<u>Chapter 23:</u>

Electricity & Magnetism

Sections I - II

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Reference Book: "**Physics for Scientists and Engineers**" by *R. A. Serway* & J. W. Hewett
Similar Book: "Physics for Scientists&Engineers" by D.C.Giancoli
Advanced: "Introduction to Electrodynamics" by D.J.Griffiths
"Classical Electrodynamics" by J.D.Jackson

Chapter Outline

The comb & the pieces of paper have opposite static electric charge, so they attract each other.

Requirements before the start:

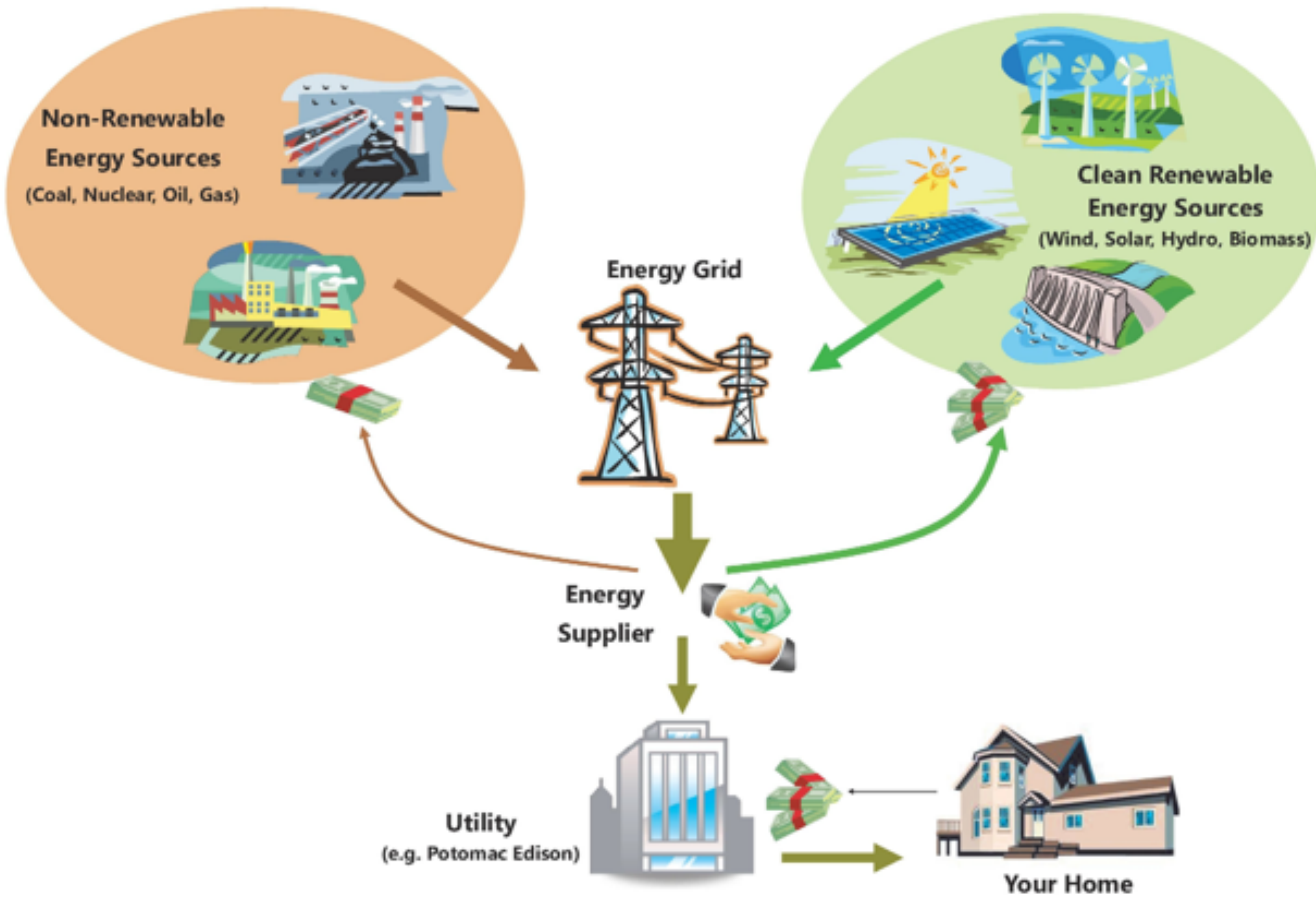
1. **Knowledge of Basic Physical Laws and Measures***
2. **Mathematics: Trigonometry**
3. **Mathematics: Integration, Limits**
4. **Linear Algebra: Vectors**

* *See the previous chapters: Physics and Measures, Law of Motions, Work and Kinetic Energy, Constants …etc.*

Introduction

- For modern times:

Energy = **Electricity** ⇨ **Production + Consumption**



Brief History

<u>**The Ancient Chinese**</u>

Some documents suggest that magnetism was observed as early as 2000 BC in China.

<u>**The Ancient Greeks**</u>

Electrical and magnetic phenomena were known as early as 700 BC. Experiments with **amber & magnetite** and constructed a city called Magnesia (**Manisa** in Turkey)

<u>**1500s**</u>

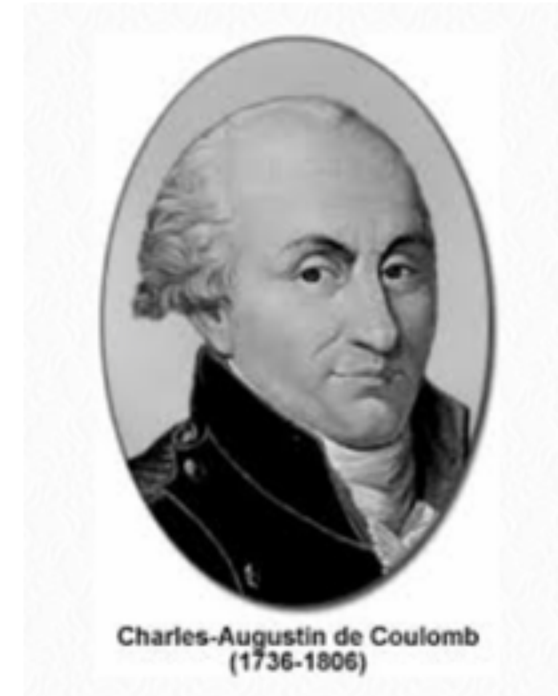
Arabic philosophers realised natural & bio electricity such as lightning, nerves which showed electricity is a general phenomena. They used a word (*raad*).

