Electrostatics
History

- The word *electricity* comes from the Greek *elektron* which means “amber”.
- The “amber effect” is what we call *static electricity*.
Brief History

- **900 BC** – Greek shepherd ‘Magnus’ (a story about Asia Minor-the region was called as Magnesia - Manisa in Turkey)
- The word magnet has come from Greek word *magnitis lithos* meaning magnesian stone- later on called as loadstone - *Loadstone effect*
- **600 BC** – Greek philosopher Thales (Discovered another material called amber (from Greek word elektron) which when rubbed with wool will attract cat fur) – *Amber effect*
- **370 BC** – Plato (both amber effect and loadstone effect are related with each other and of the same type)
- **120 AD** – Plutarc (Load stone emits exhaltations which pushes air)
- **1100 AD** – Chinese (magnetic needle pointing north-south)
– 1550 AD – Carden (amber and loadstone do not attract in the same way)
– 1600 AD – Gilbert (Introduced science of magnetism by experimentation) Introduction of other substances that would attract when rubbed e.g., glass, sulphur, wax crystals etc)
– 1752 AD – Benjamin Franklin (Kite flying in thunder storm)
– 1780 AD – Galvani (idea of moving charges)
– 1784 AD – Coulomb (measured the electric force)
– 1792 AD– Volta introduced battery (copper & zinc separated by material soaked in Brine solution-invented battery)
– 19th Century – Biot, Savart, Ampere, Oersted, Faraday (relationship between electricity & magnetism)
1864 AD – Maxwell’s contribution & later Hertz experimental evidence

Charges residing on objects explain electrostatic effects and dynamics of charges explain magnetic effects

Engineering Applications – Laser printer, photocopying, Electrostatic paint spraying

Charge - the basic entity of Electromagnetism

Properties of charge
- Charge is quantized
- Charge is conserved

Existence of two types of charges
- Plastic rod rubbed with wool ----- -ve charge
- Glass rod rubbed with silk -------- +ve charge
Electric charge and the structure of matter

– The particles of the atom are the negative electron, the positive proton, and the uncharged neutron.
– Protons and neutrons make up the tiny dense nucleus which is surrounded by electrons.
– The electric attraction between protons and electrons holds the atom together.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>Positive charge</td>
<td>Mass = 1.673 × 10^{-27} kg</td>
</tr>
<tr>
<td>Neutron</td>
<td>No charge</td>
<td>Mass = 1.675 × 10^{-27} kg</td>
</tr>
<tr>
<td>Electron</td>
<td>Negative charge</td>
<td>Mass = 9.109 × 10^{-31} kg</td>
</tr>
</tbody>
</table>

Most of the atom’s volume is occupied sparsely by electrons.

Tiny compared with the rest of the atom, the nucleus contains over 99.9% of the atom’s mass.

The charges of the electron and proton are equal in magnitude.
Atoms and ions

- A neutral atom has the same number of protons as electrons.
- A positive ion is an atom with one or more electrons removed. A negative ion has gained one or more electrons.
Ions and Polarity

• If an atom loses or gains valence electrons to become + or -, that atom is now called an ion.
• If a molecule, such as H₂O, has a net positive charge on one side and negative charge on the other it is said to be polar.
### Elementary Particles

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge, (C)</th>
<th>Mass, (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron</td>
<td>(-1.6 \times 10^{-19})</td>
<td>(9.109 \times 10^{-31})</td>
</tr>
<tr>
<td>proton</td>
<td>(+1.6 \times 10^{-19})</td>
<td>(1.673 \times 10^{-27})</td>
</tr>
<tr>
<td>neutron</td>
<td>0</td>
<td>(1.675 \times 10^{-27})</td>
</tr>
</tbody>
</table>

- If an object has a...
  - + charge $\rightarrow$ it has less electrons than normal
  - - charge $\rightarrow$ it has more electrons than normal

\[
\# electrons = \frac{q_{total}}{1.6 \times 10^{-19}}
\]
### Valency Table

<table>
<thead>
<tr>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>+4</th>
<th>−3</th>
<th>−2</th>
<th>−1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
</tr>
<tr>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ne</td>
</tr>
<tr>
<td>K</td>
<td>Ca</td>
<td>Ga</td>
<td>Ge</td>
<td>As</td>
<td>Se</td>
<td>Br</td>
<td>Ar</td>
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<tr>
<td>Rb</td>
<td>Sr</td>
<td>In</td>
<td>Sn</td>
<td>Sb</td>
<td>Te</td>
<td>I</td>
<td>Kr</td>
</tr>
<tr>
<td>Cs</td>
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<td>Po</td>
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<tr>
<td>Fr</td>
<td>Ra</td>
<td></td>
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</tr>
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</table>
Conservation of charge

