Topic 1

Charge, Current, Voltage & Resistance; Ohm's "Law"

1.1 Charge

- SI unit is Coulombs (C).
- Fundamental unit is magnitude of charge on electron/proton:

$$e = 1.6 \times 10^{-19}\,\mathrm{C}$$

1.2 Current

- Current is a measure of the flow rate of charge past a point in a circuit:

$$I = \frac{Q}{\Delta t} \longrightarrow \frac{dQ}{dt}.$$

- Current can be written in terms of microscopic quantities as

$$I = nAve,$$

  where n is the density of electrons, A is the cross-sectional area of the wire, v is the *drift velocity* of the electrons, and e is the charge of the electron.

- Batteries are *not* sources of constant current.
  Bench-top power supplies can be sources of constant current when they are in constant current , or `CC`, mode.

- SI unit is Coulombs/second (C/s), or Amperes (A).
- Ammeters measure current that flows through the meter. Ideal ammeters should have no resistance. Ammeters should be connected in series with current they they are being used to measure (so that they do not disturb the circuit under investigation).

1.3 Voltage

- Formal definition: The voltage *difference* between two points A and B in an electrical circuit is the negative of the work done *per unit charge* by electric fields in moving a charge from point A to point B.
- A voltage difference between the ends of a circuit element reflects the fact that electric fields exist within the element that will result in current through the element.
- Voltage, potential, voltage difference, and potential difference are often used interchangeably. Be careful — exact meaning can depend on context.
- Ideal batteries are sources of constant voltage difference.
  Bench-top power supplies can be sources of constant voltage difference (when they are in constant voltage, or `CV`, mode.)
- Ideal voltmeters have infinite resistance so that no current flows through them. Voltmeters should be connected in parallel with the circuit element across which the voltage difference is being measured (so that they do not disturb the ciruit under investigation)..
- Voltage is sometimes called electric potential; voltage difference is equivalent to potential difference.
- SI unit for voltage/potential is Joules/Coulomb (J/C), or Volts (V).

1.4 Resistance and Ohm's Law

As mentioned above, a potential differences between the ends of a circuit element reflects the fact that electric fields exist in the element that will cause a current to flow. In some materials there is a direct proportionality between the potential difference between two points in a circuit and the current that flows between the two points. Such materials are said to obey Ohm's Law. (This is not really a law,

but rather an observation about some materials.) In other words,

$$I = \frac{\Delta V}{R} \quad \text{or} \quad \Delta V = IR.$$

This is more commonly written $V = IR$, but I encourage you to think about potential *differences*.

1.5 Resistance, Resistivity, and Conductivity

The resistance of a wire can be written in terms of a material-dependent quantity ρ, and material-independent geometric factors:

$$R = \rho \frac{L}{A},$$

where L is the length of the wire and A is the cross-sectional area. The quantity ρ is known as the *reistivity*. This same relationship can also be expressed in terms of the *conductivity* of the material, σ, which is just the inverse of the resistivity:

$$R = \frac{1}{\sigma} \frac{L}{A},$$

Values of ρ and σ for various materials are available in many books and in online sources.