PHY224 - Experiment 4

Instruments and Wiring - Terminal Voltage Lab

Jace Alloway 1006940802 Marko Bachvarovski 1006231445

1 Introduction

The purpose of this experiment was to attempt to find the open circuit voltage, denoted V_∞, across two different power sources: one battery and one DC power supply. This open circuit voltage is then used to calculated the terminal voltage of the power source when a load is connected into the circuit, given by $V = V_\infty - IR$, where R is the load resistance and I is the current.

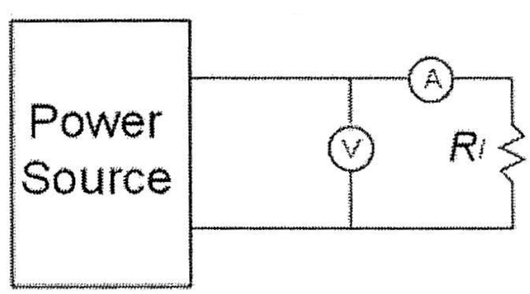
2 Methods

The equipment used was

- Two multimeters
- 5 connecting leads
- 1 "6.5V" battery
- 1 DC power supply
- Circuit board of resistors: 100ohm, 220ohm, 470ohm, 2.7Kohm

Experimental procedure:

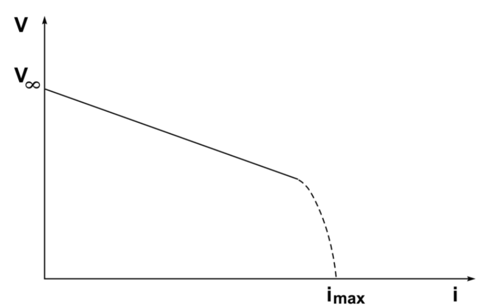
1. The following circuit was created by connecting the 5 connecting leads to the multimeters, power source, and the chosen resistor:



2. The first multimeter (A) was set to 'mA' to measure current, and the second multimeter (V) was set to 'ACV' to measure the alternating current voltage. Each dial was adjusted to show the maximum number of significant digits, and then each dial was untouched.

3. Using 100ohm, 220ohm, 470ohm, and 2700ohm resistors, the current and voltage measured from each multimeter, along with their uncertainties, were recorded. This was completed first for the battery and then the DC power. supply. The uncertainties of the resistors were also found by examining the bands on each resistor: each had gold, which implied that the tolerance was ±5%, which is considered to be the measurement error. These values were added to the data.

4. The data was imported into a **.txt** file and imported into Python to begin an analysis to find the value of the open circuit terminal voltage V_∞. This was done by first plotting the measured values of V vs I, then creating a curve-fit from a model function to create a linear curve-fit of the data. The parameter indicating the $y-$intercept of the curve is the value of V_∞, which was also printed off. This graph was used as a reference:



where the negative of the slope is the output resistance R_b or R_{ps} of the source.

