<u>Lecture Notes</u>

(Electrical Charge)

<u>Intro</u>:

- the earliest known study of electricity was conducted by the Greeks about 700 B.C.

- their study began when somebody noticed that fossilized tree sap (amber) would attract small objects after being rubbed by wool; the Greek word for amber is <u>elektron</u>

- since then we have learned that this phenomenon is not restricted to amber and wool, but occurs (to various degrees) when almost any two non-conducting substances are rubbed together

<u>Electrical Charges</u>:

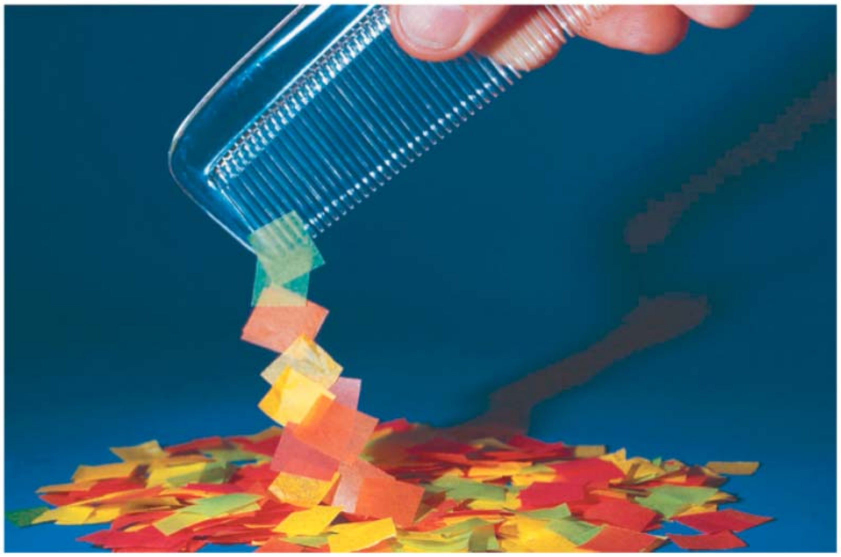
- when an electrical charge is generated by friction; i.e. (rubbing two objects together) it is called <u>static electricity</u>

- it's called "static" because it doesn't go anywhere; you don't feel this until you touch some metallic object that is connected to earth ground or to some large fixture

- but then there is a discharge, accompanied by a spark that might well startle you; it is the current, during this discharge, that causes the sensation that might make you jump

- the study of electrical charges that can be collected and held in one place is called <u>electrostatics</u>

- simple experiments which demonstrate the existence of electrostatic forces include running a plastic comb through your hair and then seeing the comb pick up tiny bits of paper



This comb has acquired a static electric charge, either from passing through hair, or being rubbed by a cloth or paper towel. The electrical charge on the comb induces a polarization (separation of charge) in scraps of paper, and thus attracts them.

Our introduction to electricity in this Chapter covers conductors and insulators, and Coulomb's law which relates the force between two point charges as a function of their distance apart. We also introduce the powerful concept of electric field.

- another example is rubbing an inflated balloon on wool or your hair and then sticking it to a wall

- when materials behave in this way, they are said to be electrically charged

- you can give your body an electrical charge by rubbing your shoes on wool carpet; you can then remove the charge by touching another object such as a door knob or person

- an object is electrically charged if it exhibits electrical interaction after rubbing

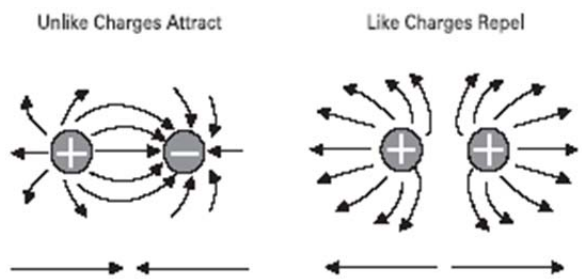
Types of Charges:

- experiments demonstrate that there are two types of electrical charges; they are positive and negative and were given these names by Benjamin Franklin

FIGURE 10.3 Benjamin Franklin (1706–1790), American statesman, inventor, scientist, and writer, was greatly interested in the phenomenon of electricity. His famous kite experiment and invention of the lightning rod gained him wide recognition. Franklin is shown here observing the behavior of a bell whose clapper is connected to a lightning rod.

