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Measuring the Output Resistance of a Power Supply

Introduction:

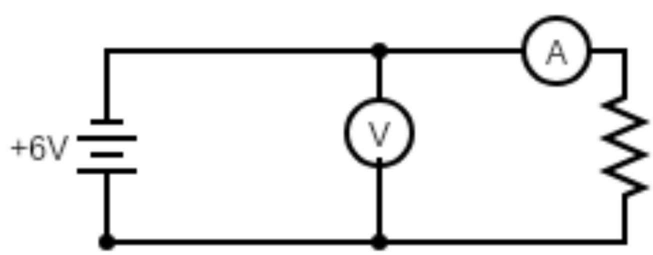
This experiment aims to investigate the output resistance of a DC power supply and a battery. It also helps us gain familiarity with electrical circuits and data collection/measurement. We investigate the differences between circuit setups which achieve the same goal, and attempt to gather information about output resistance by observing how output voltage varies with current across different external resistances. Using curve-fitting methods in Python, we estimate the output resistance for a battery and a DC power supply.

Materials:

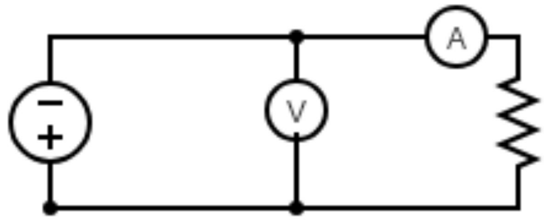
1. Wires
2. 2 multimeters (one Keithley, one Tegam model 130A)
3. DC power supply
4. Genesis NP10-6 6V 10.0Ah battery
5. Resistor board (at least 4 resistors)

Experiment:

First, set up a circuit as shown below:



Measure the voltage and current across four different resistors, and once as an open circuit (without any resistor). Then, replace the battery with a DC power supply according to the diagram below (no other changes):



Adjust the DC power supply so that the voltage is close to that put out by the battery. Be sure not to change settings on either of the multimeters so that the internal circuitry does not change. Again, measure the voltage and current across four different resistors, and also with an open circuit. Repeat this process three more times, adjusting the power supply to have a V_∞ of around 10V, 15V, and 20V.

Results:

Table One: Measurements for open circuit.

Voltage (V)	Current (mA)	Uncertainty of Voltage (V)	Uncertainty of Current (mA)
6.13	0	0.02	0.1
6.14	0	0.02	0.1
10.02	0	0.03	0.1
15.16	0	0.04	0.1
19.35	0	0.05	0.1

In the measurements below, the data is "grouped" into blocks of four rows, with each row representing a different resistor (but the same multimeter settings and inputs). The resistors we used, in order, were:

1. red grey brown gold
2. blue white orange gold
3. red yellow red gold
4. purple green red gold

Table Two: Data measurements for circuit with battery attached.

Voltage (V)	Current (mA)	Uncertainty of Voltage (V)	Uncertainty of Current (mA)
6.11	22.0	0.02	0.2
6.12	9.2	0.02	0.1
6.12	2.4	0.02	0.1
6.12	0.8	0.02	0.1

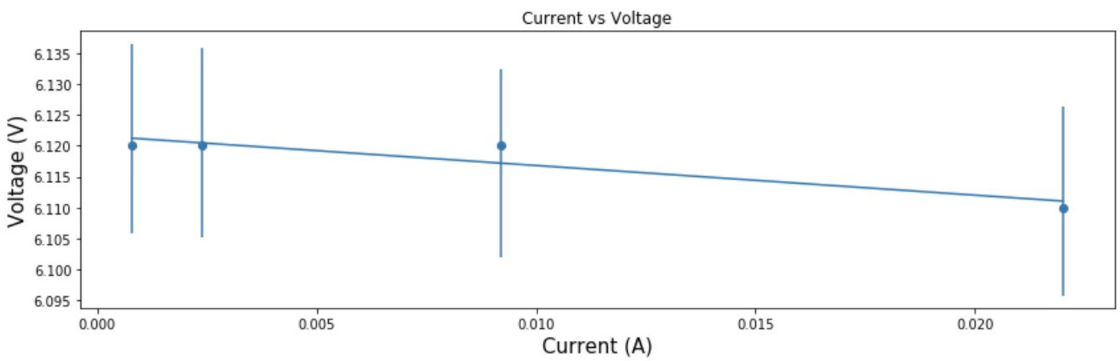
Table Three: Data measurements for circuit with power supply attached.

