Charging by Friction, Induction, & Conduction

Charging by Friction

The only reason that we are able to use electricity in our modern world is that it is possible to separate positive and negative charges from each other.

- One way to do this is by rubbing two different materials together, a process known as **charging by friction**.
- Since the two objects are made of different materials, their atoms will hold onto their electrons with different strengths.
- As they pass over each other the electrons with weaker bonds are "ripped" off of that material and collect on the other material.

Example 1: Rub a piece of **ebonite** (very hard, black rubber) across a piece of **animal fur**. **Explain** what happens.

The **fur** does not hold on to its electrons as strongly as the **ebonite**. At least some of the electrons will be ripped off of the **fur** and stay on the **ebonite**. Now the **fur** has a slightly **positive** charge (it **lost** some electrons) and the **ebonite** is slightly **negative** (it **gained** some electrons).The net charge is still zero between the two… remember the conservation of charge. No charges have been created or destroyed, just moved around.

Example 2: Rub a **glass** rod with a piece of **silk**. **Explain** what happens.

This is the same sort of situation as the one above. In this case the **silk** holds onto the electrons more strongly than the **glass**. Electrons are ripped off of the **glass** and go on to the **silk**. The **glass** is now **positive** and the **silk** is **negative**.

You may be wondering how you could ever keep track of this, since the combinations of different materials being rubbed on each other is infinite.

- Rather than try to keep track off all the combinations, we can arrange some of the more common possibilities in a chart called an "**Electrostatic Series**" that lets you find out which material will be positive and which one will be negative.
    - An electrostatic series in arranged in terms of the relative "hold" that different materials have on their electrons.

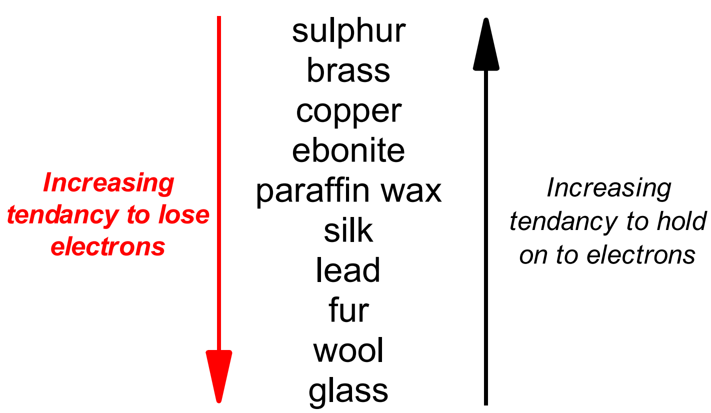

Figure 1: Electrostatic Series

- To use the electrostatic series, you first need to find the two different materials that are being rubbed.
    - Whichever material is closer to the **top** is holding electrons tightly so it will have a **negative** charge.
    - The material closer to the **bottom** has a greater chance of losing electrons, so it will be **positively** charged.

Example 3: **Determine** the charge on a piece of copper if you rub it with a piece of silk.
Looking at the electrostatic series, **copper** is closer to the top with **silk** beneath it. This means that the **copper** is **negative** and the **silk** is **positive**.

Charging by Conduction

Conduction just means that the two objects will come into actual physical contact with each other (this is why it is sometimes called "***charging by contact***").

> **Did you know?**
> If the two objects are brought close enough that an arc of electricity jumps between them, it counts as conduction also.

- Let's assume we have a negatively charged metal object and an uncharged metal sphere (**Figure 2a**). The uncharged sphere is on an insulating stand so that it will not interact with anything else.
- We bring the two objects close together. We will see a ***separation of charge*** happen in the neutral object as negative electrons are repelled to the right hand side (**Figure 2b**).
    - At this time, they are not touching and no charges have been transferred.
- We allow the two objects to touch (**Figure 2c**).
    - Some of the negative charge will transfer over to the uncharged metal object. This happens since the negative charges on the first object are repelling each other... by moving onto the second object they spread away from each other.
- When the negative object is removed, it will not be as negative as it was (**Figure 2d**).
    - Both of the objects have some of the negative charge… how much depends on the size of the objects and the materials they are made of.
    - If they are the same size, made of the same materials, then the charge will be the same on both.

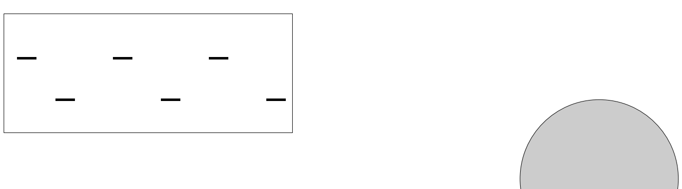

Figure 2a:
Charged and Neutral Objects

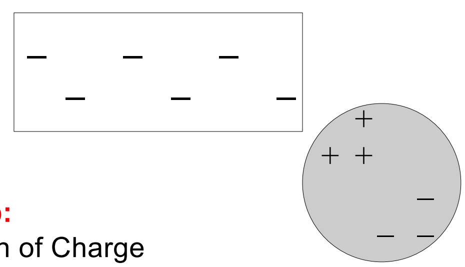

Figure 2b:
Separation of Charge

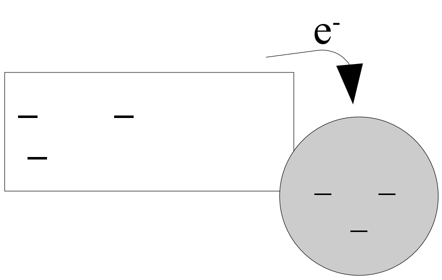

Figure 2c:
Conduction!

Figure 2d:
Afterwards

Overall the total negative charge remains constant.

