The Output Resistance of a Power Supply

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Introduction

The purpose of this lab was to determine the output resistance of two different power supplies: a cell battery and DC regulated power supply.

Methods and Materials

- cell battery
- DC regulated power supply
- ammeter
- voltmeter
- resistance box
- wires

Experimental Procedure

First, a circuit was built from option 2, as drawn on the lab handout. Next, utilizing the cell battery as the power supply, measurements were recorded for terminal voltage and current using various different resistors on the resistance box. Once this was completed, the cell battery was swapped out for the DC regulated power supply and set to the same open circuit voltage of about 6.5 V. Then, using the same methodology as before, various resistors were chosen and the terminal voltage and current was recorded for each. This process using the DC regulated power supply was repeated an additional 3 times, where the open circuit voltage was changed to 10 V, 15 V, and then finally 20 V. Subsequently, the procedure was repeated in its entirety using circuit design option 1.

Results

For selective purposes, the data for all eight resistors was collected (for all except option 2 on the cell battery). Then, four appropriate resistors were selected for analysis.

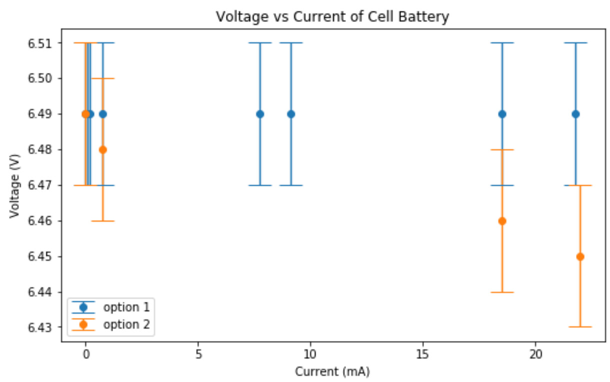

Figure 1: error bar plot of cell battery data

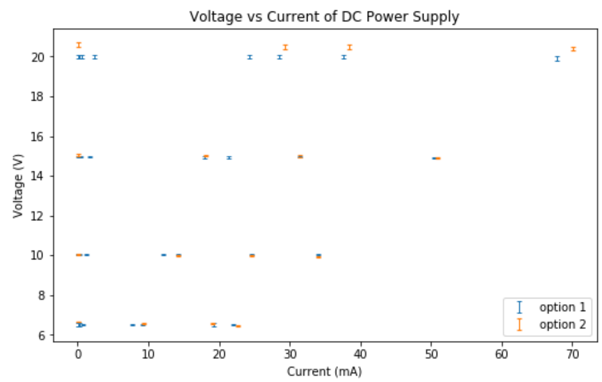

Figure 2: error bar plot of DC supply data

As can be noted from Figure 1, option 2 provided a better opportunity to observe the drop in voltage as the current increased across resistors, whereas the voltage in option 1 did not change. The following results are analyses of the data collected from using the second method. Since the equation $V = V_\infty - IR$ is linear, linear regression was performed. The optimal parameters returned by `curve_fit` are then the open circuit voltage and output resistance, representing the offset and negative of the slope, respectively.

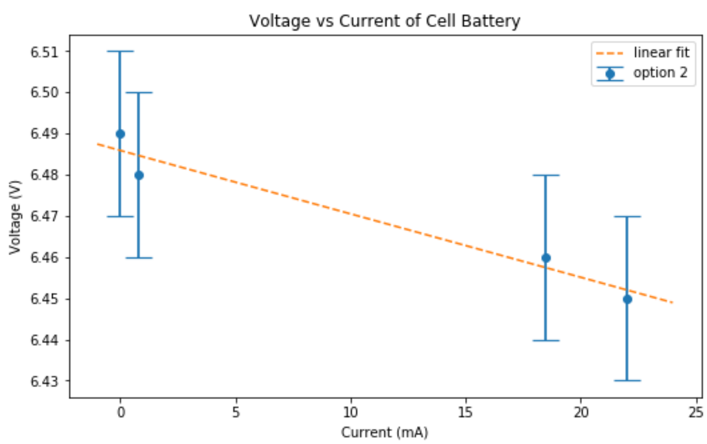

Figure 3: linear fit of cell battery data

The fit is good, as all the points are within their error distances from the function. The calculated R_b and V_∞ as a result are

