Voltage and Current

2.2 – Atoms and Their Structure

- Nucleus
  - Protons
  - Electrons
  - Neutrons

Atoms and Their Structure

- Shells and subshells of the atomic structure

- Free electrons

2.3 - Voltage

- The flow of charge is established by an external "pressure" derived from the energy that a mass has by virtue of its position: **Potential energy**
- Energy: the capacity to do work
  - If a mass (m) is raised to some height (h) above a reference plane, it has a measure of potential energy expressed in joules (J) that is determined by
  - **W (potential energy) = *mgh***

  where g is the gravitational acceleration ($9.8\ m/s^2$)

Voltage

- A potential difference of 1 volt (V) exists between two points if 1 joule (J) of energy is exchanged in moving 1 coulomb (C) of charge between the two points
- The unit of measurement **volt** was chosen to honor Alessandro Volta

Voltage

- A potential difference or voltage is always measured between two points in the system. Changing either point may change the potential difference between the two points under investigation.
- Potential difference between two points is determined by: $\mathbf{V = W/Q}$ (volts)

Voltage

- Notations for sources of voltage and loss of potential
  - E - Voltage sources (volts)
  - V - Voltage drops (volts)
- Potential – The voltage at a point with respect to another point in the electrical system. Typically the reference point is the ground, which is at zero potential.

Voltage

- Potential difference: The algebraic difference in potential (or voltage) between two points of a network.
- Voltage: When isolated, like potential, the voltage at a point with respect to some reference such as ground.
- Voltage difference: The algebraic difference in voltage (or potential) between two points of a system. A voltage drop or rise is as the terminology would suggest.
- Electromotive force (emf): The force that establishes the flow of charge (or current) in a system due to the application of a difference in potential.

Voltage

Summary

- The applied potential difference (in volts) of a voltage source in an electric circuit is the “pressure” to set the system in motion and “cause” the flow of charge or current through the electrical system.

2.4 - Current

- The free electron is the charge carrier in a copper wire or any other solid conductor of electricity
- With no external forces applied, the net flow of charge in a conductor in any one direction is zero
- Basic electric circuit

Current

- Safety considerations
  - Even small levels of current through the human body can cause serious, dangerous side effects
  - Any current over 10 mA is considered dangerous
  - currents of 50 mA can cause severe shock
  - currents over 100 mA can be fatal
  - Treat electricity with respect – not fear

2.5 – Voltage Sources

- dc – Direct current
  - Unidirectional (“one direction”) flow of charge
  - Supplies that provide a fixed voltage or current

Voltage Sources

- dc Voltage sources
  - Batteries (chemical action)
  - Generators (electromechanical)
  - Power supplies (rectification)

Voltage Sources

- Batteries: combination of two or more similar cells
  - A cell being a fundamental source of electrical energy developed through the conversion of chemical or solar energy
  - All cells are divided into Primary and Secondary types
    - Primary type is not rechargeable
    - Secondary is rechargeable; the cell can be reversed to restore its capacity
    - Two most common rechargeable batteries are the lead-acid unit (primarily automotive) and the nickel-cadmium (calculators, tools, photoflash units and shavers)

Voltage Sources

- Each cell establishes a potential difference at the expense of chemical energy and each has the following components:
  - Positive electrode
  - Negative electrode
  - Electrolyte (the contact element and the source of ions for conduction between terminals)

Voltage Sources

- Alkaline primary cells
  - Powered zinc anode (+)
  - Potassium (alkali metal) electrolyte
  - Manganese dioxide, carbon cathode (–)

Voltage Sources

- Lead-acid secondary cell
  - Sulfuric acid is the electrolyte
  - The electrodes are spongy lead (Pb) and lead peroxide ($Pb0_2$)

Voltage Sources

- Nickel-cadmium secondary cell
  - Rechargeable battery (Capable of 1,000 charge/discharge cycles)
  - charged by a constant current source
- Nickel-hydrogen and nickel-metal hydride secondary cells
  - Nickel-hydrogen cell currently limited primarily to space vehicles
  - Nickel-metal hydride cell is actually a hybrid of the nickel-cadmium and nickel-hydrogen cell – Expensive, but it is a valid option for applications such as portable computers

