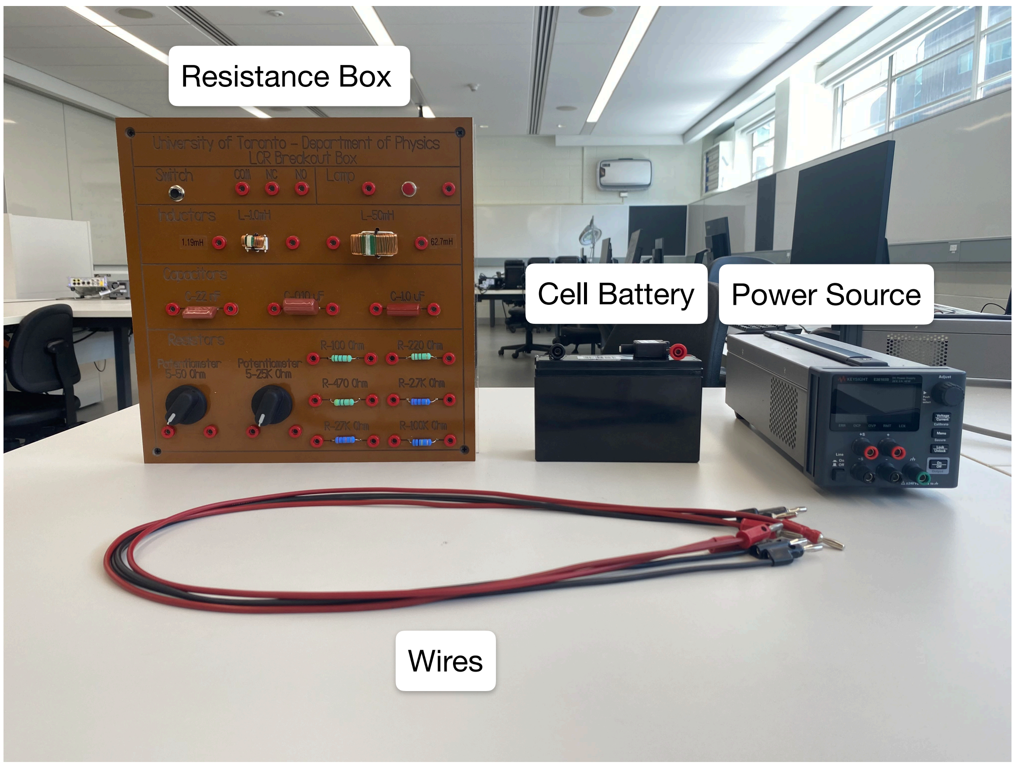
Physics
UNIVERSITY OF TORONTO

The Output Resistance of a Power Supply



Revisions

2022	T. Vahabi, E. Horsley, A. Harlick
2018	R. M. Serbanescu
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Introduction

Any source of electrical energy (generator, battery, etc.) with no load attached produces an electromotive force (emf) or voltage difference across its terminals, called the open-circuit voltage, V_∞. In itself, this number does not completely specify the power supply. In a closed circuit a current I will be drawn from the power supply and the voltage at the terminals, called *the terminal voltage* V will typically fall below V_∞:

$$V = V_\infty - R_{Int} I \tag{1}$$

where R_{Int} is called the output resistance of the power source.

A plot of the terminal voltage V as a function of current I will look like the graph shown in Figure 1:

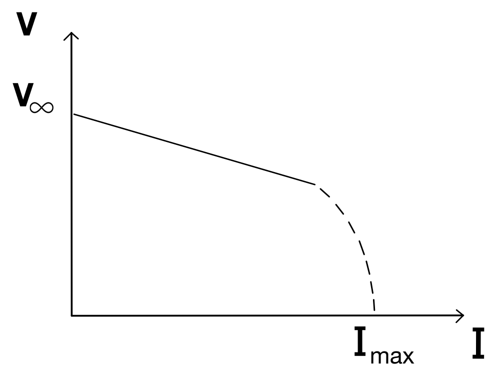


Figure 1: Terminal voltage V_∞ of the power supply as a function of current I drawn from it.

We notice a linear variation of V for small current values, followed by a non-linear behaviour at higher currents. The negative of the slope value is the output resistance of the power supply according to Equation 1.

Figure 2 shows a schematic of a power supply, which according to *Thevenin's Theorem*, is completely represented by the equivalent circuit behind the terminals.

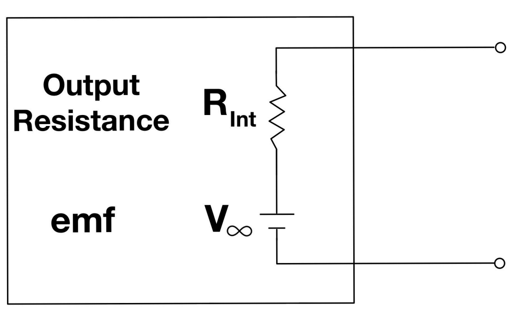


Figure 2: The equivalent circuit of a power supply

The output resistance R_{Int} of a power supply can be determined by observing how the output voltage V varies with current when attaching external resistances R_{Load} to the power source. Current and voltage are measured with appropriate multimeters.

Figures 3 and 4 schematically and realistically show two possible ways of conducting the measurements. Both would be equivalent if the multimeters were ideal (e.g. if no current flows through the voltmeter and if the resistance of the current meter (ammeter) is zero). However, a real multimeter is not ideal, which means the measurements are not exact.

