Chapter E4: Voltage

E4.2 A Mechanical Model for a Battery

Key idea: "A battery is a device that maintains a charge separation between two plates by transporting charge from one plate to the other against the electric forces acting on that charge."

E4.3 Surface Charges Direct Currents

How do electrons in a wire know to turn when the wire turns? A slight excess of charges on the surface of the wire makes sure that the field inside the wire is always uniform and points in the direction of the wire.

E4.4 The EMF of a Battery

The EMF measures the strength of a battery, and is defined as the energy per unit charge given by the "conveyor belt":

$$\mathcal{E} \equiv \frac{\text{Energy given to charge } q \text{ by battery}}{|q|} \tag{1}$$

EMF is measured in *Volts*:

$$1\text{Volt} \equiv \frac{1\text{Joule}}{1\text{Coulomb}} \tag{2}$$

Voltage is energy per unit charge.

E4.4 & E4.5 The EMF of a Battery & Voltage Differences

The voltage difference between from point A to B is defined as:

$$\Delta\mathcal{V} \equiv \frac{\Delta V_e}{q} \tag{3}$$

Where ΔV_e is the change in electrostatic potential energy when a test charge q moves from A to B.

The voltage, for an ideal battery, is equal to the EMF:

$$|\Delta\mathcal{V}| = \Delta V_e/e = eE_bD/e = E_bD = \mathcal{E} \ . \tag{4}$$

Thus,

$$|\Delta\mathcal{V}_b| = |\Delta\mathcal{V}_{\text{wire}}| = E_{\text{wire}}L \ . \tag{5}$$

EMF and Voltage have the same units, but measure different things:

- EMF is any energy transferred to a charge by a non-electrostatic force.
- Voltage difference is a change in electrostatic potential energy per charge.

E4.6 A Real Battery

Chemical reactions act like a conveyor belt and move charge from one plate to the other.

The *capacity* of a battery is the total amount of charge it can source. It is measured in either Coulomb's (since it's a charge), or, more commonly, Amp-hours:

$$1\text{Amp}\cdot\text{hours} = 3600\text{C} \ . \tag{6}$$

A typical D-Cell battery has a capacity of 5 A·h. A typical car battery has a capacity of around 100 A·h.

Examples:

1. A D-cell battery is connected to a 3 meter long piece of silver wire and draws 2 Amps. What is the field inside the wire?

2. A 2 Volt battery sources .1 Amps for 2 hours. How much energy is dissapated into thermal energy in this time? Would this be enough to appreciably warm up a cup of coffee or tea?