<u>**1600s**</u>

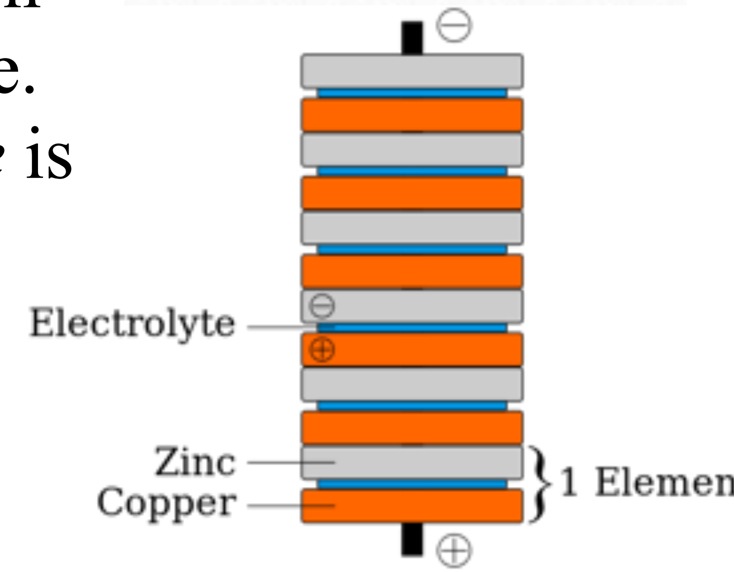
William Gilbert used to word "*electricus*" (amber-like) for the first time.

Benjamin Franklin have attached a metal key to the bottom of a dampened kite string and flown the kite in a storm-threatened sky in 1752. (Electricity produced and transmitted for the first time with a copper wire)

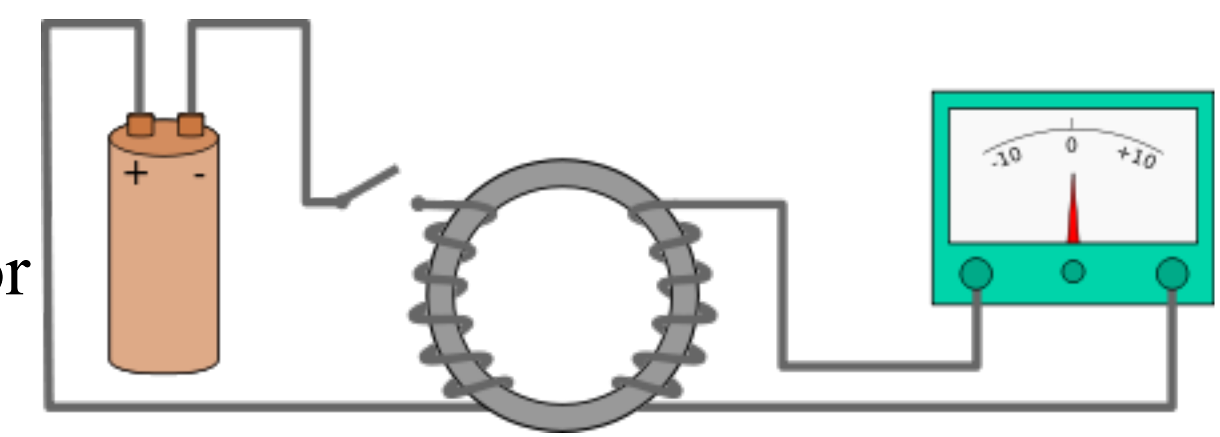
Brief History



- 1784: **Charles Coulomb;** French physicist confirmed the universal *inverse square law* form for the electric forces in.
- 1800: **Alexandro Volta and Galvani**; invented battery using zinc and copper as *electrodes* and mixed salted water with additional sulphuric acid as *electrolyde* in 1800s.
- 1820: **Andre M. Ampere;** formulated the relation between electrical current in a wire and magnetism around the wire.
- 1827: **George Ohm**; showed that the *electrical resistance* is a self-characteristic of materials.
- 1831: **Michael Faraday;** published *The Law of induction* but Joseph Henry developed the same law independently.
- 1862: **James C. Maxwell;** gathered the four electric laws together using his differential notation. (*Classical EMT*)
- 1879: **Thomas Edison;** produced light bulb commercially.
- 1929: **R. Van de Graff;** invented first electrical accelerator & generator



Voltaic Battery



Faraday Law of induction

There are many other actors in the history of *Electricity* ; but this was just a brief Chronology.

Attention: This course may not be in the <u>same chronological</u> order!!

Because we have to give the modern interpretations of events.

So Let's Start Now!

23.1. Properties of Electric Charges

1. **Experiments** show that there are
   ***Two kinds of electric charges*.**
   They are called **positive** & **negative**
   Negative Charges
   Are the type possessed by electrons.
   Positive Charges
   Are the type possessed by protons.

Question: Which experiment make you think of that way?

2. **Experiment** also shows that:

Charges of the ***same sign repel*** one another
charges with ***opposite signs attract*** one another.

23.1. Properties of Electric Charges

- Experimental Facts showed that:

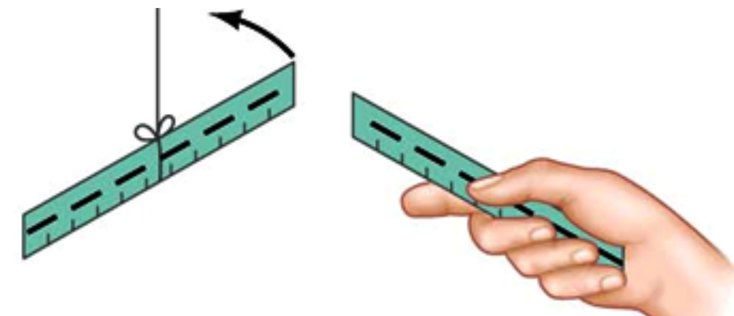
Conservation of Electric Charge

- It means:

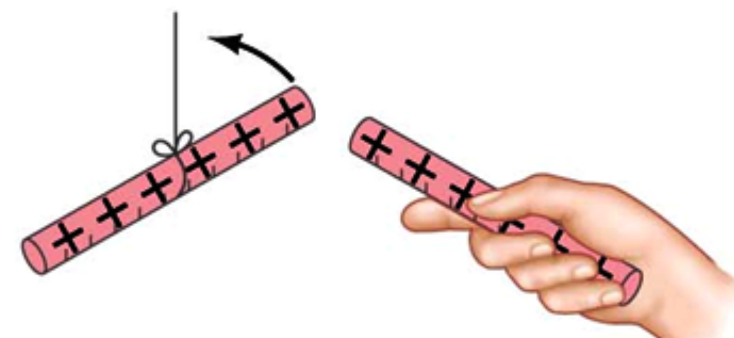
"The arithmetic sum of the total charge cannot change in any interaction"

- If we have two different kind of charge: Positive (+) & Negative (-)

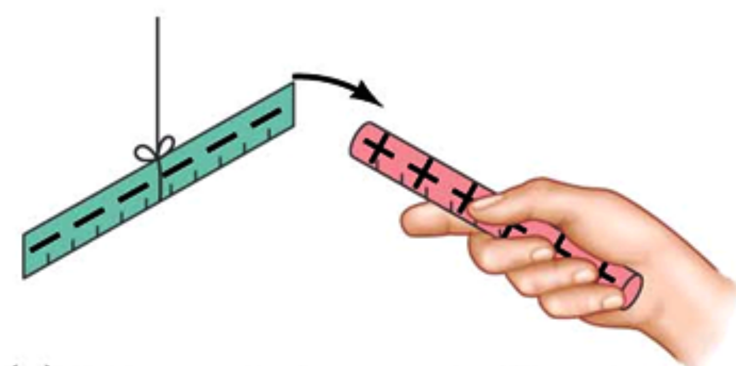
- A simple experiment shows that: *Like charges repel, opposite charges attract.*