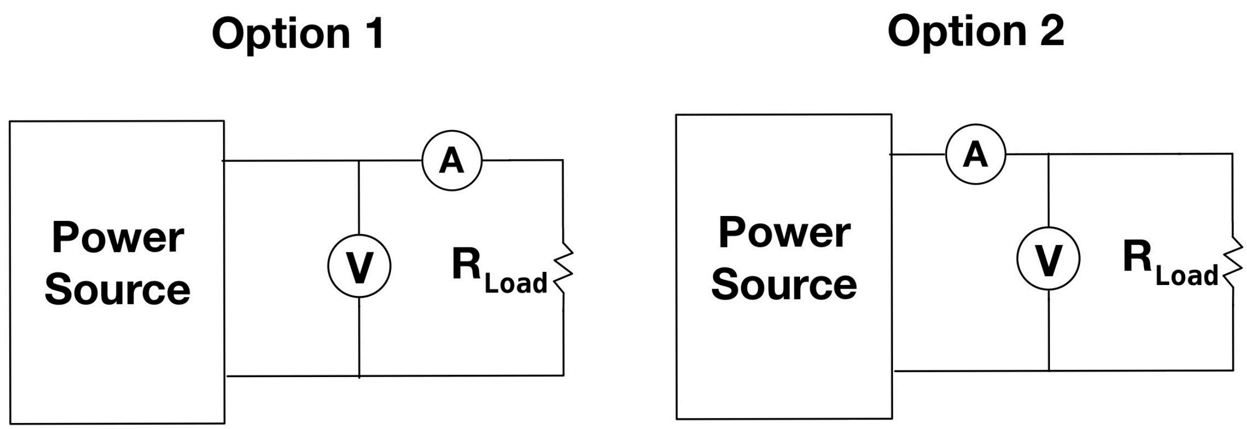
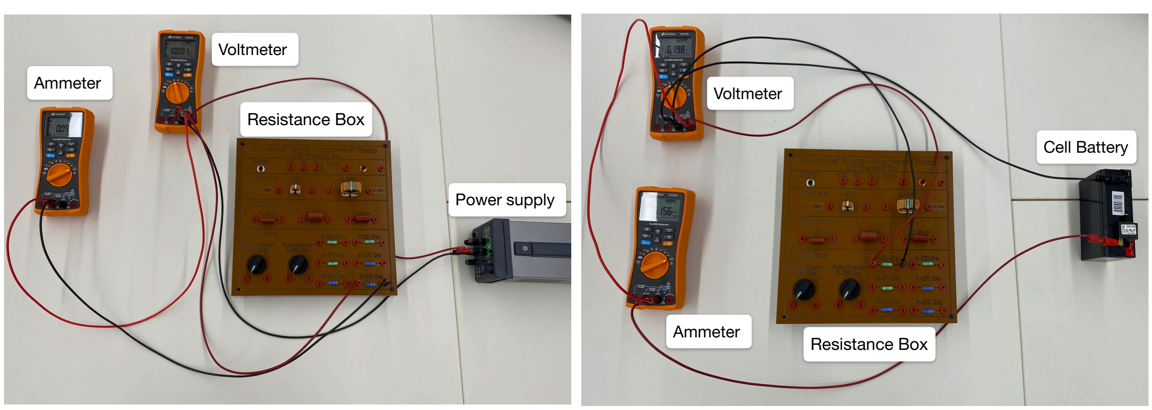


Figure 3: Circuits used to determine the output resistance of a power supply. Notice the different location of the voltage and current meters and consider what assumptions are made for each circuit.



(a) (b)

Figure 4: Visual representation of the circuit arrangement of both options (Option 1 in Figure (a) and Option 2 in Figure (b)) with the actual equipment. Note that two difference power sources (power supply in (a) and cell battery in (b) are shown for reference.)

Note: One arrangement is preferred for a non-ideal multimeter, however neither are perfect. It is recommended that you collect data using both setups and make a decision which one is more suitable for this experiment. You can make the decision based on theoretical considerations, you will need to justify your choice with scientific arguments.

The Experiment

You will use two power supplies: a cell battery and a DC regulated power supply. You will set each to an open circuit voltage of about 6.5 V. Using**at least** four choices of external load resistance R_{Load} from the resistance box provided, take measurements of terminal voltage V and current I.

1. Use the cell battery as power supply. Note that a small R_{Load} means a large current, which drains the battery quickly and leads to the heating up of the resistors. Also remember that you can connect resistors in series to create more data points.
   (a) Plot V vs I and use the data to determine the output resistance of the battery R_{b}.
   (b) Estimate all uncertainties.
2. Use the DC regulated power supply, set to the same value of V_∞ as that of the battery.
   (a) Repeat the experiment and take measurements for two-three other settings of V_∞ (10, 15 and 20 V).
   (b) Plot voltage V as a function of current I, calculate the output resistance of the power supply R_{ps}
   (c) Estimate all uncertainties.

Note: The regulated supply incorporates an active response which effectively makes $R_{\text{ps}} \approx 0$ or even slightly negative as long as the maximum current is not exceeded.

Questions

Q1 Which of the two arrangements would be better, given a non-ideal multimeter? Justify your answer with scientific arguments, rooted in physics, electronics, or based on your measurements.

Q2 Justify your choice of the load resistors R_{Load}.

Q3 Can you estimate the current through the voltmeter? Can you comment on the resistance of the ammeter?

Q4 Use the regulated DC power supply data to estimate how the maximum current I_{max} varies with V_∞. (Hint: this may be done using an appropriate plot) How would you characterize the output resistance beyond the regulation regime?