- The proton and electron have the same magnitude charge.
- The magnitude of charge of the electron or proton is a natural unit of charge. All observable charge is quantized in this unit.
- The universal principle of charge conservation states that the algebraic sum of all the electric charges in any closed system is constant.
Electric charge

- Two positive or two negative charges repel each other. A positive charge and a negative charge attract each other.
- The study of such charges is called electrostatics.
Rules of Electric Charge

- Like charges repel
  - Two positively charged bodies repel each other
  - Two negatively charged bodies repel each other

- Opposites attract
  - A negatively charged body attracts a positively charged one
  - A positively charged body attracts a negatively charged one

• Law of Conservation of Charge:
  - The net amount of electric charge produced in any process is zero.
Conductors and insulators

- A conductor permits the easy movement of charge through it. An insulator does not.
- Most metals are good conductors, while most nonmetals are insulators.
- Semiconductors are intermediate in their properties between good conductors and good insulators.
Types of materials - Conductors

Cross-section of copper wire

An external influence repels a nearby electron

The electron's neighbors find it repulsive. If it moves toward them, they move away, creating a chain of interactions that propagates through the material at the speed of light.

Copper's valence electrons move freely throughout the solid copper metal.

Atoms of insulating materials hold on tightly to their outer electrons, like good parents watching all their children. Copper and other metals tend to be "poor parents" of their outer or "valence" electrons, and they are just out wandering the neighborhood.
Types of Materials - Insulators

- Insulators: Materials in which electrons are tightly bound and belong to particular atoms and are not free to wander about among other atoms in the material, making them flow
  - Example: Rubber, glass
Types of Materials - Semiconductors

• Semiconductors: A material that can be made to behave sometimes as an insulator and sometimes as a conductor.
  – Fall in the middle range of electrical resistivity between insulators and conductors.
  – They are insulators when they are in their pure state.
  – They are conductors when they have impurities.

• Semiconductors conduct when light shines on it.
  – If a charged selenium plate is exposed to a pattern of light, the charge will leak away only from the areas exposed to light.
Types of Materials - Superconductors

• Superconductors: Materials acquire zero resistance (infinite conductivity) to the flow of charge.
  – Once electric current is established in a superconductor, the electrons flow indefinitely.
  – With no electrical resistance, current passes through a superconductor without losing energy.
  – No heat loss occurs when charges flow.
Ways to Charge

- **By Conduction**: contact occurs between charged object and neutral object.
  - Result: two objects with same charge

- **By induction**: no contact occurs between charged object and neutral object.
  - Result: two objects with opposite charge
Charging

• Charging by friction and contact.
  
  Example:
  
  Stroking cats fur, combing your hair, rubbing your shoes on a carpet

• Electrons transfer from one material to another by simply touching. For example,
  
  – when a negatively charged rod is placed in contact with a neutral object, some electrons will move to the neutral object.
Conduction
Charging by induction

- So far we have seen how a negative charge can impart a negative charge and vice versa.
- In doing so, the charging object loses some charge.
- Can also induce an opposite charge without the charging object losing any of its charge, a process called induction...

• Note how the charges can be thought of to reside in the surfaces of the objects.
**Charge Polarization**

- One side of the atom or molecule is induced into becoming more negative (or positive) than the opposite side. The atom or molecule is said to be **electrically polarized**.
- An electron buzzing around the atomic nucleus produces an electron cloud.
  
  a. The center of the negative cloud normally coincides with the center of the positive nucleus in an atom.
  
  b. When an external negative charge is brought nearby to the right, the electron cloud is distorted so that the centers of negative and positive charge no longer coincide. The atom is now electrically polarized.
Charge Polarization

• If the charged rod is negative, then the positive part of the atom or molecule is tugged in a direction toward the rod, and the negative side of the atom or molecule is pushed in a direction away from the rod.

• The positive and negative parts of the atoms and molecules become aligned. They are electrically polarized.
Charge Polarization

- When a charged comb is brought nearby, molecules in the paper are polarized.

- The sign of charge closest to the comb is opposite to the comb’s charge.

- Charges of the same sign are slightly more distant. Closeness wins, and the bits of paper experience a net attraction.
Charge Polarization

• Rub an inflated balloon on your hair, and it becomes charged.

• Place the balloon against the wall, and it sticks.

• This is because the charge on the balloon induces an opposite surface charge on the wall.

• Again, closeness wins, for the charge on the balloon is slightly closer to the opposite induced charge than to the charge of same sign.
Charge Polarization

- Many molecules—H₂O, for example—are electrically polarized in their normal states.
- The distribution of electric charge is not perfectly even.
- There is a little more negative charge on one side of the molecule than the other.
- Such molecules are said to be electric dipoles.