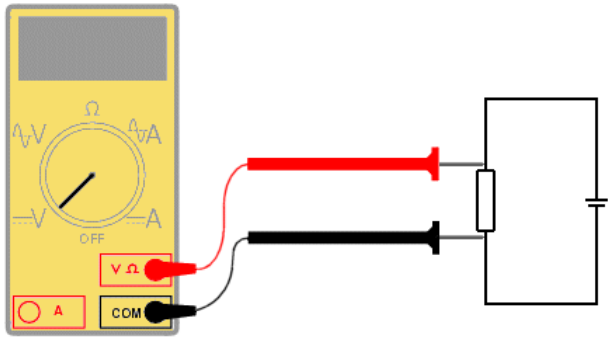
Physics 122: Electricity &Magnetism

Electric Charge



http://www.technologyuk.net/science/physics/electrical-principles/electrical-measurement.shtml

Assoc. Prof. Dr. Fulya Bağcı
Ankara University, Department of Physics Engineering

- Electric forces hold atoms and molecules together.
- Electricity controls our thinking, feeling, muscles and metabolic processes.
- Electricity and magnetism underpin much of our current technology (e.g. computers).
- Electricity and magnetism are linked on a fundamental level.

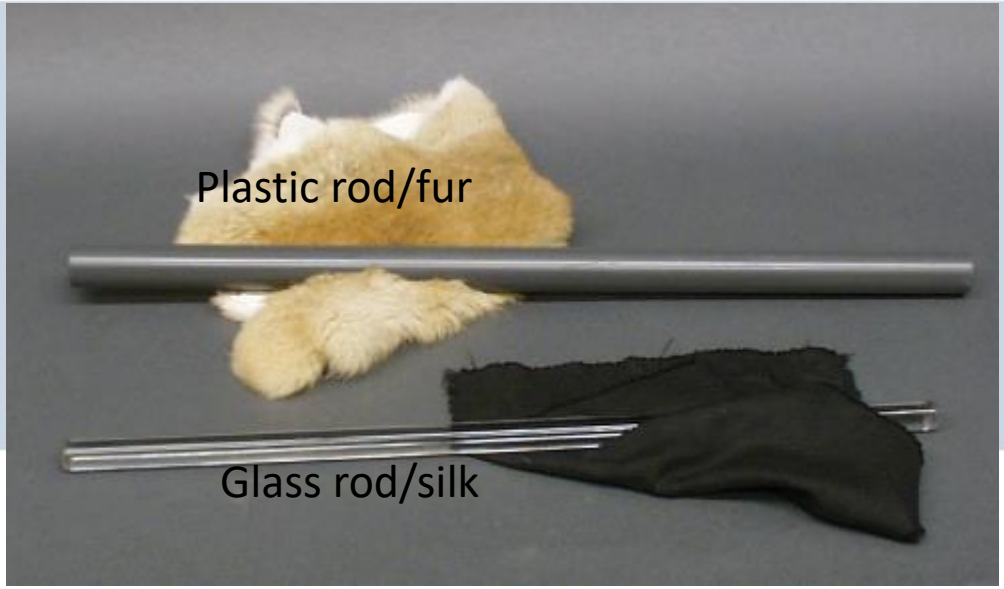
Electricity in Nature

- Most dramatic natural electrical phenomenon is lightining.
- Static electricity (balloons, comb and paper, shock from a door knob)
- Uses: Photocopying, ink-jet printing,

washing machine, vacuum cleaner, …

Demonstrations of Electrostatics

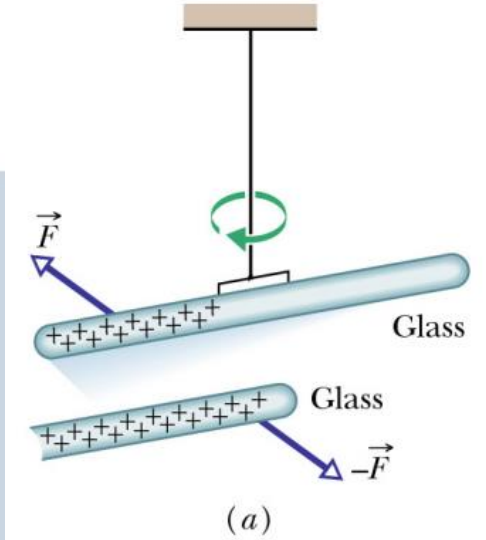
- Balloon
- Glass rod/silk
- Plastic rod/fur
- Electroscope
- Van de Graaf generator