- like charges repel each other; Ex. if you have two positive charges they repel each other

- opposite charges attract each other; Ex. positive and negative charges attract one another



<u>Triboelectric Series</u>:

- as discussed earlier, the technique of using a cloth or piece of fur to rub a solid such as glass, wax or plastic will electrify the object due to a process called ‘friction charging’

- in this process the energy supplied to the outermost atomic electrons allows them to move from the material with the least affinity or attraction for electrons to that material with the most affinity for electrons

- the process is also referred to as <u>triboelectric separation of charge</u>; the word is derived from the Greek *tribein*, meaning ‘to rub’

- electrons are therefore transferred from one object to another, one object becoming positive as it loses electrons, say the rabbit fur, and the other object becoming negative as it gains electrons, say the plastic strip

- note that in this example of the separation of charge process, the fur will most likely lose its charge quite quickly either by direct contact with the experimenter's hand or by loss to the atmosphere; it will thus regain neutrality

- this quite often makes it difficult to show that the fur has in fact become electrically charged

- every material's atoms have their own specific tendency to gain or lose electrons easily; the table below lists the triboelectric series showing several materials in order, from those that have a low affinity for electrons and will tend to become positively charged to those that have a high affinity and become negatively charged in frictional experiments

(+) Atoms have a low affinity for electrons
Rabbit or cat fur
Acetate
Perspex
Glass
Wool
Lead
Silk
Paraffin wax
Polythene
Ebonite
Copper
Rubber
Amber
Sulfur
Gold
(−) Atoms have a high affinity for electrons

- this series is easy to read because any material will become positive by losing electrons if rubbed with any other material lower in the series list

- for example, glass can become positively charged when rubbed with a silk handkerchief but negatively charged if rubbed with rabbit fur

<u>Microscopic View of Charge</u>:

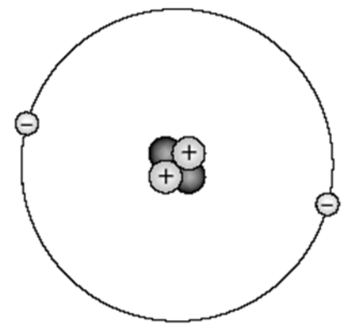


Figure 3-1. Model of an atom.

- we now know that the origin of charge is the atom

- the basic carrier of positive charge is the proton, which along with the neutrally charged neutron, forms the nucleus of an atom

- because the nucleus is firmly held in place, protons are never moved from one material to another; therefore, when an object becomes charged, it has done so because it has either lost or gained electrons

- an electron is the atom's carrier of negative charge and they orbit the nucleus

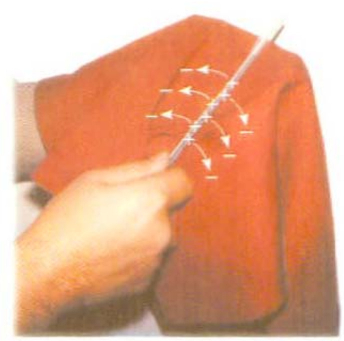


FIGURE 15.2 When a glass rod is rubbed with silk, electrons are transferred from the glass to the silk. Because of conservation of charge, each electron adds negative charge to the silk, and an equal positive charge is left behind on the rod. Also, because the charges are transferred in discrete bundles, the charges on the two objects are $\pm e$, $\pm 2e$, $\pm 3e$, and so on.

- the normal state of an atom is neutral; that is, for every positive charge in the nucleus, there is an electron orbiting the nucleus to cancel the charge

- when two neutral objects are rubbed together, a charge is not created; instead, the objects become charged because negative charge is transferred from one object to the other

- this characteristic of charge can be restated as "<u>electric charge is conserved</u>"; one object gains some amount of negative charge while the other loses an equal amount of charge

Units of Charge:

- in 1909, Robert Millikan discovered that if an object is charged, its charge is always a multiple of a fundamental unit of charge

- today, we call this quantized; charges occur as discrete bundles

- for example, objects may have a charge of ± 1 electron, ± 2e, etc... but never fractional charges such as ± 1.3e, ± 2.1e, etc...