(a) Two charged plastic rulers repel

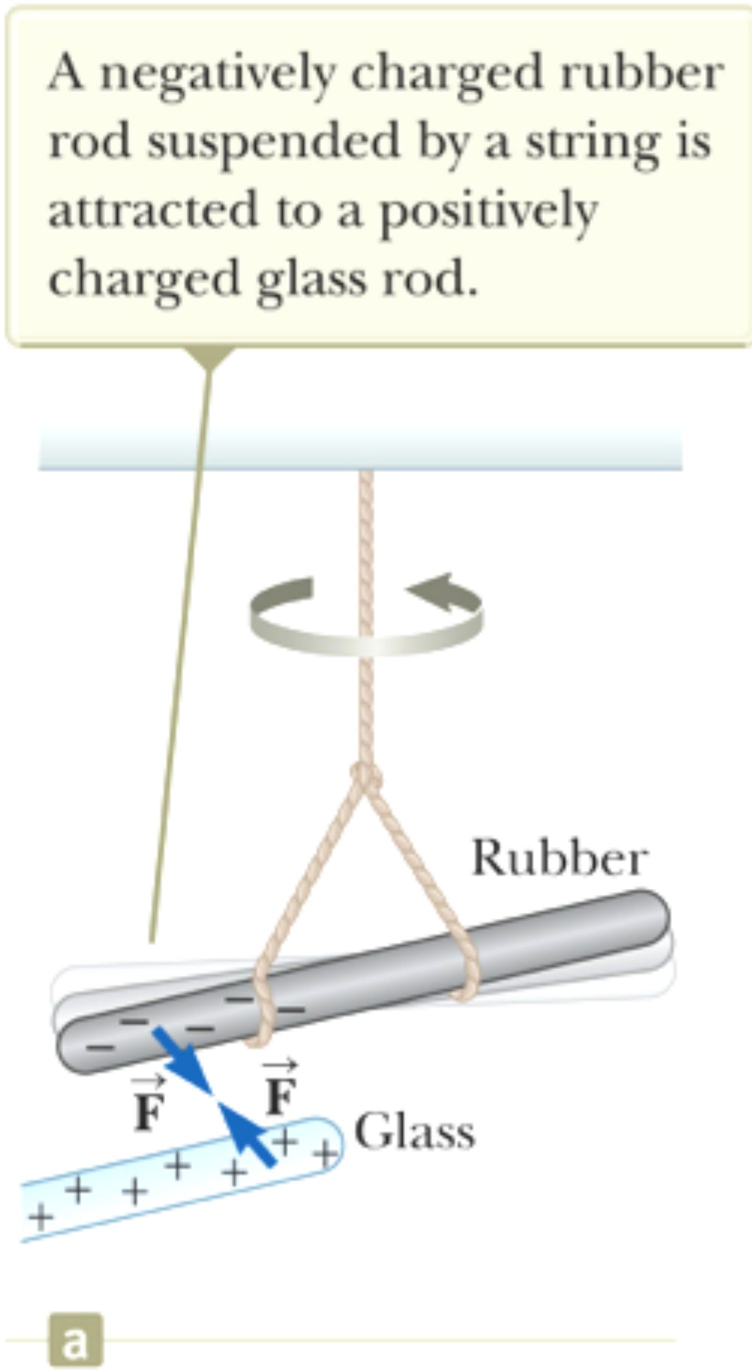


(b) Two charged glass rods repel

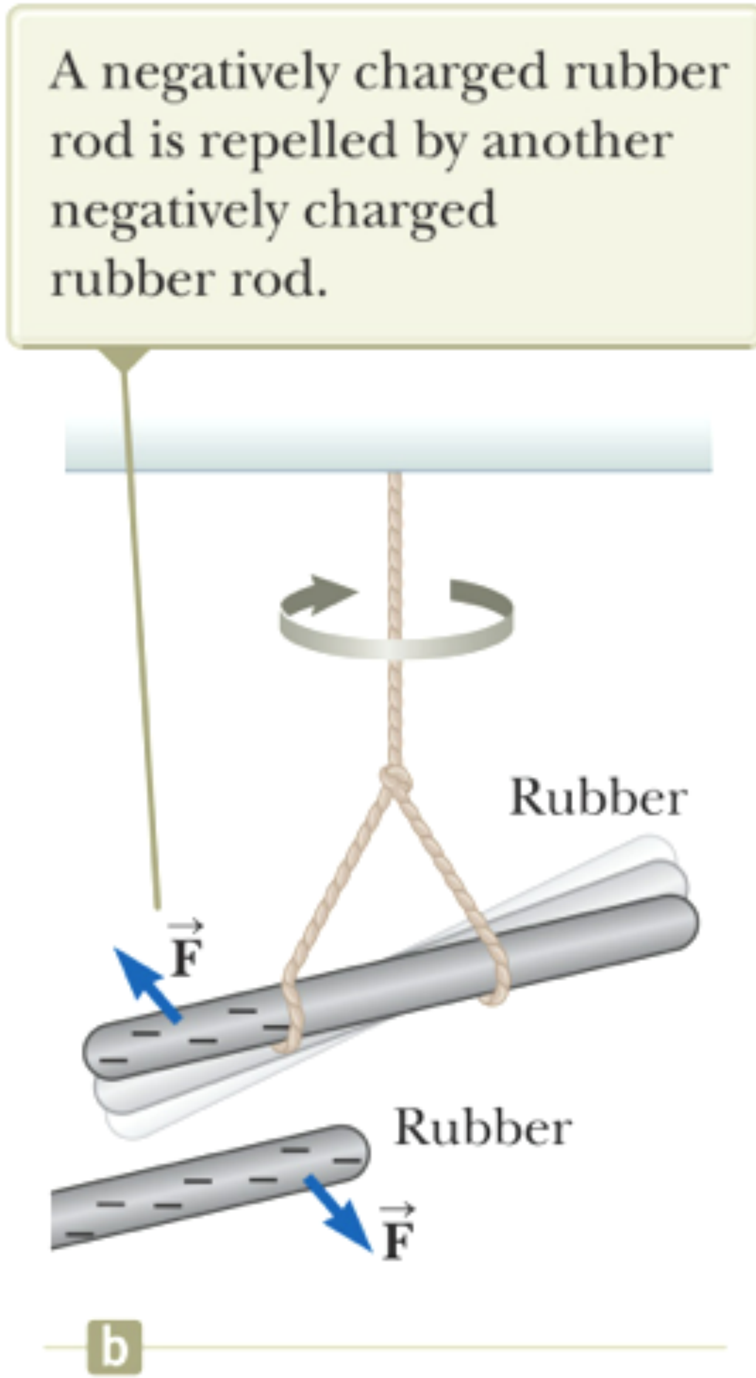


(c) Charged glass rod attracts charged plastic ruler

23.1. Properties of Electric Charges



Attraction of charged rods

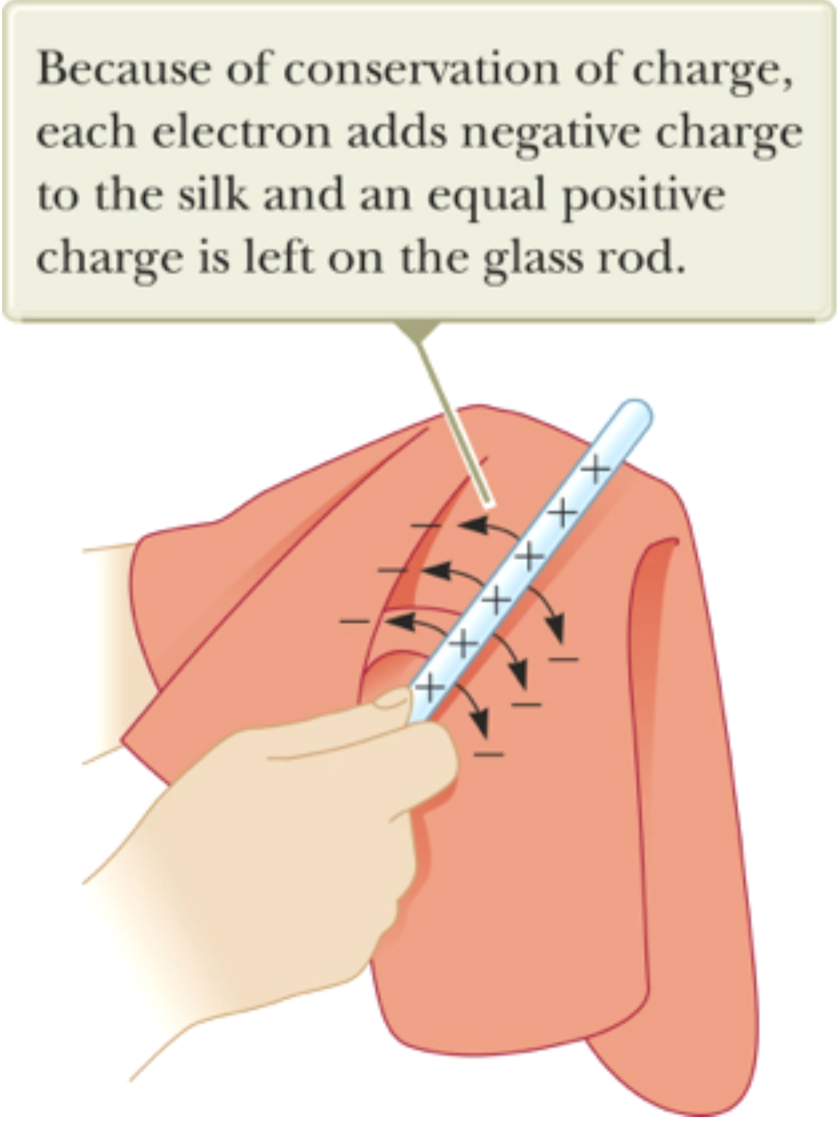


Repulsion of charged rods

23.1. Properties of Electric Charges

Example

- A glass rod is rubbed with silk.
- Electrons are transferred from the glass to the silk.
- Each electron adds a negative charge to the silk.
- An equal positive charge is left on the glass rod.



Conclusion: Material type is important for being charged or charging

23.1. Properties of Electric Charges

- **Some more facts** about electrical charges which is understood relatively sooner:

- Electric charge is **Quantized**:

An electric charge q is ***ALWAYS*** **an integer multiple of the charge on an electron e.**

Or, **electric charge q** exists only as discrete packets:

$$q \equiv \pm N e$$