$$V_\infty = 6.49 \pm 0.004\ V$$
$$R_b = 1.54 \pm 0.2\ \text{m}\Omega$$

with $\chi^2_{red} = 0.0623 << 1$, which indicates over-fitting the data.

The generated values of V vs I from the DC power supply were comparable yet different, as the actice response of the regulator greatly reduces the output resistance. Using the data from option 1, the following fits were generated for the corresponding data points.

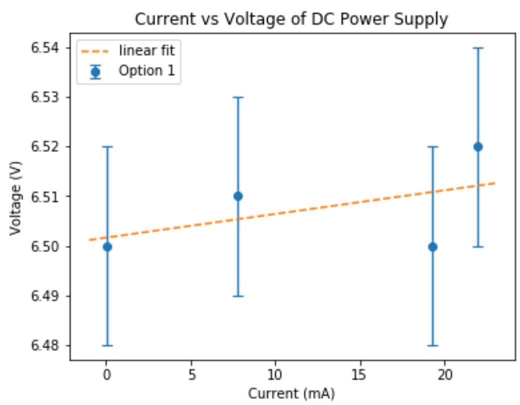

Figure 4: linear fit of DC supply data, 6.5V

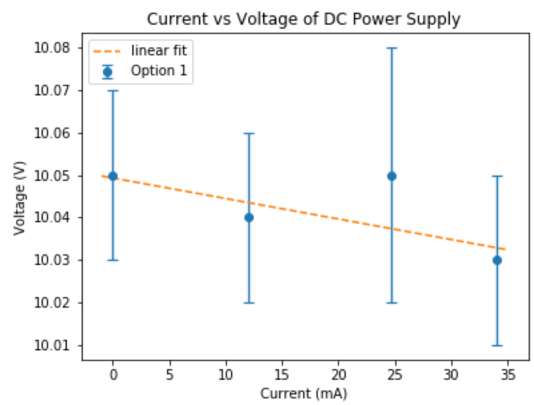

Figure 5: linear fit of DC supply data, 10V

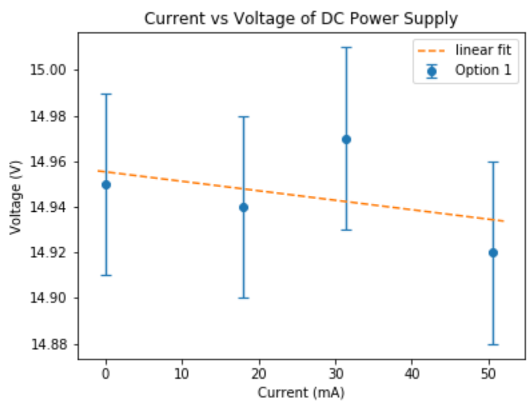

Figure 6: linear fit of DC supply data, 15V

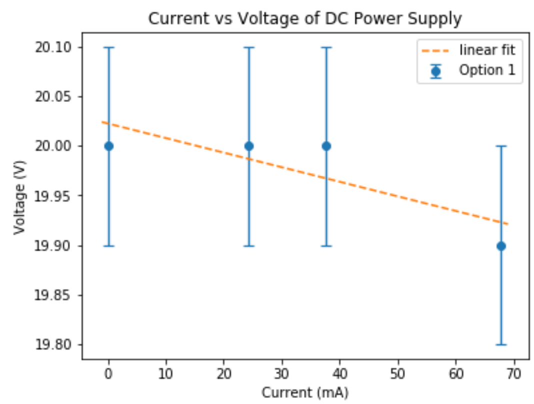

Figure 7: linear fit of DC supply data, 20V

From these fits, the optimal parameters were calculated to be

V_∞ (V)	uncertainty $(\pm V)$
6.50	0.009
10.05	0.006
14.96	0.02
20.0	0.03

Table 1: calculated values of open circuit voltage

R_{ps} (mΩ)	uncertainty ($\pm$mΩ)
-0.478	0.6
0.4838	0.3
0.4156	0.6
1.48	0.7

Table 2: calculated values of output resistance

The corresponding χ^2_{red} are

$V_\infty(V)$	χ^2_{red}
6.5	0.513
10	0.0970
15	0.00342
20	0.00239

Table 3: reduced chi squared for each linear fit

indicating overfit models.

Discussion

While it was expected that the output resistance of the power supply would be relatively small, it was unexpected that the same would be true for that of the cell battery. For comparison, a 9V alkaline battery would have an internal resistance of $\sim 1\Omega$, which is $\sim 650\times$ the calculated value for R_b. This could be as a result of the different inner structures of the batteries- the battery provided has different interactions with imperfect conductors than that of a chemical 9V battery.

Meanwhile as noted, the DC supply source's active response greatly limits the effects of the output resistance. Table 2 exhibits the small magnitude of R_{ps}, even being slightly negative in the first entry.

Questions

1. Option 1 affects the readings of the ammeter, and Option 2 affects the readings of the voltmeter. For this reason, both options have their downfalls and aren't ideal, but one is the lesser of the two evils: Option 2 is better for observing the cell battery because you can note a change in voltage, so you can more easily find the output resistance. Whereas with Option 1, the voltage is constant and so the calculation for output resistance is more tricky, as you only have a change in current to work with. Conversely, Option 1 is more suited for observing the regulated battery, whose active response mechanism mitigates the effects of output resistance, anyway.

