THE OUTPUT RESISTANCE OF A POWER SUPPLY

Goal: to investigate the properties of power supplies; to review basic electrical measurement techniques.

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_{∞}:

$$V = V_{\infty} - RI \qquad (1)$$

R is called *the output resistance of the power source*.

A plot of the terminal voltage V vs. current I will look like Figure 1:

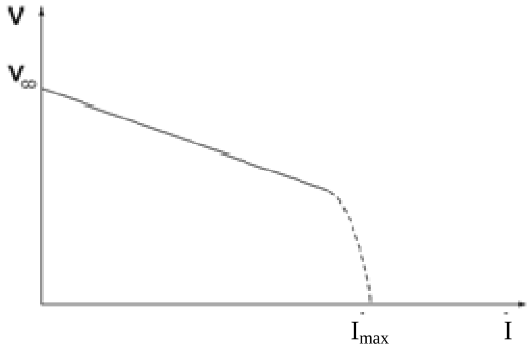

Figure 1. Terminal voltage vs. current

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).
According to Thevenin's theorem, the power supply is completely represented by the equivalent circuit behind the terminals (Figure 2):

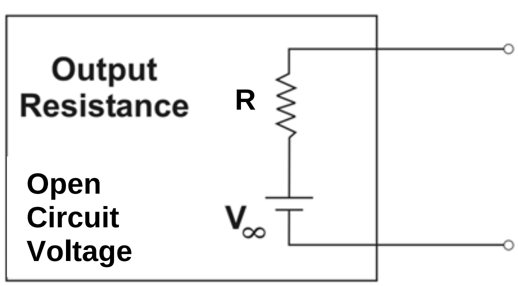

Figure 2. The equivalent circuit of a power supply

The output resistance R of a power supply can be determined by seeing how the output voltage V varies with current when attaching external resistances R_l to the power source and measuring the current and voltage with a multimeter.
Figure 3 schematically shows two possible ways of doing this. 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.

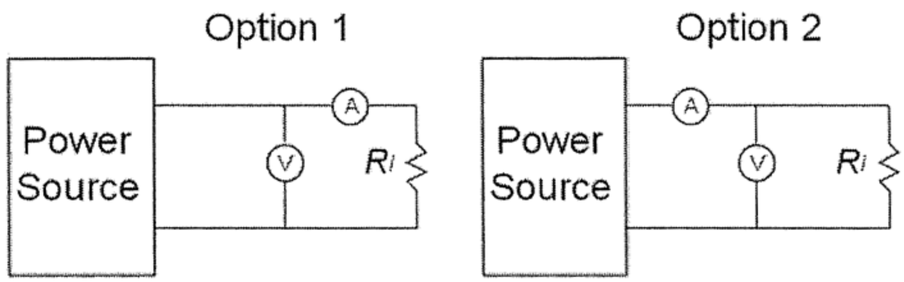

Figure 3. Circuits used to determine the output resistance of a power supply.

➔Q.1. Which of the two arrangements would be better, given a non-ideal multimeter?

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 four choices of external load resistance R_l from the box provided, take measurements of terminal voltage V and current I.

1) Use the cell battery as power supply. Note that a small R_l means a large current, which drains the battery quickly. Plot ***V*** *vs. I*, calculate the output resistance of the battery R_b. Estimate the uncertainties.
2) Use the DC regulated power supply, set to the same value of V_∞ as that of the battery. Repeat measurements for 2-3 other settings of V_∞ (10, 15 and 20 V). Plot ***V*** *vs. I*, calculate the output resistance of the power supply R_{ps}. Estimate the uncertainties.

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

➔Q.2. Justify your choice of resistors R_l.
➔Q.3. Can you estimate the current which flows through the voltmeter? Can you comment on the resistance of the ammeter?
➔Q.4. Use the regulated DC power supply data to estimate how the maximum current I_{max} varies with V_∞. How would you characterize the output resistance beyond the regulation regime?

➔Provide a sketch of your setup (this is more detailed than Figure 3 and should be sufficient for another student to exactly reproduce your measurements).
➔Answer all questions
➔Submit Python plots and calculations, including chi2 and goodness of the fit.

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