Electron Flow and Resistance: Atoms, Charge and Current

Session 1a of Basic Electricity
A Fairfield University E-Course
Powered by LearnLinc

Basic Electricity

Two Parts

- Electron Flow and Resistance
  - 5 on-line sessions
  - Lab
- Inductance and Capacitance
  - 5 on-line sessions
  - Lab

Mastery Test, Part 1

Basic Electricity (Continued)

- Text: "Electricity One-Seven," Harry Mileaf, Prentice-Hall, 1996, ISBN 0-13-889585-6 (Covers several Modules and more)
- References:
  - "Digital Mini Test: Principles of Electricity Lessons One and Two," SNET Home Study Coordinator, (203) 771-5400
  - Electronics Tutorial (Thanks to Alex Pounds at alex_tb@hotmail.com)
  - Electronics Tutorial (Thanks to Mark Sokos at sokos@desupernet.net)

Section 1:
Electron Flow and Resistance

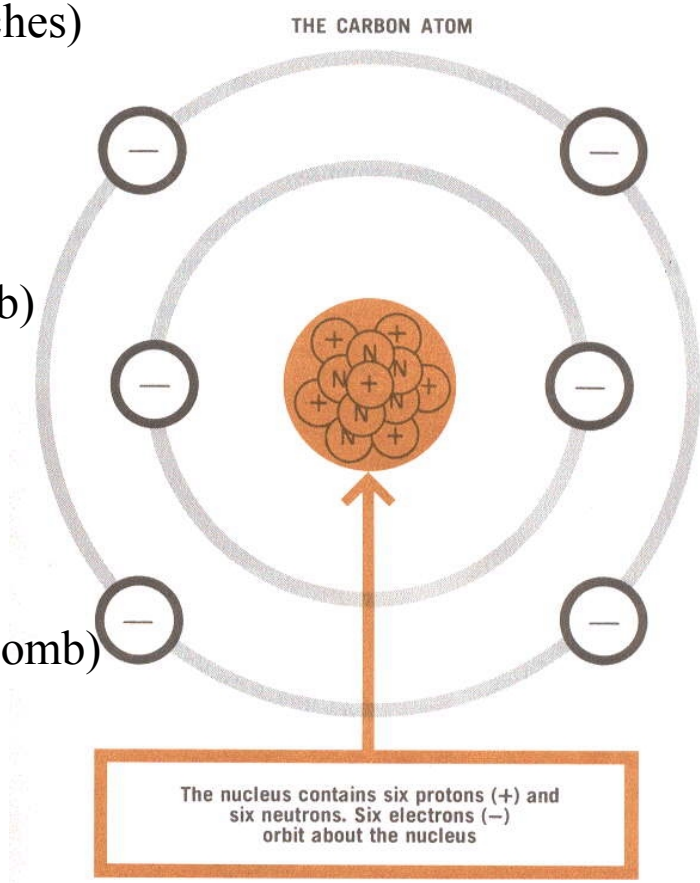
- 0BJECTIVES: This section introduces five basic electrical concepts as well as the underlying atomic structure of electrical materials.
  - Conductance(G),
  - Resistance (R),
  - Current (I),
  - Power (P), and
  - Electromotive force (E) or voltage (V).

Section 1 Schedule:

Session a – 03/04	**Atoms, Charge and Current**	**Text 1.1 – 1.39**
	Conductivity (G), Electric Fields and Electromotive Force (EMF)	**Text 1.40 – 1.68**
Session b – 03/06	Resistance (R), Conductance (G), Ohms Law (Ω) & Power (Watts)	Text 2.1 – 2.52
Session c – 03/11	Working with Equations	Text 2.53 – 2.98
Session d – 03/13 (Lab - 03/16 sat.)	Resistors in Series and Parallel	2.99 – 2.115
	Kirchoff, Thevenin & Norton	2.116 – 2.133
Session e – 03/18	Review: The Water Model	1.42, 1.63, 2.5, 2.129 Sokos

