CS 241 Lab 11 – Lab Report
Wednesday, April 7th, 2021
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Steps (Assignment 0):

1. Put one 9v battery and a multimeter into a tinkcad simulation.
    a. Measure the open circuit **voltage** of the battery.
        i. With real industrial-scale batteries, would it be safe to touch the battery leads to a voltage meter?
            1. Yes, it is safe as the current is low.
    b. Measure the peak short circuit **current** through the battery.
        i. With real industrial-scale batteries, would it be safe to short circuit the battery through a meter?
            1. No, it would not because the current would be way too high during the short and could cause damage to the battery and or you, CURRENT KILLS!
        ii. With real batteries, the voltage drops as the battery discharges. Do you see evidence of this in the simulation?
            1. You do not see evidence of this major drop in the simulation.
        iii. In real batteries, open circuit voltage divided by short circuit current is a pessimistic estimate of the battery's internal **resistance** (smaller loads will show lower resistance). Compute the battery's internal resistance this way (ohms = volts/amps). Does this resistance seem plausible for a real 9v battery?
            1. 9V/6A = 1.5 Ω
2. With two 9v batteries in the simulation, connect them in **series (2S)**.
    a. Measure the voltage, peak current, and compute the internal resistance. How do these compare with a single battery?
        i. Doubles the voltage (add in series). The total voltage is 18.0 V compared to the 9.0 V seen previously.
        ii. Peak current: 6 A (Same as previous)
        iii. Internal resistance: 18V/6A = 3Ω (Doubled internal resistance)
    b. Would this happen with real batteries?
        i. Yes, this is how it happens in real life.
3. With two 9v batteries in the simulation, connect them in **parallel (2P)**. How does the voltage and current change from a single battery?
    a. Measure the voltage, peak current, and compute the internal resistance. How do these numbers compare with a single battery?
        i. Same as a single battery (9.0 V) in parallel. The peak current in 12 A (double previous). Internal resistance is 9V/12A = 0.75 or ¾ ohms. (half of previous).

4. With four 9v batteries in the simulation, connect them in a **2S 2P** configuration (two parallel strings of two batteries each).
    a. Measure the voltage, peak current, and compute the internal resistance. How do these numbers compare with a single battery?
        i. Voltage: 18 volts
        ii. Peak current: 12 amps
        iii. Internal resistance: 18/12 = 1.5 Ω
    b. Why might you choose a 2S 2P battery configuration?
        i. We might use a 2S 2P battery configuration to ensure that the lifespan of the batteries increases over time. This is present in remotes or other common disposable batteries scenarios.
            1. Also helps in voltage management if we use the 2S 2P configuration for futureproofing our layout flexibility in new design considerations.

Steps (Assignment 1):

1. Start by measuring the voltage across the **LED**. Hook up a 9v battery, 1k ohm resistor, and LED, with a meter to measure the voltage across the LED's pins when it is fully lit.
    a. How many volts does it take to light up a Tinkercad LED?
        i. To fully light up a red LED, you will need 2 V at 15 mA.
2. Use a **meter** to measure the voltage, peak current, and internal resistance of a Tinkercad potato battery.
    a. Voltage: 670 mV
    b. Peak current: 118 µA
    c. Internal resistance: 5.68 kΩ
3. Compute how many potato batteries you'll need to drive the LED at the voltage needed to light it up.
    a. How many is this? Should you wire the potatoes in **series or parallel** to reach this voltage?
        i. 3 (or 2.985 rounded) potato batteries total. We should wire the potatoes up in series to ensure that we reach this voltage.
4. Wire up the **potatoes** to the LED. (You only need a current limiting resistor if the battery peak current is above 1mA)
    a. Does the LED light up?
        i. Yes, but very dim.
    b. Is it as bright as the 9v version?

        i. No, this new wiring scheme is not as bright as the original 9v battery version.
    c. What is the voltage across the LED terminals? Does this match your answer from step 1, and why or why not?
        i. 1.64 volts → Yes, as the voltage goes below 2 V it drops less after passing through the LED.
5. Add a 100 uF **capacitor** across the terminals of the LED (capacitor in parallel with the LED), and measure the voltage across the LED terminals.
    a. What happens to the voltage as the simulation starts? Why?
        i. The voltage takes longer to get up to 1.64V
    b. Does the capacitor increase the long-term LED voltage?
        i. No, it does not, it would only provide a small amount of voltage at the right current for an extremely short time.
            1. Similar to what was discussed in class with batteries of different sizes not able to sustain and jump-start a vehicle.
    c. Does this match what you'd expect from a real circuit?
        i. Yes, because the capacitor would only have to work for a small amount of time.
    d. What kind of loads would be helped by having a capacitor hooked up like this?
        i. For example, to start a motor or to flash a LED...
6. A **Tesla battery** runs at 400V. Ignoring internal resistance, how many potatoes would it take to reach this voltage?
    a. Math time: 400V/0.670V = 598 potatoes!