Lesson 7: Insulators, Conductors, and the Others

There are four categories of materials based on their **conductivity** (ability to allow charges to move freely).

- **Conductivity** is just a way of describing how easily charges can move through a material.

Illustration 1: Comparison of Conductivity

Insulators & Conductors

Imagine you have two metal spheres, one charged and the other neutral.

- If you place an **iron nail** between the two so it touches both spheres, the uncharged sphere is now charged (the other one is also still charged, just not as much as it was originally).
- If you had used a piece of **rubber** instead, the uncharged sphere would not have gained any noticeable charge.

We say that the **iron** is a **conductor**, while the **rubber** is an **insulator**.

As a rule…

- most metals are pretty good **conductors**, since they allow charges to move around quite easily.
- most other materials are **insulators** , since they resist the movement of electrical charges. Keep in mind that even **insulators** will conduct a little charge.

Semiconductors

There are a few materials (silicon, germanium, carbon) that are **semiconductors**.

- Even though you would not normally think that these non-metals can conduct electricity, they can. It just depends on the conditions.
  - For some semiconductors, temperature is the key. At low temperatures they act like **insulators**, while at room temperatures and above they act as **conductors**.
  - Selenium (which is used on the drums of some photocopiers) depends on the amount of light it is exposed to. It is an **insulator** in the dark, but becomes a **conductor** when exposed to light.
- This is one of the reasons that chemists refer to these elements as **metalloids** ("sort-of-metals")
- A significant amount of research is done with **semiconductors**, specifically in the field of computer electronics.

Superconductors

There is one other group, the **superconductors**, which are such fantastic conductors that they lose practically no energy at all as they transfer electricity.

- Unfortunately, superconductors usually only work at very cold temperatures near absolute zero.
- Some ceramic based superconductors have been created that work at around the same temperatures as liquid nitrogen (about -200°C) which is very easy and cheap to make.

Absolute zero is the temperature at which atoms have no kinetic energy and stop moving. This happens at -273.15°C which is 0°K.

Reasons for Different Conductivity

The reason for the different properties of these types, especially for conductors and insulators, is found on an atomic level…

- In **conductors**, the electrons furthest away from the nucleus in the outer levels (valence electrons) are not attracted as strongly by the nucleus of the atom.
  - For this reason the electrons in **conductors** can move around somewhat freely.
- In **insulators** the electrons are tightly bound to the nucleus and don't move as freely.

When a charged object is brought close to a **conductor**, the free electrons in the **conductor** will move either away or towards the object depending on the charge of the other object.

- Remember that like charges repel, unlike attract.
- In this example, a positively charged object is brought near a neutral conductor.

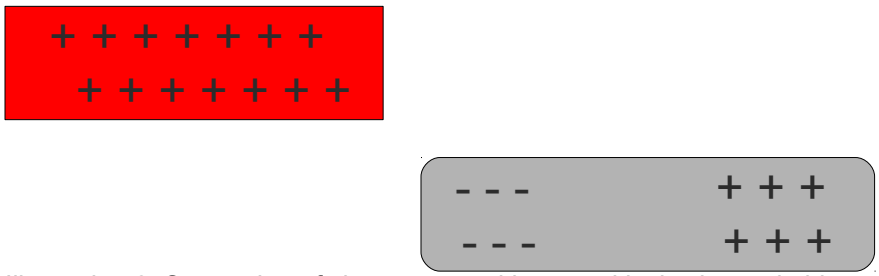

Illustration 2: Separation of charge caused by a positively charged object.

- The electrons in the neutral object have shifted to the left since they are attracted towards the positive object.
- Always remember that in any situation, ***only electrons can move***! The protons are "trapped" in the nucleus and can't move around. That means the protons remain on the right.
- This is referred to as a **separation of charge**. There are still equal numbers of negative and positive charges that cancel each other out, but they are separate from each other.

If a negatively charged object is brought close to a conductor…

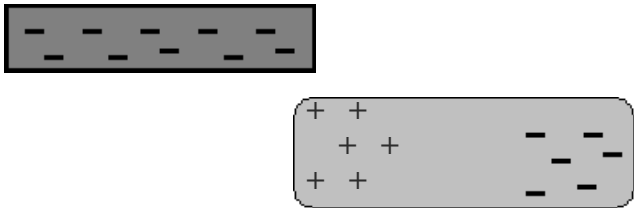

Illustration 3: Separation of charge caused by a negative object

- The negative charges in the conductor will pile up as far away from the object as possible.
- The positive charges remaining on the left side make it positive.
- Again, this is a **separation of charge**.

In a **semiconductor**, there are only a few electrons that can freely move around, and in an **insulator** almost none.

- If you bring a charged object near one of these, you won't see this **separation of charge** happen.

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