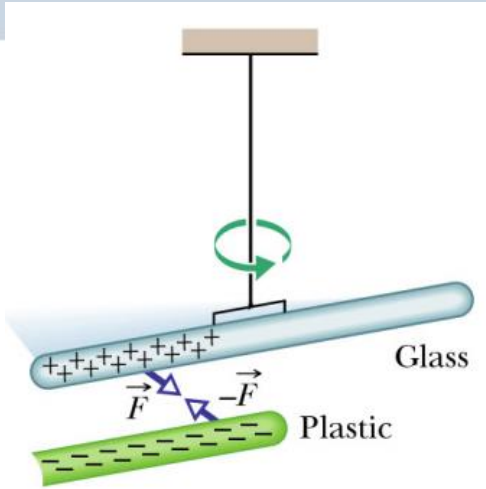
After rubbing a balloon on your hair on a dry day, you will find that the balloon attracts bits of paper.

Glass rod / Plastic rod

- A glass rod rubbed with silk gets a positive charge.
- A plastic rod rubbed with fur gets a negative charge.
- Suspend a charged glass rod from a thread and another charged glass rod repels it.
- A charged plastic rod, however, attracts it.
- This force is called the electric force.
- Benjamin Franklin (around 1750): There are 2 types of charges. Positive and negative.
- He also has discovered that charge was not created by rubbing, but rather the charge is transferred from the rubbing material to the rubbed object, or vice versa.



(a)



(b)

Forces Between Charges

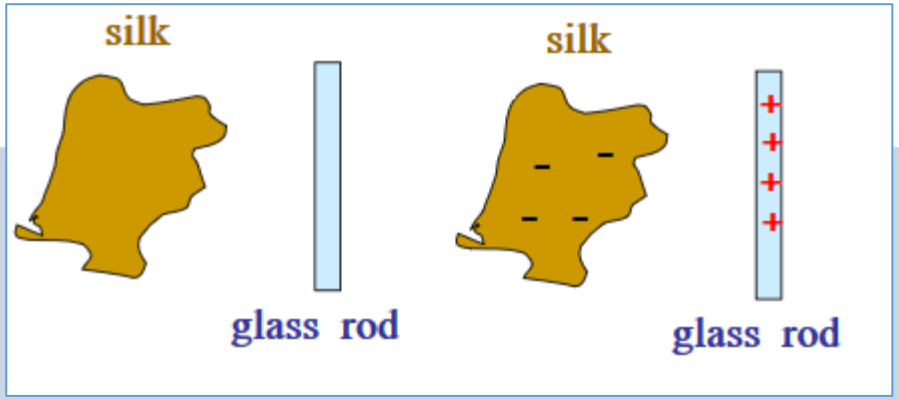
- We observe that

Like charges repel each other.

Opposite charges attact each other.

Electric charge is always **conserved** in an isolated system.

transfer of charge from one object to the other



When a glass rod is rubbed with silk, the silk obtains a negative charge that is equal in magnitude to the positive charge on the glass rod. Electrons are transferred from the glass to the silk in the rubbing process.

In 1909, Robert Millikan (1868–1953) discovered that electric charge always occurs as some integral multiple of a fundamental amount of charge *e*. In modern terms, the electric charge *q* is said to be **quantized**. Electric charge exists as discrete "packets," and we can write $q = Ne$, where *N* is some integer. The electron has a charge $-e$ and the proton has a charge of equal magnitude but opposite sign $+e$. Some particles, such as the neutron, have no charge.

23.2 Charging Objects By Induction

Electrical conductors are materials in which some of the electrons are free electrons that are not bound to atoms and can move relatively freely through the material. Exp. copper, aluminum, and silver.