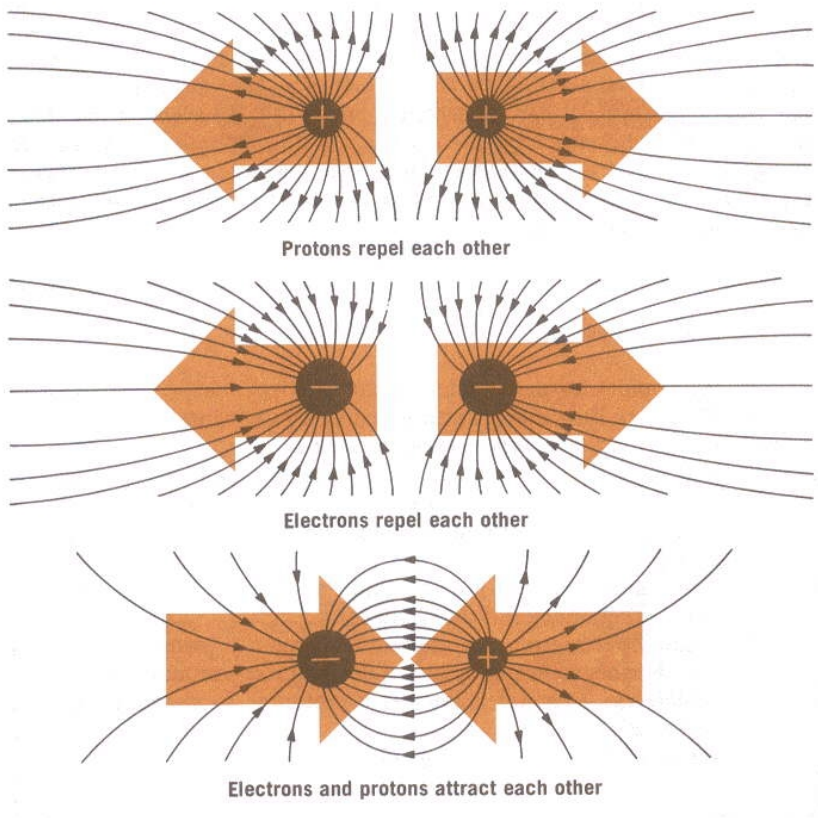
Atoms, Charge and Current

- Atoms (Hydrogen Diameter 0.2 x 10^{-9} inches)
  - Electrons
    - Small (0.22 x 10^{-9} inches)
    - Light (0.91 x 10^{-28} grams)
    - Negative Charge (1.6 x 10^{-19} coulomb)
  - Nucleus
    - Protons
      - Smaller (0.07 x 10^{-9} inches)
      - Heavy (1840 x electron)
      - Positive charge (1.6 x 10^{-19} coulomb)
    - Neutrons
      - Heavy (same as proton)
      - Neutral charge



Electric Fields

- Like charges repel each other.
- Opposite charges attract each other.
- An E-Field is measured in Volts/meter (Count AlessandroVolta, 1745 - 1827).



Coulomb's Law

Charles Augustin de Coulomb
(koolom) 1736-1806

The force between two point charges is given by:

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 d^2}$$

Where:

F – Electrostatic force (Newtons - Sir Isaac Newton, 1643-1727)

Q – Charge (Coulombs)

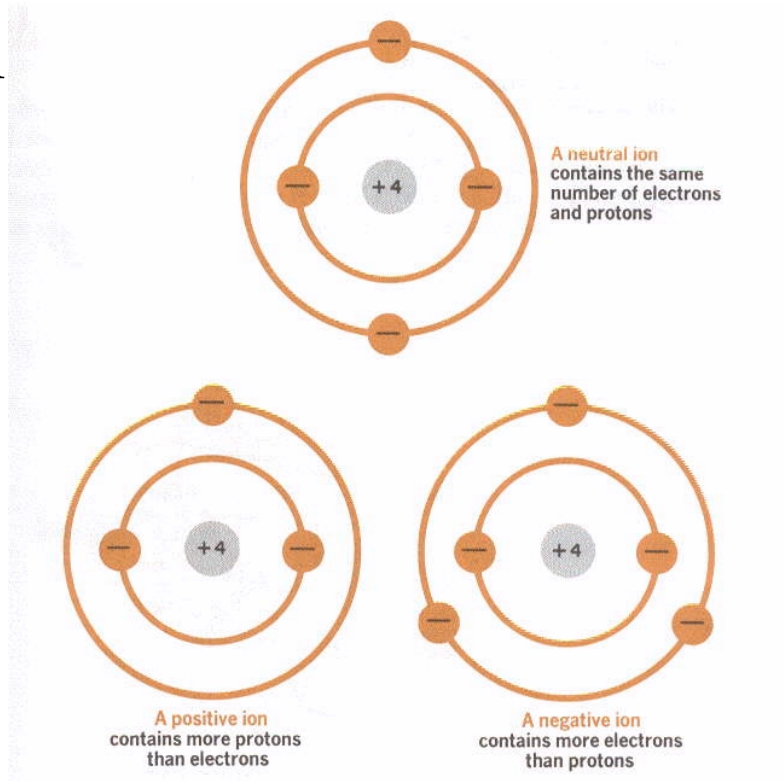
d – Distance between the charges (Meters)

