Unit 2: Fields

Part 1: Electrostatics (Read section 524 - 534)

Section I : Definition of Electrostatics

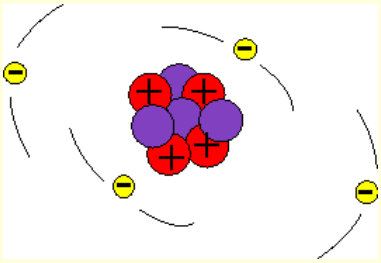
Electrostatics is the study of electricity at rest.

Early Greeks noticed that when a piece of **sap or amber** was rubbed with a cloth or another piece of material, it attracted small objects. They called this phenomenon the **"amber effect."** The Greek word for amber is **"elektron"** and the effect became known as the **"electriks" or electricity**. Anything that behaved in this manner was said to be electrically charged. Any material that did not exhibit this quantity was said to be **neutral.**

Substances that possessed an electric charge were noticed to show two different states; these were classified as either **negative or positive**. From this we observed that opposite electrical charges attracted each other and similar electrical charges repelled each other. Also, it was found in some instances that charged objects attract neutral objects. This is called the **fundamental law of electric charges.**

Section II: The Electric Structure of Matter

1. All matter is composed of submicroscopic particles called **atoms**. An **atom** is the smallest part of an element which can take part in a chemical reaction. While no one really knows for sure what an atom is exactly like, a model that helps explain electrostatics is shown here. Experiments suggest that atoms are mostly empty space with the bits in the middle having one kind of charge, and the bits swirling around on the outside having another kind of charge. As the years went by, scientists discovered some particles in the middle had no charge at all!



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2. Atoms are composed of a number of smaller particles called **protons, electrons, and neutrons**. These structures are present in a specific manner within the atom, the number and arrangement of each is dependent on the particular atom that is considered. (More in unit 3)

3. The very centre of the atom is called the **nucleus**. It is composed of **protons and neutrons**. (Neutrons are heavier than protons.) $m_n \approx m_p + m_e$

   This small heavy region makes up almost 99% of the mass of the atom but occupies less than 5% of the space that an atom occupies.

4. The **protons** in the atom provide the positive charge. The charge that is present on each proton is the same. Thus, if we know the size ~~if~~ of the charge on one proton and the number of protons, we know the size of the charge on the nucleus.

   We simply multiply the charge by the number of protons. The basic charge on a proton is called the elementary charge. The **elementary charge is 1.60×10^{-19} Coulombs**.

   $Q = Ne$ where N is the number of protons (or electrons)
   e is the elementary charge
   Q is the total charge

5. The third component of an atom is located a considerable distance from the nucleus. The area in which the third part, the electron, may be located, is called the **orbital**. The **orbital** consists mostly of empty space. However, it makes up more than 95% of the space that the atom occupies.

6. The **electron**, though only 1/2000 of the mass of a proton, has a charge of exactly the same magnitude as the proton. The charge of the electron is opposite of the charge of a proton. Thus, it has a **negative charge**. The charge on one electron is -1.6×10^{-19} C.

7. In nature, all atoms have exactly the same number of electrons and protons, thus the atom is said to be **neutral**. If the atom gains or loses any electrons, the atom will become charged. An atom that has a net charge is called an ion.

8. An excess of negative charges means that the atom has more negative charges than normal and consequently, the atom has a net negative charge. **(Negative ion)** A deficit of electrons means that the atom has fewer than electrons than normal and thus has an overall net positive charge. **(Positive ion)**

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Fundamental Law of Electric Charges

Opposite electric charges attract.
Like electric charges repel.
Charged objects attract some neutral objects.

Section III: Conductors and Insulators (18.2)

Insulators are solids in which the electrons are not free to move easily from atom to atom because they are bound tightly to the nucleus. Electrons removed from one end of an insulator will not move to the other end. Good insulators are plastic, cork, glass, wood and rubber.

Conductors are solids in which electrons are able to move easily from one atom to another. Electrons removed from one end will be replaced by electrons moving in from the other end. Electrons in these materials do not act as if they belong to one specific atom but to the object as a whole. Most metals are excellent conductors, the best being silver, copper and aluminum.

Semi-conductors possess properties that mimic those of both insulators and conductors; electrons are free to move but not as freely as in conductors. Examples are copper oxide, silicon, and germanium.