Electrical insulators are materials in which all electrons are bound to atoms and cannot move freely through the material. Exp. glass, rubber, and wood.

If you hold a copper rod in your hand and rub it with wool or fur, it will not attract a small piece of paper. Why???

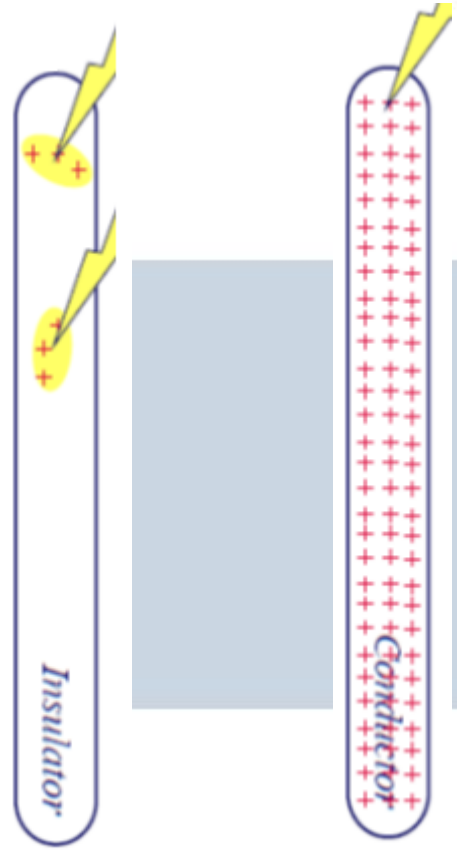
Semiconductors are a third class of materials, and their electrical properties are somewhere between those of insulators and those of conductors. Exp. silicon and germanium The electrical properties of semiconductors can be changed over many orders of magnitude by the addition of controlled amounts of certain atoms to the materials.

silicon

germanium

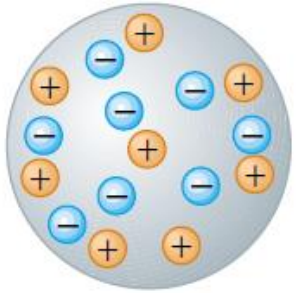
Insulators and Conductors

- Both insulators and conductors can be charged.
- The difference is that
  - On an insulator charges are not able to move from place to place. If you charge an insulator, you are typically depositing (or removing) charges only from the surface, and they will stay where you put them.
  - On a conductor, charges can freely move. If you try to place charge on a conductor, it will quickly spread over the entire conductor.

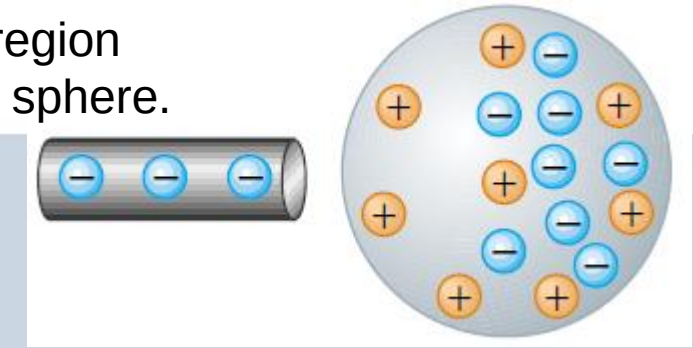


Induction

Consider a neutral (uncharged) conducting sphere insulated from the ground.

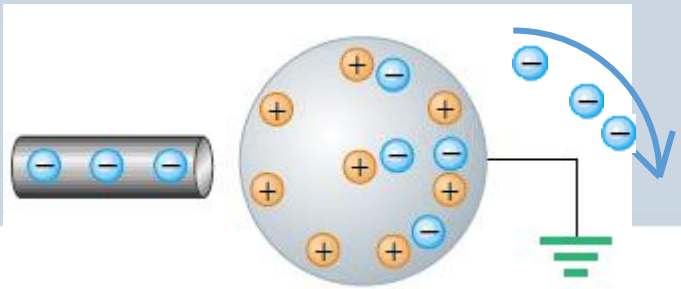


When a negatively charged rubber rod is brought near the sphere, electrons in the region nearest the rod experience a repulsive force and migrate to the opposite side of the sphere.