Voltage (V)	Current (mA)	Uncertainty of Voltage (V)	Uncertainty of Current (mA)
6.11	22.0	0.02	0.2
6.12	9.3	0.02	0.1
6.13	2.4	0.02	0.1
6.14	0.8	0.02	0.1
9.97	35.9	0.02	0.3
9.99	15.1	0.02	0.1
10.00	4.0	0.03	0.1
10.01	1.3	0.03	0.1
15.03	54.1	0.04	0.4
15.07	22.8	0.04	0.2
15.11	6.1	0.04	0.1
15.12	2.0	0.04	0.1
19.26	69.3	0.05	0.5
19.29	29.2	0.05	0.2
19.31	7.8	0.05	0.1

19.32	2.6	0.05	0.1

Current vs voltage plot for the battery.

Image One



Current vs voltage plot for the power supply at various voltages (~6.12V, ~10.1V, ~15.1V, ~19.3V).

Image Two

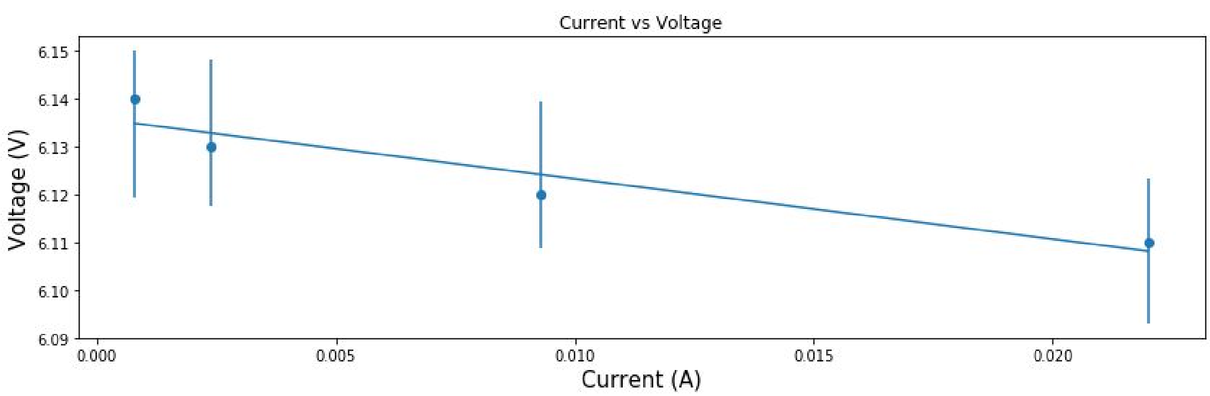


Image Three

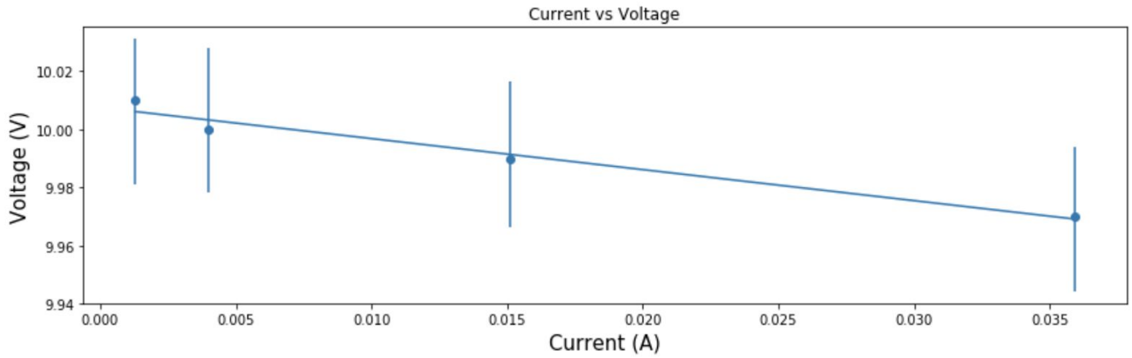


Image Four

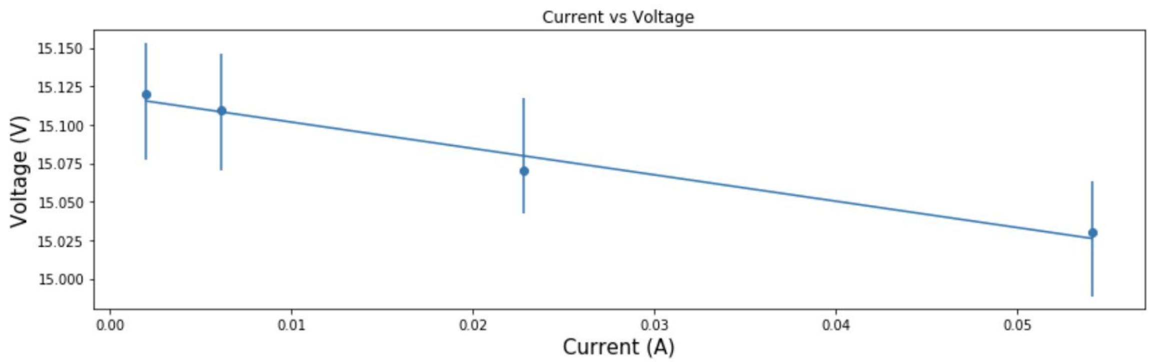


Image Five

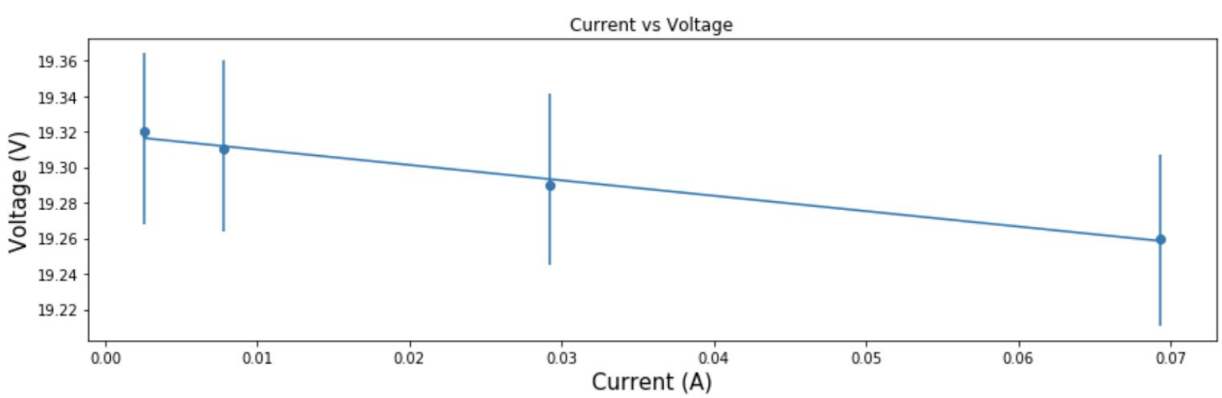


Table Four: Calculations of output resistances.

	Resistance (Ohms)	Error (Ohms)	Reduced Chi Squared of Fit
Battery	0.480	0.915	0.023

Power supply at ~6.13V	1.261	0.915	0.117
Power supply at ~10.1V	1.068	0.916	0.022
Power supply at ~15.1V	1.713	0.918	0.047
Power supply at ~19.3V	0.866	0.918	0.006

Analysis:

The reduced chi squared values for the fits are very small (<1). The reduced chi squared values are a measure of goodness of fit relative to uncertainties, and the small values indicate that the scatter observed in the model is small relative to the uncertainties.

Estimate of R_b: 0.480 Ohms. Corresponding error: 0.915 Ohms. This was calculated using Python curve-fitting methods. The negative slope of the plot corresponding to the battery plot is the resistance.

Estimate of R_{ps}: 1.227 Ohms. Corresponding error: 0.841 Ohms. This was calculated by taking the average of the negative slope of the fits for the data for the power supply. The uncertainty was calculated by taking the square root of the sum of the squares of the uncertainties and dividing by the number of observations (4).

Sources of error could come from the electromagnetic field in the room, as the system is not isolated. The multimeters and wires would also have an additional resistance.

Questions/Answers:

