Basic Concepts

Charge, Current, Voltage, Power, Energy
Objective

- Discuss the mathematical relationships between charge, current, voltage, power, and energy.
  - Chapter 1.3-1.5
- Explain the differences between positive and negative power using passive sign convention.
  - Chapter 1.5
- Describe the application of the conservation of energy in electrical circuits.
  - Chapter 1.5
Charge

- Electrical property of atomic particles
  - Electrons are negatively charged
  - Protons are positivity charged
- The absolute value of the charge on an electron is $1.6 \times 10^{-19}$ C
- The symbol used is $Q$ or $q$
  - Uppercase is used to denote a steady-state or constant value
  - Lowercase is used to denote an instantaneous value or time-varying quantity
Current

- The flow of charge through a cross-sectional area as a function of time or the time rate of change of charge
- Symbol used is I or i

\[ i = \frac{dq}{dt} \]

\[ Q = \int_{t_1}^{t_2} i \, dt \]
DC vs. AC

- **DC (or dc)** is the acronym for direct current.
  - The current remains constant with time.
    - Uppercase variables are used when calculating dc values.
- **AC (or ac)** is the acronym for alternating current.
  - Specifically, AC current varies sinusoidally with time and the average value of the current over one period of the sinusoid is zero.
    - Lowercase variables are used when calculating ac values.
  - Other time-varying currents exist, but there isn’t an acronym defined for them.
Voltage (Potential Difference)

- The electromotive force (emf) that causes charge to move.
- 1 Volt = 1 Joule/1 Coulomb

\[ V = \frac{dW}{dq} \]
The change in energy as a function of time is power, which is measured in watts (W).

\[ p = \frac{dw}{dt} = \frac{dw}{dq} \frac{dq}{dt} = vi \]
Energy

- Energy is the capacity to do work.

\[ W = \int_{t_1}^{t_2} p \, dt = \int_{t_1}^{t_2} v \, i \, dt \]

- Units for energy are kW-hr, which is what the electric company measures on your electric meter.
  - \( 1 \, \text{kW-hr} = 3.6 \, \text{MJ} \).
Positive vs. Negative Power

- Power consumed/dissipated by a component is positive power

\[ P = + 1W \]
Passive Sign Convention

- Generated power has a negative sign
  \[ P = -1W \]
Conservation of Energy

- All power instantaneously consumed by components must be instantly generated by other components within the circuit.

$$\sum p = 0$$
Example

There are 4 electrical components in the circuit shown to the right.

Component #1 is generating 2 W of power and supplying this power to the circuit.

Components #2 and #3 are consuming power.

Component #2 is dissipating 3 W of power while Component #3 is dissipating 5 W of power.

Component #4 must be generating 6 W of power in order to maintain the Conservation of Energy.

\[ \sum p = p_{\text{Component#1}} + p_{\text{Component#2}} + p_{\text{Component#3}} + p_{\text{Component#4}} = 0 \]

\[ p_{\text{Component#4}} = -(p_{\text{Component#1}} + p_{\text{Component#2}} + p_{\text{Component#3}}) = -(-2 \text{ W} + 3 \text{ W} + 5 \text{ W}) = -6 \text{ W} \]
Summary

- The relationship between charge, current, voltage, power, and energy was presented.
- Passive sign convention will be used in this course.
- Conservation of energy means that a circuit must contain elements that supply all of the power that is dissipated by the remaining elements in it.