2. For the cell battery, the four resistors were chosen in order to test a wide range of resistance. The values of the resistances are unknown, but there were groups of resistors whose values were very similar. This selection allows for spread in the range of measured currents. For the power supply, the same reason holds, with emphasis on the selection of the weakest resistor, which corresponded to the greatest value of current. This information is necessary to analysis of the maximum current I_{max}.

3. An ideal voltmeter would have a resistance of infinity. With that said, one could say that any non-ideal voltmeter would have a very large resistance. The effect of the less-than-infinity resistance on the data would be a slight diversion of current before a measurement is made by the ammeter. To compare the drop in current, the data from Option 1 can be compared to the data from Option 2. However, the second option had slightly altered values of voltage as a result of an imperfect ammeter, which makes comparing voltages difficult. For most measurements, the current values from Options 1 and 2 are within 1mA of each other. When they aren't, the range is as large as 5mA, so the current diverted to the voltmeter is not large. Similarly, the resistance of the ammeter can be found by the change in voltage across the options. Strangely, measuring the resistance of the ammeter directly yielded $100.4 \pm 0.5\Omega$.

4. From Table 2, R_{ps} can be noted to be increasing, aside from a slight decrease from the second to third entry, while V_∞ increases. As R_{ps} increases in magnitude from values close to zero, V_∞ decreases as a function of current I. Thus, the maximum current I_{max} must decrease with V_∞. This can be corroborated by inspecting the last points of Figures 5, 6, and 7, who deviate from the average in the downward direction, implying a greater rate when I_{max} is reached. When the supply is unable to regulate the output resistance, the effects of the resistance are implied to be steep with a derivative large in magnitude.

Conclusion

Batteries are not perfect sources of measurable energy, as the resistance encountered within the batteries cause the open-circuit potential difference V_∞ to drop, at a rate increasing with current I. Regulated power supplies decrease this effect, but their potentials are also affected when the current reaches the maximum, I_{max}.