EECS 16A Designing Information Devices and Systems I
Spring 2015 Note 10

Lecture notes by Rachel Zhang (02/24/2015)

Midterm Regrades

Write up what you think might be incorrectly graded and why.
Attach your write-up to the exam and hand it in to the GSIs or professors (Elad or Gireeja).
NOTE: Your entire exam will be regraded so your exam grade could *go down*.

Electricity – Water Analogy

Electricity

- The battery is charged at a factory by a chemical reaction such that the electrons are pushed up in potential energy.
- Something in the battery blocks the electrons from traveling to lower potential energy.
- **Voltage:** Potential difference
- **Current:** Flow of electrons
  - Current results in the electrons losing potential energy and gaining kinetic energy.
  - Flow of electrons indicates that they have velocities. The flow of electrons over a period of time corresponds to an amount of charge.

Water

- A water pump drives water from a reservoir up into a water tower, thereby increasing the water molecules' potential energy by increasing the height they are at.
- Something in the water tower prevents the water from traveling to lower potential energy (prevents water from flowing back down where it came from).
- **Pressure:** Potential difference imposed by the height
- **Water flow:** Flow of water molecules
  - Flow of water results in the water losing potential energy and gaining kinetic energy.
  - When the water hits the ground, it generates some heat and transfer energy, for example to the container walls, but most of the heat is absorbed by the water.

Circuit Components and Definitions

- **Short Circuit:**
  Direct wire contact that allows for easy flow of electrons. If the two terminals of a battery are "shorted", this is analogous to dumping all of the water in the water tower at once

- **Open Circuit:**
  Circuit does not allow current to flow (i.e. wires are not connected). In battery context, an "open circuit" load would mean the battery would stay charged forever, but in reality some charge would "leak through" the battery itself.

- **Battery:**
  Voltage Source; contain material preventing charge from flowing backwards until connected in a circuit; some rechargeable

- **Source:**
  Ideal element that fixes either the voltage across its terminals (voltage source) or the current flowing through it (current source).

- **Voltage:**
  A relative measure of potential difference between two points on the circuit; for batteries, refers to difference in potential between the positive (anode) terminal and the negative (cathode) terminal.

- **Ground:**
  Reference potential to compare every other point against; could be arbitrary but for convenience, it's usually the cathode of the battery; does not always mean an actual physical connection to the earth

- **DC:**
  "Direct Current"; current is a fixed value (constant with time); the converse is "Alternating Current" (do not need to know for this class)

- **Wires:**
  Assume, for this class, that the wire is a perfect wire, which means there is no voltage drop as charge travels through the wire

- **Junction:**
  Point where multiple wires are electrically connected to each other

- **Resistors:**
  Opposes the flow of chargeand this limits the current given a certain voltage across it. In the water analogy, it is a fixed constriction that limits water flow

- **Resistance:**
  Measurement of constriction in terms of how much it limits flow of charge. Units are Ohms (Ω); dependent of resistivity of wire, length of wire, and cross-sectional area of wire

$$resistance = \frac{voltage}{current} = \frac{voltage * time}{charge}$$

- **Conductance:**
  Inverse of resistance; units are mhos or Siemens; conductivity has units of Siemens per meter S/m

- **Resistivity:**
  Fundamental material dependent parameter; units are ohm-meters $\Omega \cdot m$; represented by rho ρ; temperature dependent; resistance $R = \rho \frac{L}{A}$, where L is in the direction of current flow and A is the cross-sectional area.

Ohm's Law

$$V = IR$$

- **V:** voltage (Volts)
- **I:** current (Amperes)
- **R:** resistance (Ohms)
- Intuitively, if you "increase the flow, you must increase the pressure".

Touchscreen

(Refer to Touch Screen Technology slides 7, 17-20)

- **No touch:** zero current (open circuit)
- **Touch:** current and output voltage depend on the where you touch the screen ("short circuit")
- **Digitizer:** readout device that figures out where the touch is based on measuring the output voltage
- Plates of touchscreen are moderately resistive, like a long resistor.
- 2D structure and the position of the touch changes the lengths of the "resistors"; like a mesh grid
- There are smears of highly conductive silver ink (outside of where touch should occur) across 2 ends of the structure to have zero resistance in one dimension. (No voltage drop across or current through the resistors parallel to the silver ink stripes.)

Questions

1. *What if you connect a wire from the anode to the cathode of a battery?*
   If it is a good wire, it will generate a lot of heat (maybe even light). This is "shorting" the battery - do not do this.
2. *Are all batteries rechargeable?*
   Truthfully, yes. Safely, no. The act of charging a battery is reversing the chemical reactions inside, which do not always return to their original states and can lead to explosions. Alkaline batteries can recharge slowly. On the other hand, cell phone batteries are meant to be rechargeable (chemical reactions designed to be reversible).
3. *Doesn't discharging a battery decrease it's voltage (like draining the water tower decreases the pressure)?*
   Yes, but really good ones have voltage drops that are really small until a long period of time passes. At that point, the voltage drops off very quickly.
4. *Does the size of the battery affect the voltage?*
   No, but it sets the capacity of battery (the voltage is set by the chemistry of the battery).
5. *Right when a circuit is connected, what happens to the current?*
   For simplicity right now, assume the circuits are time invariant.

Helpful Links

Introduction
Charge and Current
Charge, Current, and Voltage