e: The Fundamental Unit of Charge

N: A large integer, |e|=1.6 10^{-19} C,

Electron: q = -e, Proton: q = +e

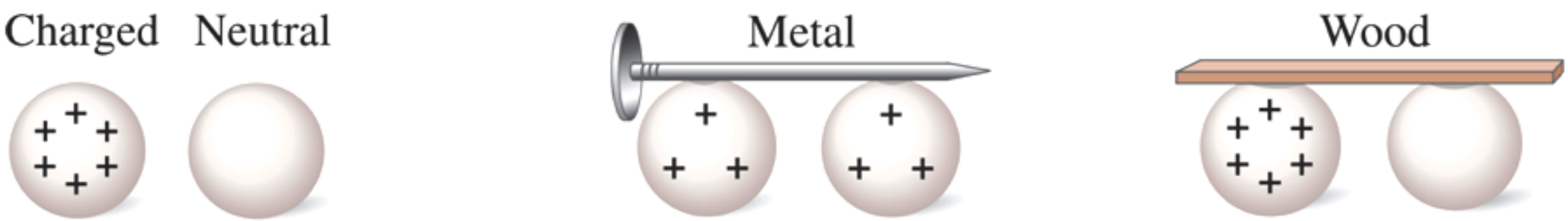
23.2. Insulators and Conductors

Conductor

A **Conductor is a material in which charge flows freely**. The most common types of conductors are metals.

Insulator

An **Insulator is a material in which almost no charge flows.** Most non-metallic materials are insulators.



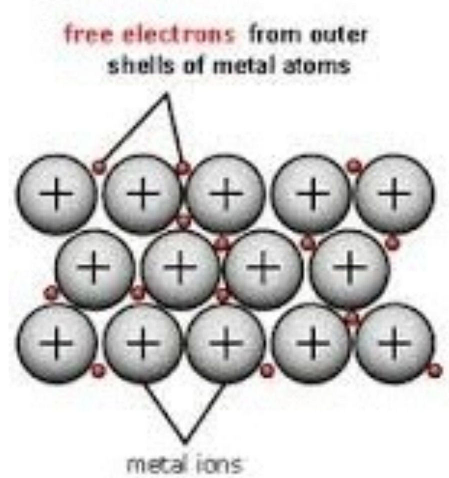
Semiconductor

A **Semiconductor is a material with special properties, somewhere in between conductors & insulators.** Without semiconductors (especially silicon, **Si**), modern technology would not exist!

23.2. Insulators and Conductors

Electrical Conductors are materials in which some of the electrons are ***"free electrons".***

- "Free electrons" are not bound to the atoms.
- "Free electrons" can move relatively freely through the material.
- Examples of good conductors include copper, aluminum and silver.