ε_0 – $8.85 * 10^{-12}$ (Nm^3/C)

π - 3.141592653589798
(The ratio between the circumference and diameter of a circle)

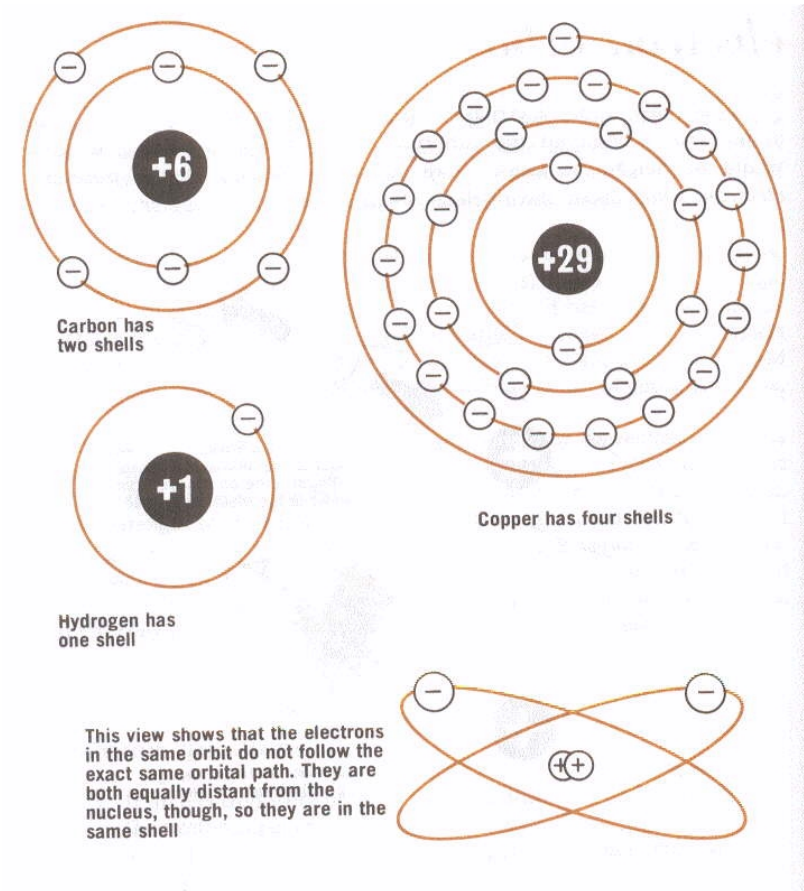
Ions

- Ions can move through liquids (or gasses) under the influence of an electric field.



Electron Shells

- Only the outer electrons (valence shell) form molecular bonds
- Unbound outer electrons can easily move through materials when an electric field is applied.