Voltage Sources

- Solar cell
  - A fixed illumination of the solar cell will provide a fairly steady dc voltage for driving loads from watches to automobiles
  - Conversion efficiencies are currently between 10% and 14%

Voltage Sources

- Ampere-hour rating
  - Batteries have a capacity rating in ampere-hours
  - A battery with an ampere-hour rating of 100 will theoretically provide a steady current of 1A for 100 h, 2A for 50 h or 10A for 10 h
  - Factors affecting the rating: rate of discharge and temperature
    - The capacity of a dc battery decreases with an increase in the current demand
    - The capacity of a dc battery decreases at relatively (compared to room temperature) low and high temperatures

Voltage Sources

- Generators
  - Voltage and power-handling capabilities of the dc generator are typically higher than those of most batteries, and its lifetime is determined only by its construction
  - Power supplies
  - The dc supply encountered most frequently in the laboratory employs the rectification and filtering processes as its means toward obtaining a steady dc voltage

Voltage Sources

- dc Current sources
  - The current source will supply, ideally, a fixed current to an electrical/electronic system, even though there may be variations in the terminal voltage as determined by the system

2.8 Conductors and Insulators

- Conductors are those materials that permit a generous flow of electrons with very little external force (voltage) applied

  In addition,

- Good conductors typically have only one electron in the valance (most distant from the nucleus) ring.

Conductors and Insulators

- Insulators are those materials that have very few free electrons and require a large applied potential (voltage) to establish a measurable current level
- Insulators are commonly used as covering for current-carrying wire, which, if uninsulated, could cause dangerous side effects
- Rubber gloves and rubber mats are used to help insulated workers when working on power lines
- Even the best insulator will break down if a sufficiently large potential is applied across it

Conductors and Insulators

- Table 2.1 shows the relative conductivity of various materials

TABLE 2.1

Relative conductivity of various materials.

Metal	Relative Conductivity (%)
Silver	105
Copper	100
Gold	70.5
Aluminum	61
Tungsten	31.2
Nickel	22.1
Iron	14
Constantan	3.52
Nichrome	1.73
Calorite	1.44

- Table 2.2 shows breakdown strength of some common insulators

TABLE 2.2

Breakdown strength of some common insulators.

Material	Average Breakdown Strength (kV/cm)
Air	30
Porcelain	70
Oils	140
Bakelite	150
Rubber	270
Paper (paraffin-coated)	500
Teflon	600
Glass	900
Mica	2000

2.9 Semiconductors

- Semiconductors are a specific group of elements that exhibit characteristics between those of insulators and conductors
- Semiconductor materials typically have four electrons in the outermost valence ring
- Semiconductors are further characterized as being photoconductive and having a negative temperature coefficient
  - Photoconductivity: Photons from incident light can increase the carrier density in the material and thereby the charge flow level
  - Negative temperature coefficient: Resistance will decrease with an increase in temperature (opposite to that of most conductors)

2.10 Ammeters and Voltmeters

- Ammeter (Milliammeter or Microammeter)
  - Used to measure current levels
  - Must be placed in the network such that the charge will flow through the meter
- Voltmeter
  - Used to measure the potential difference between two points

Ammeters and Voltmeters

- Volt-ohm-milliammeter (VOM) and digital multimeter (DMM)
  - Both instruments will measure voltage and current and a third quantity, resistance
  - The VOM uses an analog scale, which requires interpreting the position of the pointer on a continuous scale
  - The DMM provides a display of numbers with decimal point accuracy determined by the chosen scale.

2.11 Applications

- Flashlight
  - Simplest of electrical circuits
  - Batteries are connected in series to provide a higher voltage (sum of the battery voltages)

Applications

- 12-V Car battery charger
  - Used to convert 120-V ac outlet power to dc charging power for a 12-V automotive battery, using a transformer to step down the voltage, diodes to rectify the ac (convert it to dc), and in some cases a regulator to provide a dc voltage that varies with level of charge.

Applications

- Answering machines/Phones dc supply
  - A wide variety of devices receive their dc operating voltage from an ac/dc conversion system
  - The conversion system uses a transformer to step the voltage down to the appropriate level, then diodes “rectify” the ac to dc, and capacitors provide filtering to smooth out the dc.