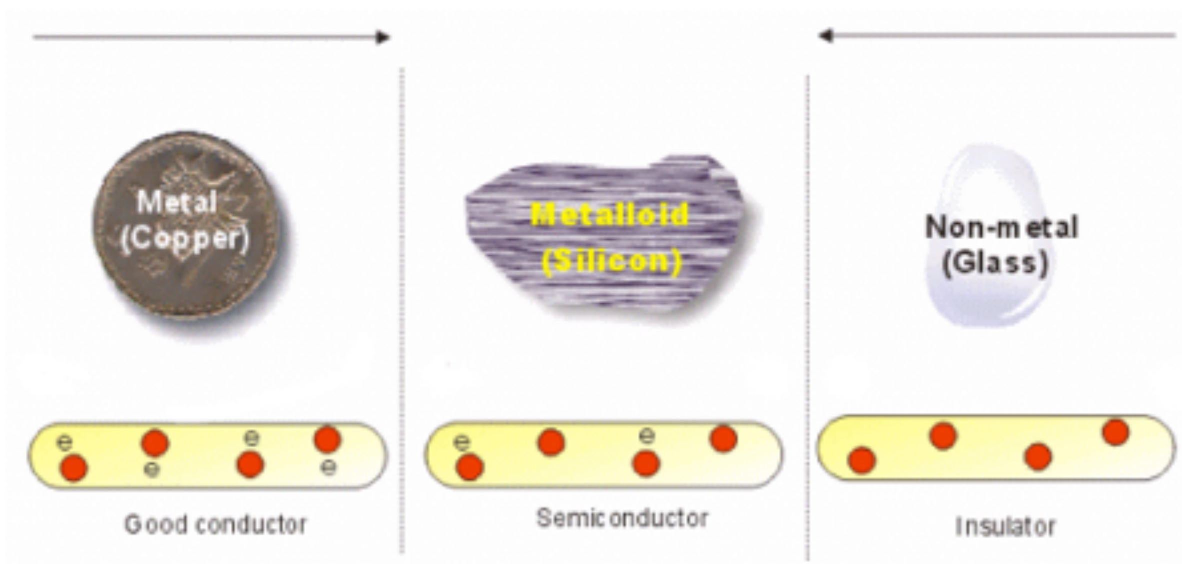
Experimental Fact

When a good conductor is charged in a small region, the charge readily distributes itself over the entire surface of the material.

23.2. Insulators and Conductors

Electrical Insulators are materials in which all of the electrons are bound to atoms.

- These electrons cannot move relatively freely through the material.
- Examples of good insulators include glass, rubber and wood.



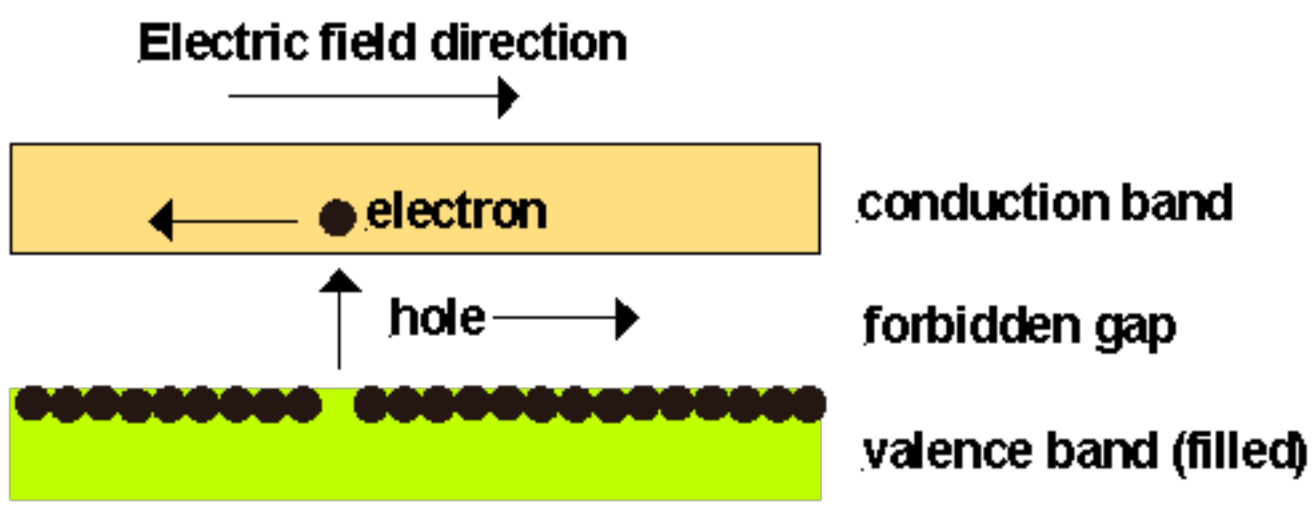
Experimental Fact

When a good insulator is charged in a small region, the charge is unable to move to other regions of the material.

23.2. Insulators and Conductors

The electrical properties of ***Semiconductors*** are somewhere between those of insulators & conductors.

Examples of semiconductor materials include silicon & germanium. These materials are commonly used in making electronic chips.



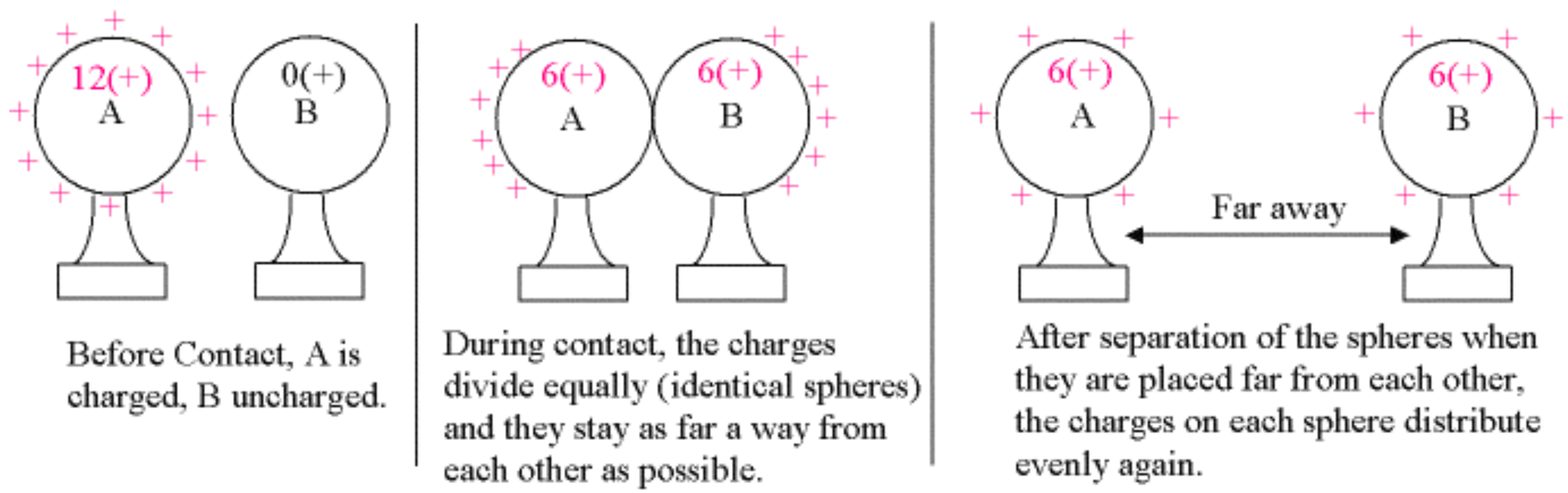
Conduction via electrons & holes in a semiconductor

Experimental Fact

The electrical properties of semiconductors can be changed by the addition of controlled amounts of certain atoms to the material.

