Electric Charge and Charging Processes

20.1-20.2
Elementary Charge

- The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge (e).
  - The magnitude of the elementary charge is equal to \( e = 1.6 \times 10^{-19} \text{ C} \).
  - Electrons have a negative elementary charge: \( -1.6 \times 10^{-19} \text{ C} \)
  - Protons have a positive elementary charge: \( +1.6 \times 10^{-19} \text{ C} \)
- Although the proton and electron have the same magnitude of charge, the mass of a proton is much larger than the mass of an electron.
Quantization of Charge

- Since the elementary particles are the source of charge, and we cannot have part of an electron or part of a proton, charge always exists in integer multiples of the elementary charge.
Types of Charge

- There are only two kinds of electric charge: **positive and negative**.
- The net charge of a system is equal to the sum of the charges of all the objects in the system.
- Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.
Conservation of Charge

- For all systems under all circumstances, charge is conserved. For an isolated or a closed system, charge is constant. In an open system, charge is exchanged with its surroundings.
- The charge distribution in a system can be altered by the effects of electric forces produced by a charged object.
- The exchange of electric charges among a set of objects in a system conserves electric charge.
Conductors

- Conductors are materials through or along which charge easily moves.
- The outer (valence) electrons are only weakly bound to the nuclei and are free to wander about the entire solid (the "sea of electrons").
Insulators

- Insulators are materials on or in which charges remain fixed in place. The electrons are tightly bound to the positive nuclei and not free to move around. The charge in each atom in an insulator can be slightly polarized. (More on this later.)
Acquiring Charge

- Protons are extremely tightly bound and cannot be added or removed from atoms. Electrons, on the other hand are bound much more loosely (they are in the electron cloud) and can be removed with little effort. Therefore:
  - Objects acquire a negative charge by gaining electrons.
  - Objects acquire a positive charge by losing electrons.

- Charge can be acquired through three processes:
  - friction
  - contact
  - induction
Charging by Friction

- The frictional force causes molecular bonds to break at the surface as the two objects slide past each other. This creates ions.
- Charging an insulator by friction leaves patches of ions on the surface, but these patches are immobile.
Charging by Contact

1. Negative charges are transferred from the rod to the metal sphere upon contact.
2. Metal is a conductor. Therefore charge spreads (very rapidly) throughout the entire electroscope. The leaves become negatively charged.
3. Like charges repel. The negatively charged leaves exert repulsive forces on each other, causing them to spread apart.

Charging by contact between objects in a system conserves the electric charge of the entire system.
Polarization

The neutral sphere contains equal amounts of positive and negative charge.

Negative charge is attracted to the positive rod. This leaves behind positive charge on the other side of the sphere.

The rod doesn’t touch the sphere.

The negative charge on the sphere is close to the rod, so it is strongly attracted to the rod.

The positive charge on the sphere is far from the rod, so it is weakly repelled by the rod.

Charge separation in a neutral system can be induced by an external charged object placed close to the neutral system. An induced charge separation can cause a neutral object to become polarized.

- Did the charge in the rod change?
- Did the charge in the sphere change?

Charged objects or systems may attract neutral systems by changing the distribution of charge in the neutral system.
Dipoles

- An atom itself in an insulator can be polarized. If we bring a positively charged object near an neutral atom, the charge polarizes the atom by attracting the electron cloud.
- Added together, these can have a large net effect, making it possible to polarize an insulator.
Hydrogen Bonding

- Hydrogen bonding is the result of permanent electric dipoles.

The slightly negative oxygen is attracted to the slightly positive hydrogen of a neighbor.

This water molecule forms hydrogen bonds with four neighbors.

The base pairs of the two strands can join only in certain combinations.

Three hydrogen bonds join these bases.

Two hydrogen bonds join these bases.
Grounding involves the transfer of excess charge to another larger system (e.g., the Earth).
Charging by Induction

- Charging by induction can occur when a polarized conducting object is touched by another object.
The figure shows five pairs of plates: $A$, $B$, and $D$ are charged plastic plates and $C$ is an electrically neutral copper plate. The electrostatic forces between the pairs of plates are shown for three of the pairs. For the remaining two pairs, do the plates repel or attract each other?