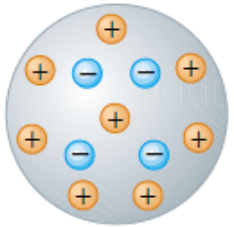


Even if the rod never actually touches the sphere!!!

If the same experiment is performed with a conducting wire connected from the sphere to the Earth, some of the electrons in the conductor are so strongly repelled by the presence of the negative charge in the rod that they move out of the sphere through the wire and into the Earth.



When the rubber rod is removed from the vicinity of the sphere, this induced positive charge remains on the ungrounded sphere.

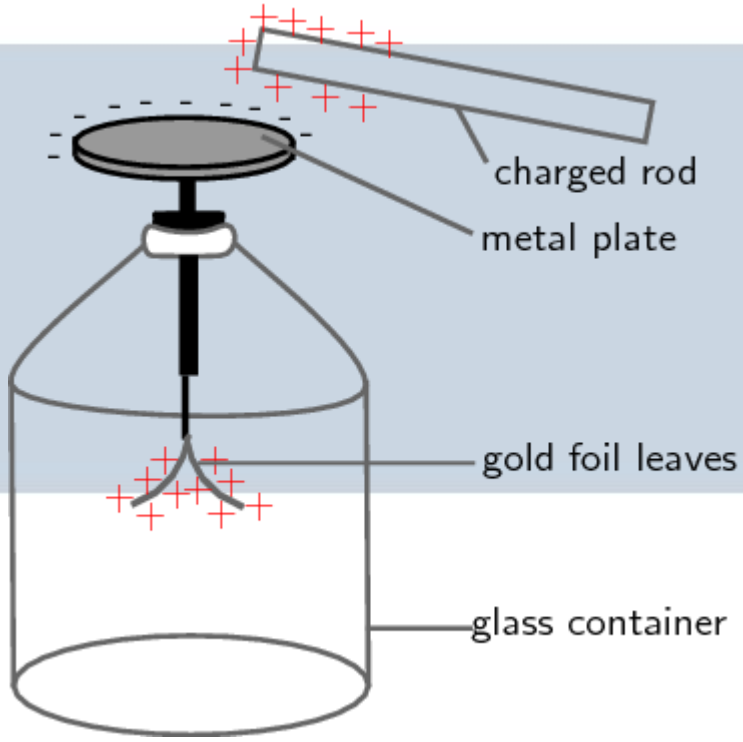


Serway Physics, 6th edition, page 692, Serway and Jewett

Note: Charging an object by **induction** requires no contact with the object inducing the charge. This is in contrast to charging an object by rubbing (that is, by **conduction**), which does require contact between the two objects.

Electroscope

- This is a device that can visually show whether it is charged with static electricity.
- Here is an example charged positive electroscope.
- Notice that the charges collect near the ends, and since like charges repel, they exert a force sideways.
- You can make the deflection arm move by adding either positive or negative charge.
- We make it move without touching it?

