral charges are attracted to charged (+ or –) objects.

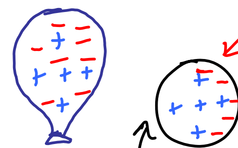
But what about that so-called amber effect? Why are seemingly uncharged objects attracted to charged amber (or combs for that matter)?

It has to do with something called… INDUCTION!

Consider a rubber balloon that has been rubbed on someone's hair and a tin can.

charged with extra electrons





Note that the electrons on the can…are able to move freely so that as the can rolls a + charge always faces the balloon.

Other examples of electrostatic charges in everyday life include:

(1) Rubbing your feet on the carpet then touching a door knob.

(2) Jumping on a trampoline then stepping on the metal rail.

(3) When you pull your clothes out of the dryer, the sock sticks to your sweater.

Ok enough playing around, where's the formulas?!?

Coulomb determined that the force between two charged objects is proportional to their charges and inversely proportional to the square of their distances or:

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

Where:

q_1 = 1st charge, in Coulombs (C)

q_2 = 2nd charge, " " "

r = distance between charges

k = Coulomb's Constant

= $9.0 \times 10^9\ N\cdot\frac{m^2}{C^2}$

There are two important things to notice from this equation.

First, this equation is quite similar to…universal gravitation

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

Second, electrostatic forces are much stronger than gravitational forces.

$G = 6.67\times10^{-11}\ N\frac{m^2}{kg^2}$ whereas $K = 9.0\times10^9\ N\frac{m^2}{C^2}$

There is a very important difference between gravitational and electrostatic forces:

Gravity ALWAYS…attracts

Electrostatic force can..attract or repels

When solving for electrostatic forces we will NOT…use +/− signs of charges even though force is a vector.

Instead we will determine the direction of the force based on…

whether it is an attraction or repulsion

Example:
Two 85 kg students are 1.0 m apart. What is the gravitational force between them?

$$F_g = \frac{G m_1 m_2}{r^2} = \frac{(6.67\times10^{-11})(85)(85)}{(1.0)^2}$$
$$= 4.82\times10^{-7}\ N$$

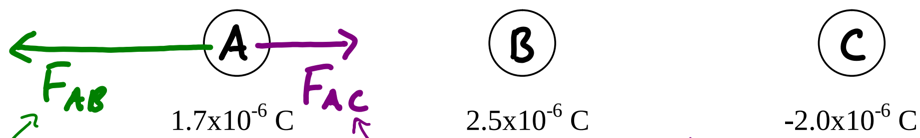
If these two students each have a charge of 2.0x10^{-3} C, what is the electrostatic force between them?

$$F_E = \frac{k q_1 q_2}{r^2} = \frac{(9.0\times10^9)(2.0\times10^{-3})(2.0\times10^{-3})}{(1.0)^2}$$
$$= 36000\ N$$

Example:
Two point charges of 1.8x10^{-6} C and 2.4x10^{-6} C produce a force of 2.2x10^{-3} N on each other. How far apart are these two charges?

$$F_E = \frac{k q_1 q_2}{r^2}$$
$$r = \sqrt{\frac{k q_1 q_2}{F_E}}$$
$$= \sqrt{\frac{(9.0\times10^9)(1.8\times10^{-6})(2.4\times10^{-6})}{(2.2\times10^{-3})}}$$
$$= 4.2\,m$$

Example:
A charge of 1.7x10^{-6} C is placed 2.0x10^{-2} m from a charge of 2.5x10^{-6} C and 3.5x10^{-2} m from a charge of -2.0x10^{-6} as shown.



since A+B are positive they repel

since A+C are opposite they attract

What is the net electric force on the 1.7x10^{-6} charge?

Winner - Loser

$$F_{net} = F_{AB} - F_{AC}$$
$$= \frac{k q_A q_B}{r_{AB}^2} - \frac{k q_A q_C}{r_{AC}^2}$$
$$= \frac{(9.0\times10^9)(1.7\times10^{-6})(2.5\times10^{-6})}{(2.0\times10^{-2})^2} - \frac{(9.0\times10^9)(1.7\times10^{-6})(2.0\times10^{-6})}{(3.5\times10^{-2})^2}$$

don't use negative sign!!!

$$= 71\ N$$