- other experiments around this time showed that the electron has a charge of $-$e and the proton has a charge of $+$e

- charges are measured in units named coulombs (C), and will be discussed later

Conductors:

- in some materials, electrons move easily from atom to atom; in others, the electrons move with difficulty; and in some materials, it is almost impossible to get them to move

- an electrical conductor is a substance in which the electrons are mobile and move freely

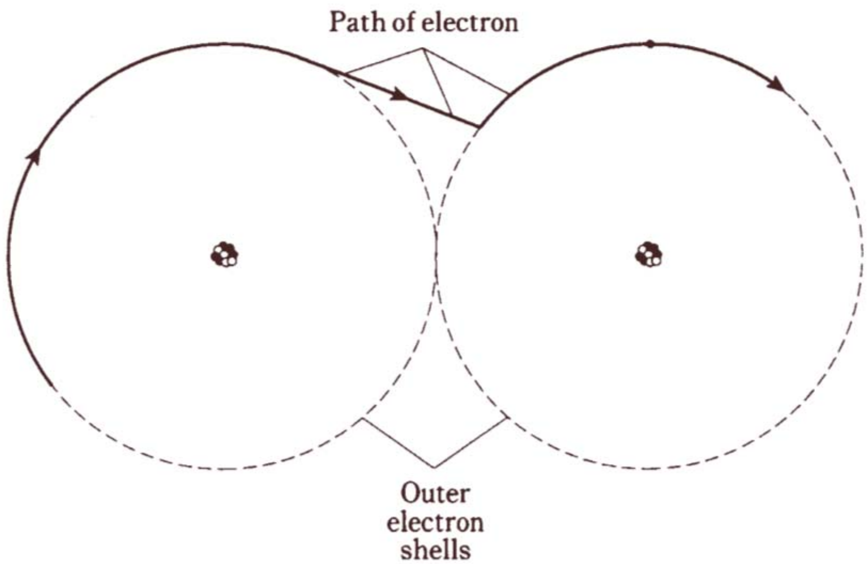
- the best conductor at room temperature is pure elemental silver; copper and aluminum are also excellent electrical conductors; iron, steel, and various other metals are fair to good conductors of electricity

- in most electrical circuits and systems, copper or aluminum wire is used; silver is impractical because of its high cost

- some liquids are good electrical conductors; mercury is one example; salt water is a fair conductor

- gases are, in general, poor conductors of electricity; this is because the atoms or molecules are usually too far apart to allow a free exchange of electrons; but if a gas becomes ionized, it is a fair conductor of electricity

- electrons in a conductor do not move in a steady stream, like molecules of water through a garden hose; instead, you can see in the diagram below, that they are passed from one atom to another right next to it



1-5 In a conductor, electrons are passed from atom to atom.

- this happens to countless atoms all the time; as a result, literally trillions of electrons pass a given point each second in a typical electrical circuit

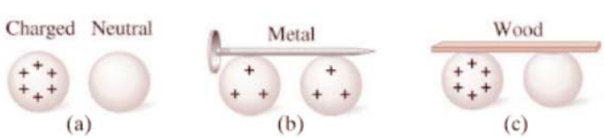


FIGURE 16–5 (a) A charged metal sphere and a neutral metal sphere. (b) The two spheres connected by a conductor (a metal nail), which conducts charge from one sphere to the other. (c) The two spheres connected by an insulator (wood); almost no charge is conducted.

<u>Insulators</u>:

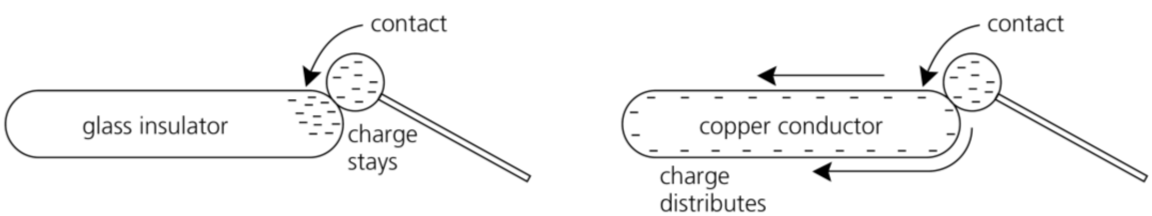
- <u>insulators</u> are materials through which charges will not move easily

- most gases are good electrical insulators; glass, dry wood, paper, and plastics are other examples

- pure water is a good electrical insulator, although it conducts some current with even the slightest impurity

- metal oxides can be good insulators, even though the metal in pure form is a good conductor

- glass and rubber are insulators; when such materials are charged by rubbing, only the rubbed area becomes charged and there is no tendency for the charge to move into other regions of the material



<u>Semiconductors</u>:

- a third type of material is called the <u>semiconductor</u>, whose electrical properties fall somewhere between insulators and conductors