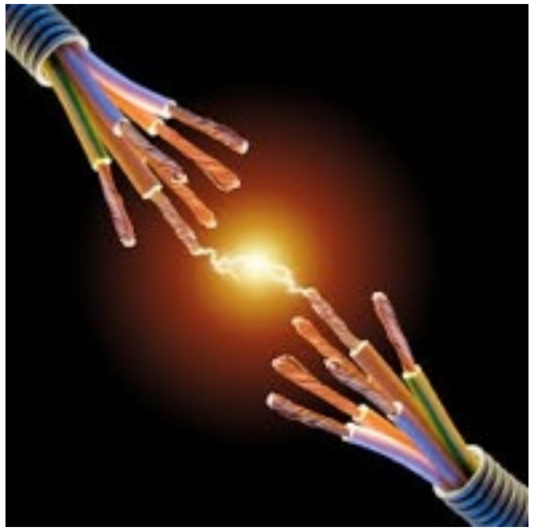
23.2. Insulators and Conductors

- **Conduction** means charging the material by contact or rearranging the materials charge balance by touching with each others.



- Objects in touch equally shares the electrical charges with respect to their **capacities**. Also keep in my that;

Charges like gathering around the sharp corners !!

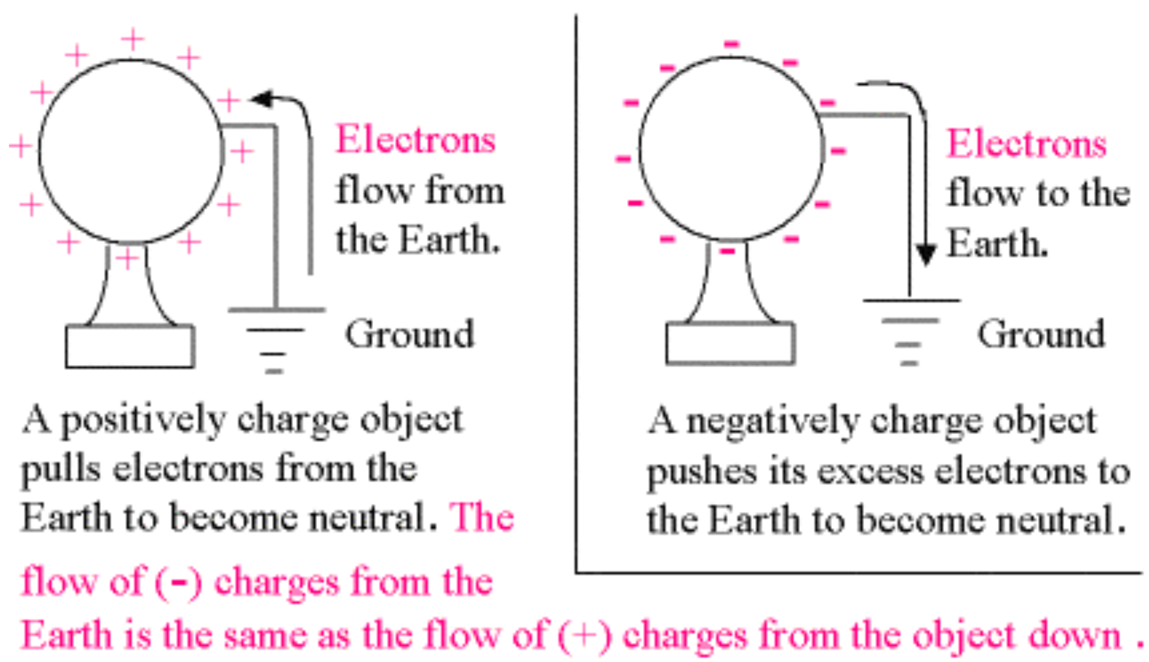


23.2. Insulators and Conductors

- When a conductor is connected to the Earth by means of a conducting wire or pipe, it is said to be **grounded.**

Ground neutralises any of the charged materials!

- The Earth can then be considered an infinite **"sink"** to which electric charges can easily migrate. With this in mind, we can understand how to charge a conductor by a process known as **induction.**



23.2. Insulators and Conductors

Charging a metallic object by ***induction*** (that is, the two objects never touch each other).

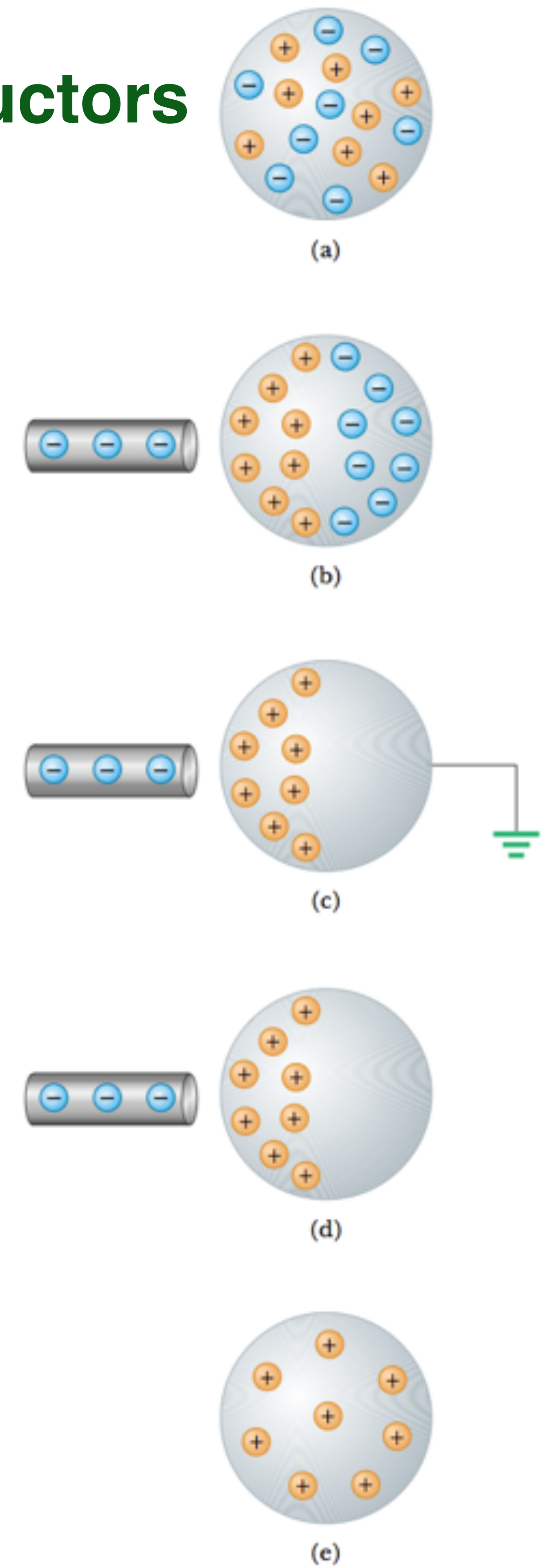
(a) A neutral metallic sphere, with equal numbers of positive and negative charges.