Current

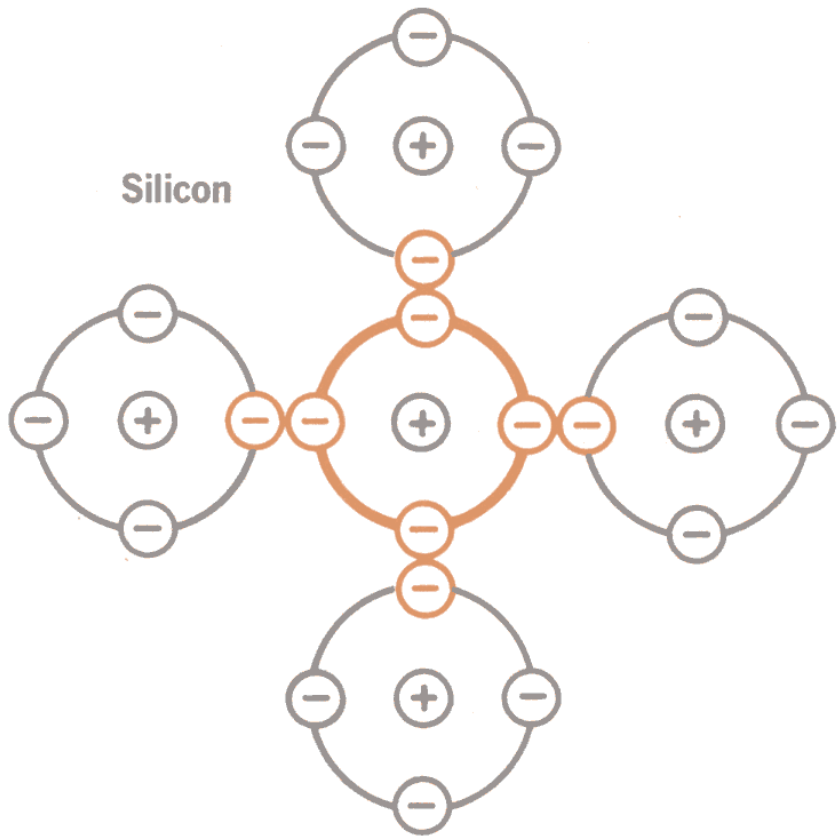
- The flow of electrical charge per unit time (C/sec or Amps - André Marie Ampère 1775 - 1836)
  - Electrons flowing through conductors
    - Conductors have loosely bound outer shell electrons.
    - Insulators have tightly bound electrons in their outer shell.
  - Ions moving through liquids
- Speed of Electricity
  - Electrons flow slowly through a conductive medium
  - Changes in current flow move almost instantaneously
    - Forces between electrons propagate the change as an electromagnetic effect at speeds approaching that of light.
    - Approximately one foot per nanosecond (10^{-9}sec).

Semiconductors

- Group 4 materials (4 outer shell electrons)
  - Carbon (as diamond)
  - Silicon
  - Germanium
  - Tin and lead (not useful)
- Some compounds
  - Gallium Arsenide (GaAs - LEDs)
  - Indium Antimony (InSb – Photo Diodes)

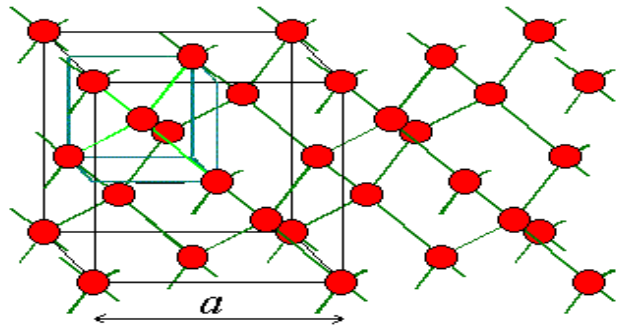
Covalent Bonds

- Crystalline silicon is formed when each of the four valence electrons forms a covalent chemical bond with a neighboring silicon atom.

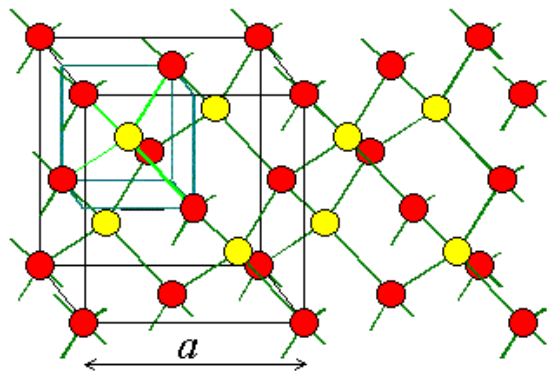


Semiconductor Crystals

The most common crystal structure among frequently used semiconductors (Si, Ge) is the diamond lattice, shown top right. Each atom in the diamond lattice has a covalent bond with four adjacent atoms, which together form a tetrahedron.



Compound semiconductors such as GaAs and InP have a crystal structure that is similar to that of diamond. However, the lattice contains two different types of atoms. Each atom still has four covalent bonds, but they are bonds with atoms of the other type



Current in Semiconductors

- If a pure crystal, there are no free valence electrons and therefore no current can flow
- N – Type
  - If a contaminant is diffused into the structure that has 5 electrons in the outer shell, there is now one free electron per contaminating atom and current can flow
- P – Type
  - If a contaminant is diffused into the structure that has 3 electrons in the outer shell, there is now one missing electron per contaminating atom and current can flow as moving “holes” in the crystal

Homework

- Assignments - Electricity 1-7
  - Review Questions:
    - P 1.13, 1.22
    - P 1.39, 1.47
    - P 1.61, 1.68
- Readings for next session
  - Read next session's chapters in Electricity 1-7
    - 2.1 – 2.35
  - Explore Web resources