- semiconductors are a modern class of materials including silicon, germanium, gallium arsenide and various metal oxides that, in their natural state, are relatively poor conductors compared with metals

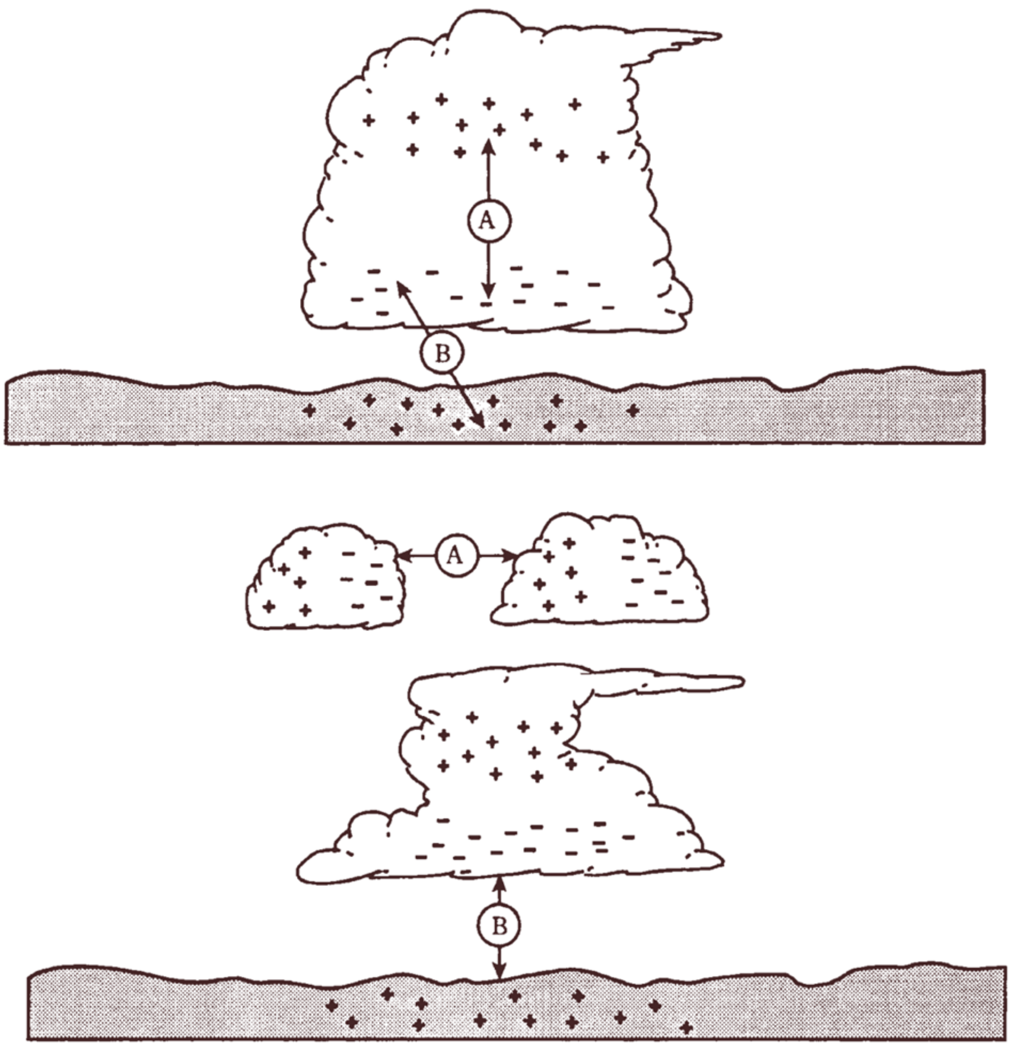
- however, the conductivity of these crystalline materials can be artificially improved by the addition of selected impurity elements into their crystal structure

- their conductivity is variable and can even be switched on and off

- semiconductors have become the basis of modern electronic chips; transistors, diodes, and other solid-state electronic device are based on semiconductors

Air Becoming a Conductor:

- although air is ordinarily an insulator, under certain conditions, such as when lightning occurs, air acts like a conductor and allows charges to move freely



1-8 Cloud-to-cloud (A) and cloud-to-ground (B) charge buildup can both occur in a single thunderstorm.

- excess charges between the ground and the clouds of a thunderstorm remove electrons from the air; the charged air particles begin to move and form a conductor