(b) The charge on the neutral sphere is redistributed when a charged rubber rod is placed near the sphere.

(c) When the sphere is grounded, some of its electrons leave through the ground wire.

(d) When the ground connection is removed, the sphere has excess positive charge that is nonuniformly distributed.

(e) When the rod is removed, the excess positive charge becomes uni- formly distributed over the surface of the sphere



23.2. Insulators and Conductors

- We have seen charging by conduction and induction for metals and conductors.

What about insulators?

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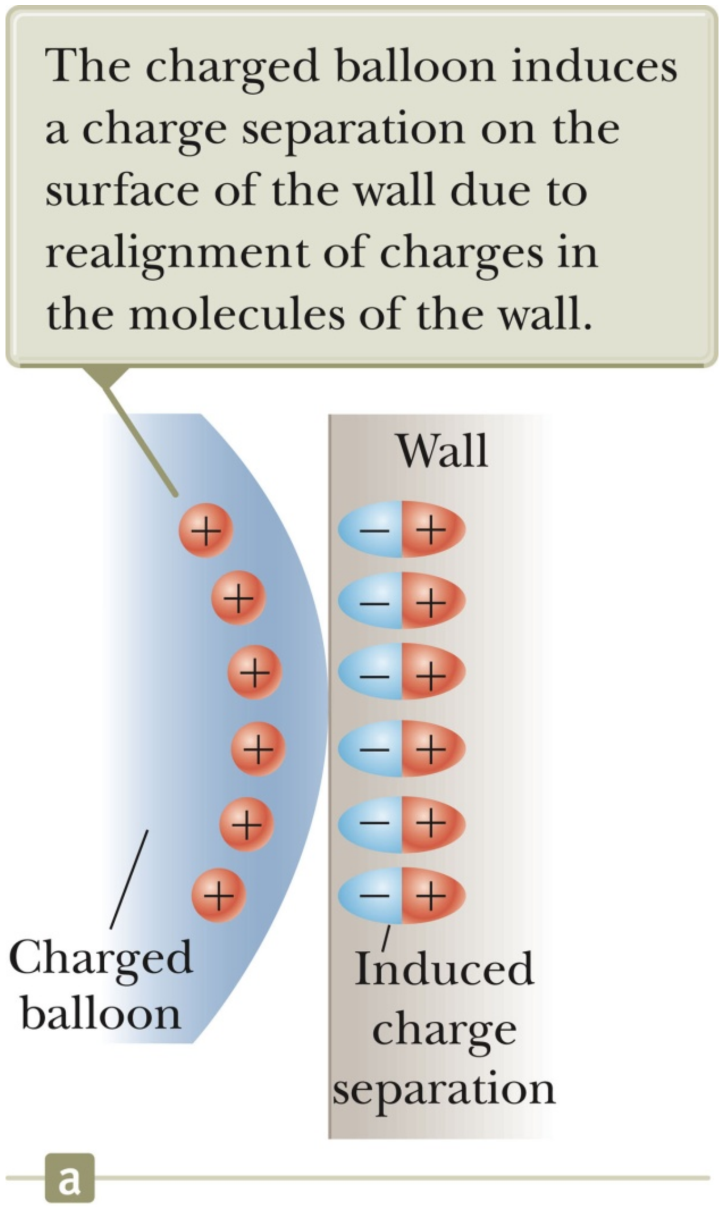
- We have seen charging by <u>conduction and induction</u> for metals and conductors.

What about insulators?

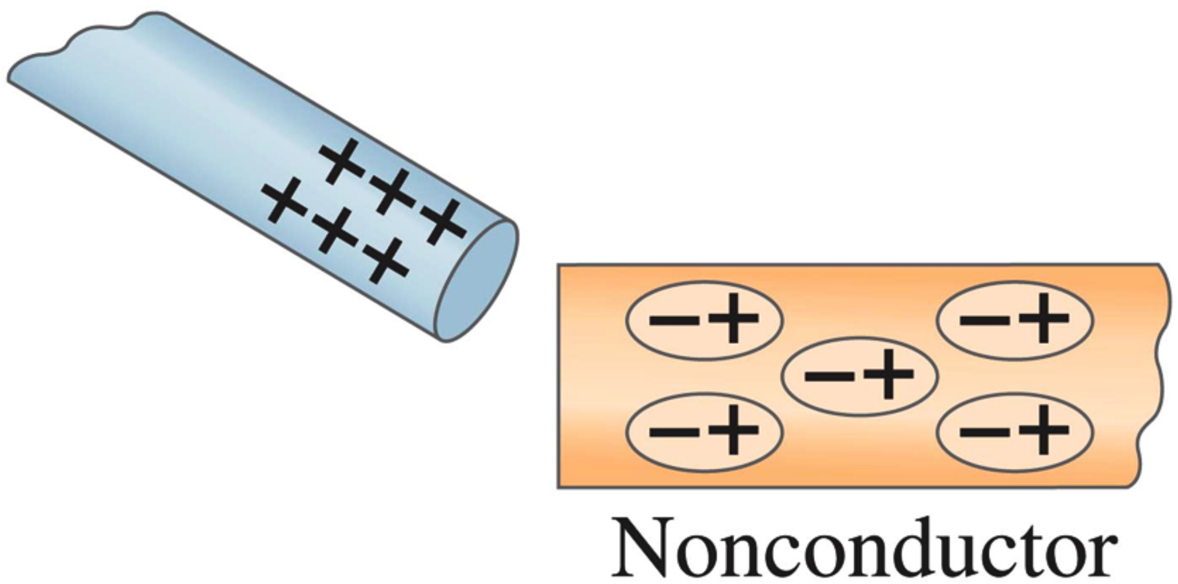
<u>A process similar to induction can happen in insulators</u>.



The charges within the molecules of the material are rearranged.
The proximity of the positive charges on the surface of the object and the negative charges on the surface of the insulator results in an attractive force between the object and the insulator.