3 Results

3.1 Battery

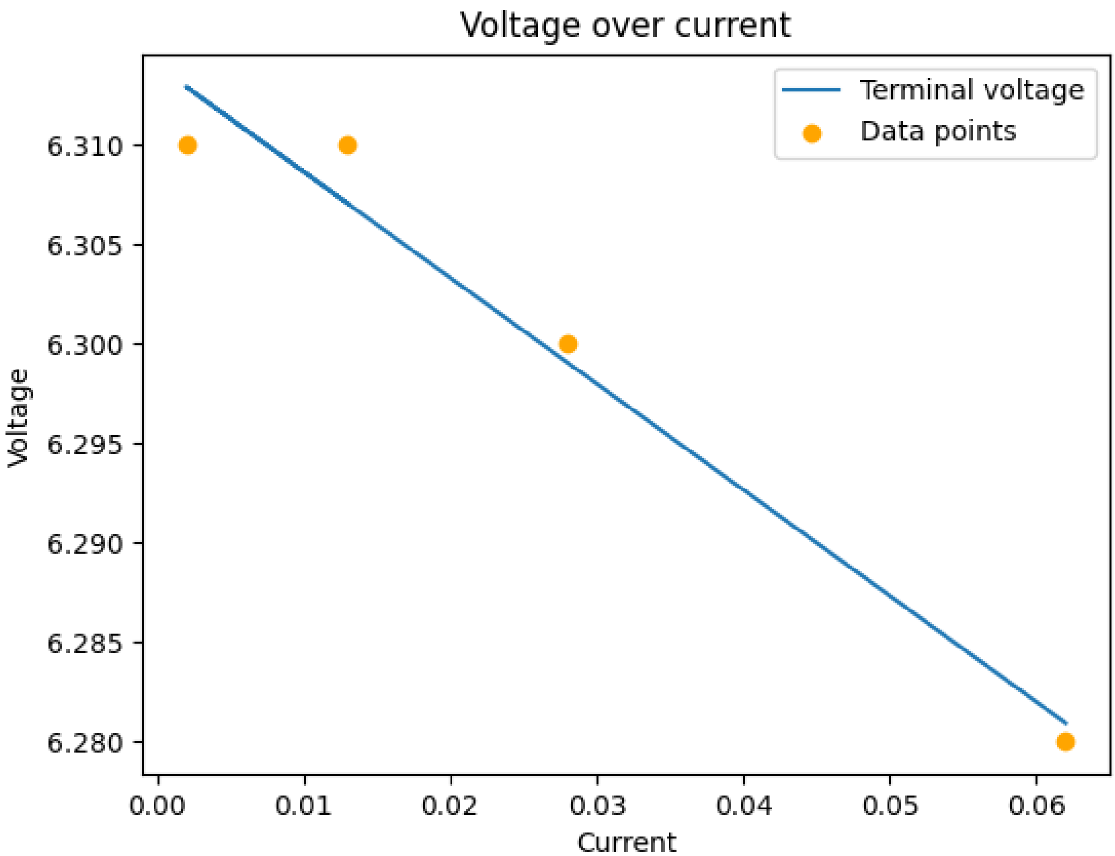
This is the data gathered from the battery:

Table 2: Measurements from the battery

Trial	Voltage (V)	Voltage	Current (I)	Current	Resistor (Ω)
1	6.280	0.005	0.0620	0.0005	100
2	6.300	0.005	0.0280	0.0005	220
3	6.310	0.005	0.0130	0.0005	470
4	6.310	0.005	0.002	0.0005	2700

The data is consistent - the voltage is roughly the same on all trials, while the current decreases as resistance increases. The open circuit voltage was estimated as 6.314 by the curve_fit function, while the internal resistance of the battery was estimated at 0.533 Ohms.

Here is a plot of all the data points and the function of the terminal voltage as calculated using curve_fit:



As you can see, the line drawn with the parameters gathered from curve_fit is a very good model for the line of best fit of the data.