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Section IV: Charging by Friction

There are three ways of charging an object:

1 Friction: This is used to charge put an electric charge on an insulator. This method cannot be used to place a residual charge.

2 Contact: This method is used to place a residual charge on a conductor. (conductor receives the same charge)

3 Induction: This method is also used to place a charge on a conductor. In this case the charge may be temporary or residual.
(conductor receives opposite charge).

When we discussed negative and positive charges in atom, we only considered the gain ~~of~~ or loss of electrons. **Only electrons are gained or lost in solids. Protons never move.** Each specific type of atom will always have the same number of protons.

Adding energy to an atom allows us to remove or add one or more electrons from an atom or substance. Different materials have different **affinities or attractions** for electrons; some give them up easily and some do not.

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Electric Static Series Table

Cat's fur
Acetate
Glass
Wool
Lead
Silk
Wax
Ebonite
Copper
Rubber
Amber
Sulphur
Gold

Weak Attraction for Electrons
(Becomes Positive)

Strong Attraction for Electrons
(Becomes Negative)

Substances which have a **weak attraction** for the outer electrons give them up easily and are more likely to become **positive when rubbed**.

Other Examples: nylon, leather, and hair

Substances which have a **strong attraction** for their outer electrons accept electrons easily and are more likely to become **negative when rubbed**.

Other Examples: cotton, vinyl, polyethylene

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The direction in which the electrons move depends upon the affinity or attraction that the particular atoms have for electrons.

Substances higher on the list have a greater attraction for electrons than substances found lower on the list. When two substances are rubbed together, the electrons move from the substance found lower on the list to the substance found higher on the list.

For example, when we rub a plastic rod with fur, electrons are removed from the fur and are placed on the plastic rod.

Therefore:
Higher on the table - greater attraction - obtains a negative charge
Lower in the table - less attraction - obtains a positive charge

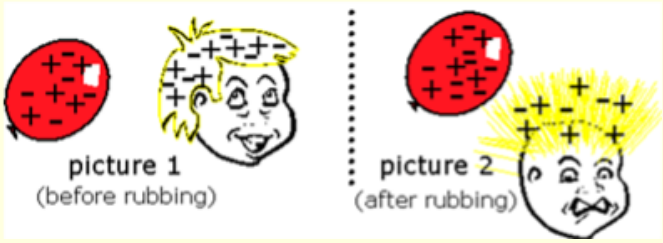
Question: What will be the result of rubbing a piece of vinyl with wool?

Answer: The friction between the vinyl and wool will 'scrape' the electrons from the wool. This occurs because the wool has a lesser hold on its electrons than does the vinyl. Therefore, the vinyl now has an excess of electrons and is said to be negatively charged. The wool has a deficit of electrons and is said to be positively charged.

Question: Is any charge created when the vinyl is rubbed with the wool?

Answer: No!! No charge is created. It is just rearranged. The **Law of Conservation of Electric Charge** means that in a closed system, **the amount of charge is constant**. Charge can be rearranged within the system but the total number of electrons and protons remains constant.

Look at the pictures below. Each "-" represents billions of electrons, and each "+" represents billions of protons. In picture 1 (before rubbing) the balloon has just as much negative charge as positive charge. It is neutral. Likewise your hair is neutral. (Count the +'s and -'s on the balloon and on your hair).



Next count the +'s and -'s in picture 2 (after rubbing). The balloon ha picked up 3 of the -'s from your hair. So, the balloon has an over-abundance of negative charge. But your hair now has 3 fewer -'s than +'s. Your hair has an over-abundance of positive charge. You can see that it is indeed conserved if you count all the +'s and all -'s in the pictures. You will find the same number in picture 1 and picture 2. The charge shifted, but none was created and none was destroyed.

Question: Why does dry hair sometimes 'stand up' when you comb it?

Answer: Your comb is made of hard rubber, nylon, or a vinyl type plastic. All of these substances have a tendency to hold on to their electrons tightly. Your hair, however, holds its electrons more loosely. The friction between your comb and your hair causes the electrons to move from your hair to the comb. Therefore, your comb has an excess of electrons and is negatively charged. Your hair has a deficiency of electrons and is positively charged. In other words, each stand of hair has the **same charge**. As a result, each strand of hair is repelling all neighboring strands. The result is that all hairs "stand out" form your hair.

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