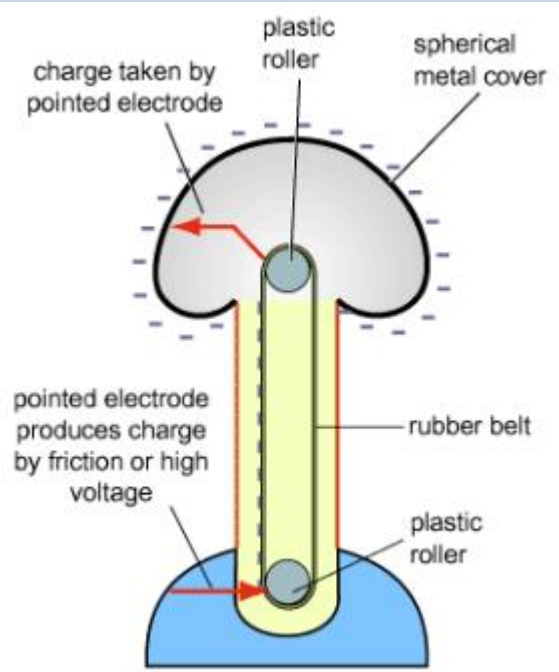


everythingmaths.co.za

Electrostatic induction

Van de Graaf Generator

A Van de Graaff generator is an electrostatic generator which uses a moving belt to accumulate electric charge on a hollow metal globe on the top of an insulated column, creating very high electric potentials. It produces very high voltage direct current (DC) electricity at low current levels. It was invented by American physicist Robert J. Van de Graaff in 1929. The potential difference achieved by modern Van de Graaff generators can be as much as 5 megavolts. It was the most powerful type of accelerator of the 1930s until the cyclotron was developed.



https://en.wikipedia.org/wiki/Van_de_Graaff_generator

Van de Graaff generator

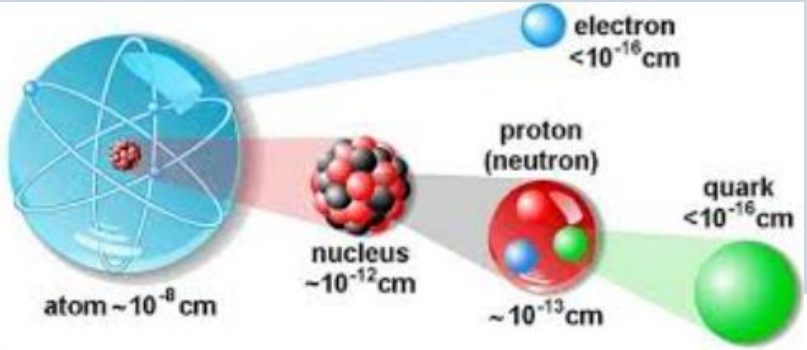
Woman touching Van de Graaff generator at the American Museum of Science and Energy. The charged strands of hair repel each other and stand out from her head

An educational program at the Theater of Electricity, Boston Museum of Science demonstrates the world's largest air-insulated Van de Graaff generator, built by Van de Graaff in the 1930s.

The Atom

- We now know that all atoms are made of positive charges in the nucleus, surrounded by a cloud of tiny electrons.

Proton charge +e, electron charge –e where $e=1.602\times10^{-19}$ C

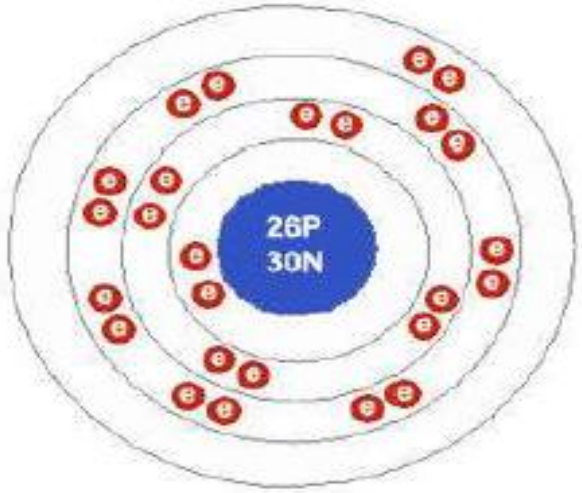


- Atoms are normally neutral, meaning that they have exactly the same number of protons as they do electrons.
- The charges balance, and the atom has no net charge.

- In fact, protons are vastly more difficult to remove, and for all practical purposes it never happens except in radioactive materials. In this course, we will ignore this case. Only electrons can be removed.

Metals and Conduction

- Notice that metals are not only good electrical conductors but they are also good heat conductors, tend to be shiny (if polished), and are maleable (can be bent or shaped).
- These are all properties that come from the ability of electrons to move easily.



gold

iron

This iron atom has 26 protons and 26 electrons, so it has 2 electrons in its outer shell.
Outer shell electrons can move from one iron atom to the next in a metal.