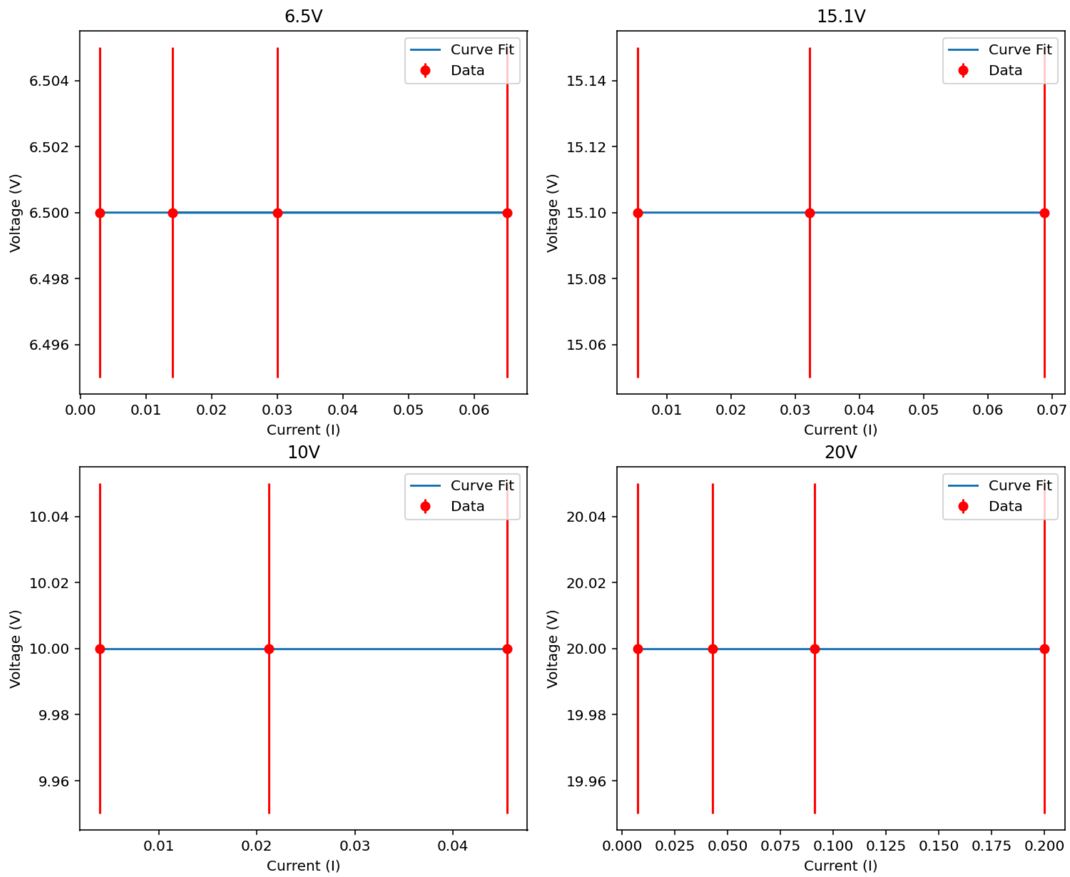
3.2 DC Power Supply

The following table is the table for the 14 trials completed using the DC power supply on different resistors:

Table 2: Measurements from the DC power supply

Trial	Voltage (V)	Voltage Error (± V)	Current (I)	Current Error ($\pm I$)	Resistor (Ω)	Resistor Error (±Ω, 5%)
1	6.500	0.005	0.0140	0.005	470	23.5
2	6.500	0.005	0.0650	0.005	100	5
3	6.500	0.005	0.030	0.005	220	11
4	6.500	0.005	0.0030	0.0005	2700	135
5	10.00	0.05	0.0040	0.0005	2700	135
6	10.00	0.05	0.0212	0.00005	470	23.5
7	10.00	0.05	0.0455	0.00005	220	11
8	15.10	0.05	0.0054	0.00005	2700	135
9	15.10	0.05	0.0322	0.00005	470	23.5
10	15.10	0.05	0.0688	0.00005	220	11
11	20.00	0.05	0.0072	0.00005	2700	135
12	20.00	0.05	0.0427	0.00005	470	23.5
13	20.00	0.05	0.0911	0.00005	220	11
14	20.00	0.05	0.200	0.0005	100	5

The following plots are the measured V vs I plots. The red bars are the uncertainty values for each voltage measurement, and the blue line is the curve fit. The slope of the blue line is the value of R_{ps}, the output resistance of the power supply.



The values of the $y-$intercept V_∞ and R_{ps} were printed:

```
V_infinity for the 6.5V setting is 6.5 V.
V_infinity for the 10V setting is 10.0 V.
V_infinity for the 15.1V setting is 15.1 V.
V_infinity for the 20V setting is 20.0 V.
The output resistance Rps for the 6.5V setting is 0.0 ohms.
The output resistance Rps for the 10V setting is -0.0 ohms.
The output resistance Rps for the 15.1V setting is 0.0 ohms.
The output resistance Rps for the 20V setting is 0.0 ohms.
```

4 Discussion Questions

4.1 Q1

We believe that the better arrangement is Option 2. Given a non-ideal multimeter hence a non-ideal voltmeter, it's impedance is finite, and thus it will draw current when measuring the source emf, therefore it will not properly the emf of the source. With the voltmeter placed after the ammeter, the ammeter will still read the next amount of current being drawn from the source, while if the ammeter was placed after the voltmeter, the amount of current passing though the circuit may be different from the value actually read on the ammeter.

4.2 Q2

We chose resistors with quite a small resistance to be able to compare the values of current and voltage more accurately. There was no advantage to choosing a resistor with a resistance in the thousands, it would've made the comparison more difficult since there would be very little current flowing through it. The 100 Ohm resistor specifically was really easy to work with since the voltage was just a 100 times smaller than the voltage, so it was easy to predict the current - just take the voltage and move the decimal 2 digits to the right and you'd have a pretty good estimate of what the current is. Since we used the 100 Ohm resistor first, it made sense to choose resistors close to it to be able to compare the current flow more accurately.