23.2. Insulators and Conductors

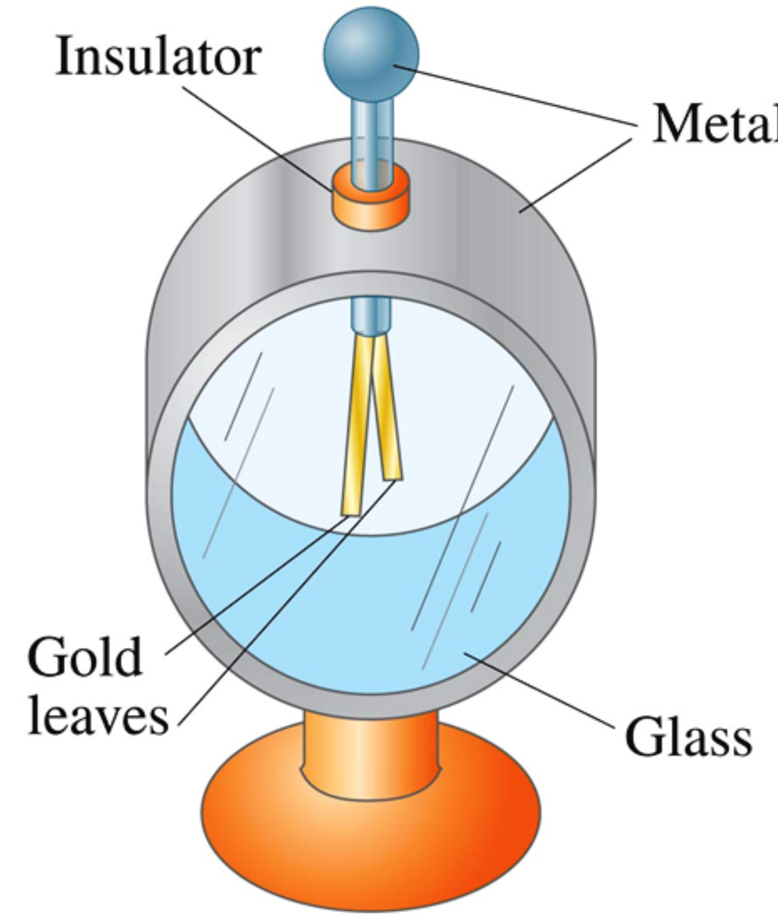
- As we just said, nonconductors won't become charged by conduction or induction, but will experience charge separation:



- After we take the charged material away, insulators immediately turn neutral state.

23.2. Insulators and Conductors

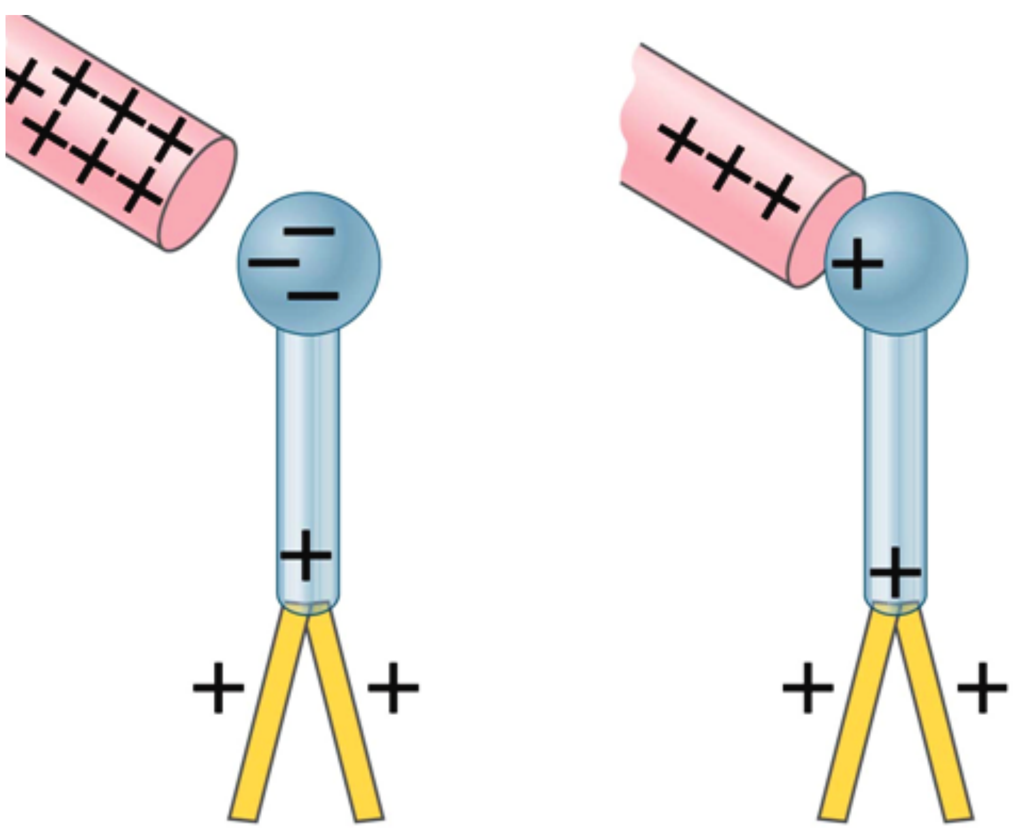
An instrument used for detecting charge is called
Electroscope

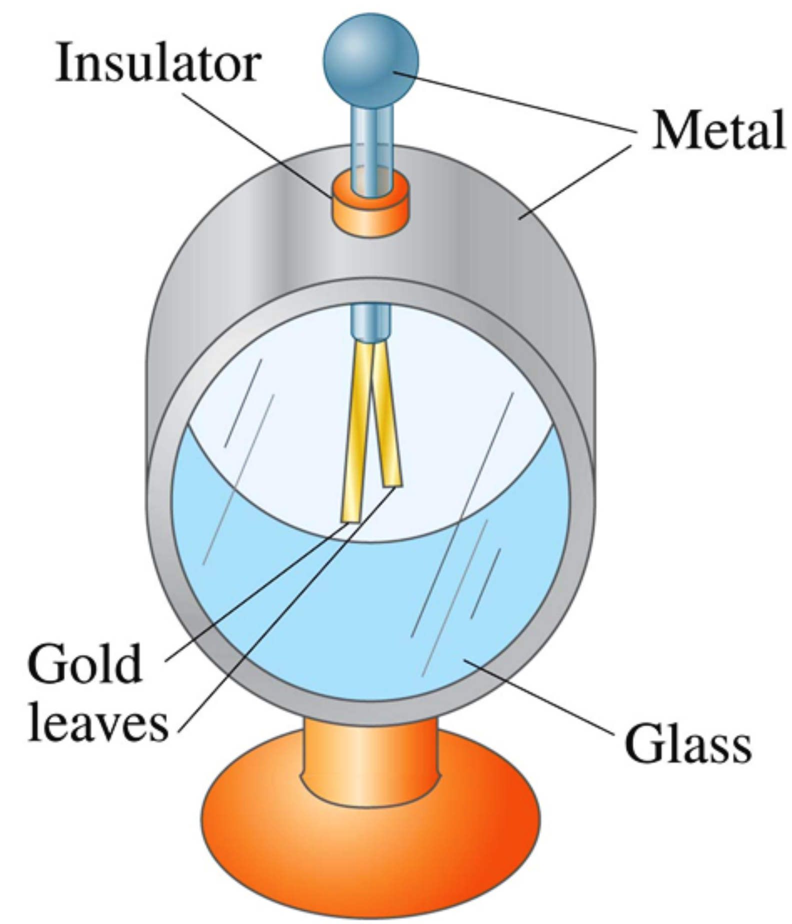


23.2. Insulators and Conductors

An instrument used for detecting charge is called **Electroscope**

An **Electroscope** can be charged either by conduction or by induction.





How can one to determine which charge is loaded for a material? + or - ?