- We started with six negative charges, and we ended up with a total of six.
- Notice that this means a negative object causes a negative charge on another object.
- What would happen if you used a positive rod to touch the metal sphere?
    - The same sort of thing, except that the neutral object will transfer electrons to the positively charged object.
    - See if you can draw it for yourself!!!

In any of these cases the results depend on if the materials used are conductors or insulators.

- In the examples I've given so far, all the materials have been conductors, so the charges flow easily from one to the other and spread out.
- If the materials used were insulators, only the specific areas that actually touched would show any change in charge.
    - That's because the charges can't move through the insulators easily.

Charging by Induction

It is possible to charge a conductor without coming into direct contact with it.

- You do have to follow some special procedures.
    - The most important one is the use of a **grounding wire**.
    - A **grounding wire** is simply a conductor that connects the object to the ground.
    - Think of the earth as a huge reservoir of charge… it can both gain or donate electrons as needed. Depending on what the situation is, either electrons will travel up the **grounding wire** to the object being charged, or travel down to the ground.

Charging by induction is a more complex process than conduction, as the example below shows…

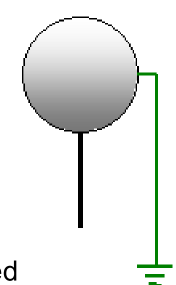

Figure 3a:
Neutral Sphere Grounded

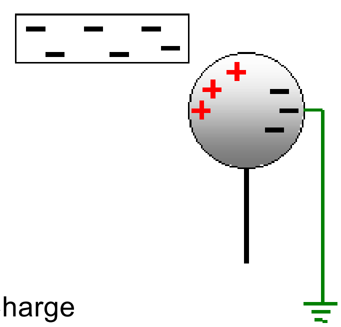

Figure 3b:
Separation of Charge

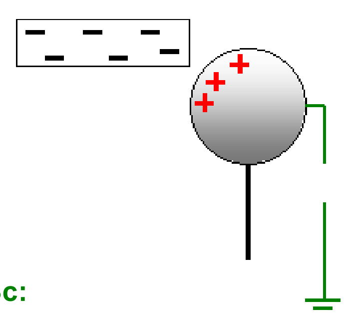

Figure 3c:
Snip the Wire!

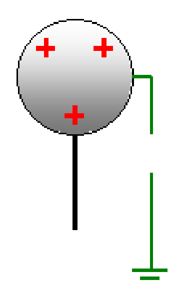

Figure 3d:
Afterwards

Figure 3a: The metal sphere is on an insulating stand. It also has a **ground wire** attached to it.

Figure 3b: We bring a negative object nearby. This will cause a separation of charge in the sphere. If you think about it, those electrons piled up at the edge want to get as far away as possible, and since they are free to move they do just that. They will travel down the ground wire.

Figure 3c: This step is VERY important. Keeping the negative object nearby we snip the **ground wire**. Now there is no way for the electrons to travel back up they wire to the sphere. If we had skipped this step and just moved the negative object away without snipping the ground wire, the negative charges would have just gone back up the wire onto the sphere and it would be neutral again.

Figure 3d: We remove the negative object… now the sphere has a net positive charge.

The same sort of thing happens if you bring a positively charged object near to a grounded sphere.

- In that case, electrons would come up the grounding wire to be closer to the object. This would leave the sphere with a negative charge.
- Notice that when you charge by induction you get the opposite charge on the metal sphere.

Electroscopes

How can you tell if an object has a charge, especially if you're doing research in the 1700's?

- Very early on physicists started using electroscopes to measure very small charges on objects.
- An electroscope is made up of a couple of very thin metal leaves that hang down near to each other. They are connected to a metal rod that extends upwards, and ends in a knob on the end.
- The whole apparatus is usually insulated from outside effects by being in a metal container with a mica window to look in at the leaves. A rubber stopper insulates the rod from touching the metal container.

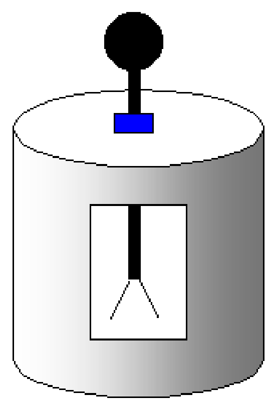

Figure 4: An electroscope

Imagine what happens to the metal leaves if a charged object is brought nearby…

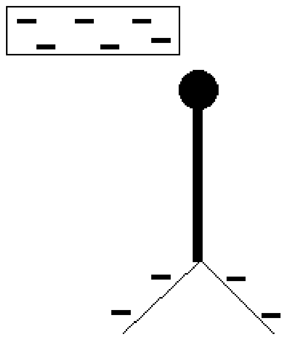

Figure 5a: In this situation a negative object is brought nearby the electroscope. This causes free moving electrons in the electroscope to move down into the leaves. Since the leaves both have negative charge they repel each other and move apart.

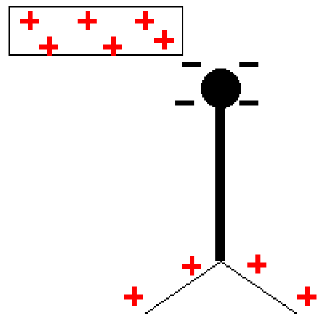

Figure 5b: Bring a positive object nearby and the free electrons in the electroscope all start moving up towards the top. This means the bottom has a net positive charge. The leaves will spread apart again.

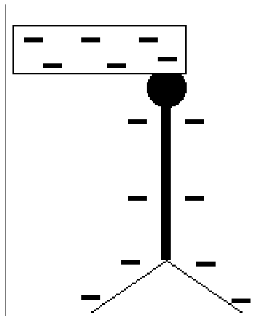

Figure 5c: Touch the electroscope with any charged object and you'll give it an overall charge by conduction. The leaves will stay spread apart even if you remove the object.