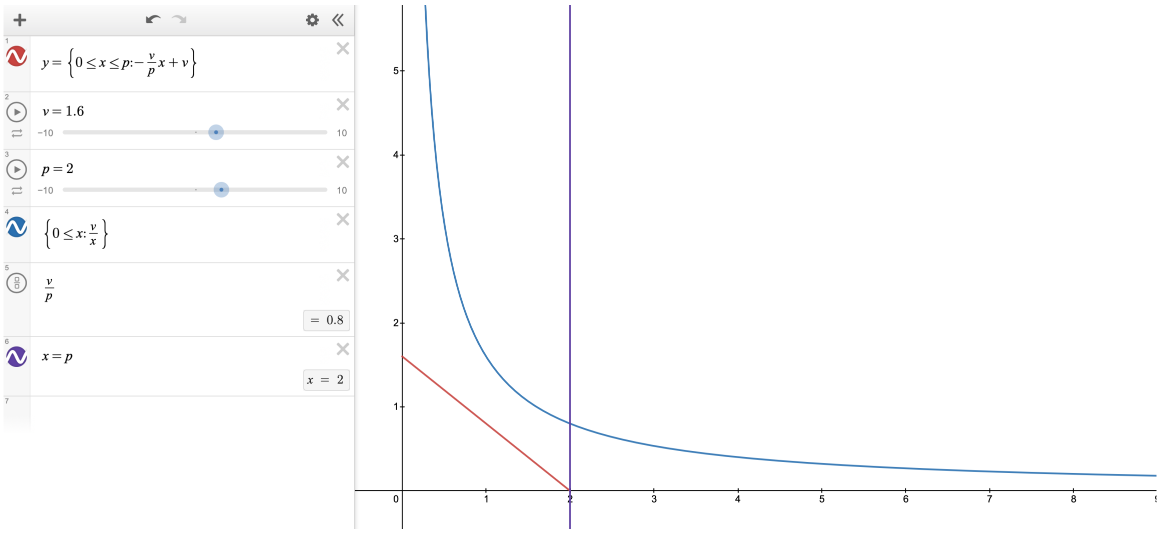
4.3 Q3

To estimate the current flowing out of the battery, we can take the open circuit voltage and the internal resistance of the battery and use Ohm's law to determine the current : $V = IR \Rightarrow 6.314 = (0.533)I \Rightarrow I = 11.8A$.
To estimate the resistance of the ammeter, first we need to know the voltage that goes into the resistor.We'll use the data from trial one for the estimation. There's 0.062A of current flowing into a 100 Ohm resistor. By Ohm's law, that means that there's 6.20 Volts going into the resistor. But there's 6.28V measured in the voltmeter, and in parallel circuits the voltage remains the same across all paths, meaning that there's 6.28V going into the ammeter, but only 6.20V coming out of it and going into the resistor. Using Ohm's law again we get $R = \frac{V_in - V_out}{I} = \frac{6.28V - 6.20V}{0.062A} = 1.29\Omega$. This seems very reasonable for an estimation for the resistance of the ammeter.

4.4 Q4

From examining the data, we believe that as the terminal voltage V_∞ increases, the maximum current I_{max} will also increase. We took this assumption directly from the graph showing that eventually, the voltage will drop off at I_{max} according to the negative slope approaching $V = 0$ as the current I increased. Otherwise, this is very difficult to answer since our values of slope R_{ps} are zero.

Now V_∞ is held constant for a fixed source, which implies that as I_{max} increases, we expect that the output resistance will decrease. Intuitively this makes sense, since the slope of the line relates to the negative of the output resistance. Hence we characterize the output resistance beyond the regulated regime as a negative exponential decay:



Experiment with the demo here: Desmos

5 Conclusion

The experiment was successful in determining the open circuit voltage of different types of power supplies. The concept of internal resistance was also explored as well as using the ammeter and voltmeter in a parallel circuit. Conclusions drawn were that every power supply has a difference of potentials at its terminals called the open source voltage and every power supply has a slight resistance due to no material being ideal to provide no resistance.