1. Option one (the setup we used) is better for this experiment. This is because when the voltage passes through the voltmeter, in option one there is less resistance (only in the wires) and therefore the voltage is closer to what is coming out of the battery. In option two, the voltage first passes through the ammeter and therefore there is the additional resistance of the ammeter acting on the current before reaching the voltmeter, making the reading less accurate.

2. We used resistors that kept the current within 200 mA but above 20 mA. This way the internal circuitry of the ammeter doesn't change since the multimeter setting that we used did not need to change.

3. The current that is going through the voltmeter is estimable as the uncertainties measured from the ammeter are relatively small. The resistance that is going through the ammeter is not estimable as the uncertainties that were measured (shown in the plots) are too large to make any conclusions.

4. The higher the V_{inf} is the bigger the max current is as well. The output resistance is linear and decreases as the current increases which is to be expected, since the voltage stays the same.

Conclusion:

The goal of this experiment was to investigate the output resistance of a battery and a DC power supply. It is very important to consider the resistance of the devices used in a circuit as it will influence the results when there is a different goal in mind (other experiments). This lab also shows why the way a circuit is setup is also important—a different setup can have an impact on measurements because equipment (namely multimeters in this case) are not ideal in the real world. The resistances of the battery and the DC power supply were both small, but the uncertainties associated with them were high, relative to the measurements/calculations. To improve this lab, and therefore the results, more data can be taken with more precise resistors. That way, the multimeter settings will still not have to be changed, but the uncertainties could be smaller and more conclusions can be made.