KIRCHHOFF'S LAWS and ELECTRIC POWER

Introduction: In part one of this lab, we test Kirchhoff's Loop and Junction Rules. In part two, we discover how to maximize the effective power drawn from a non-ideal battery. Text Reference: Young & Freedman 26.2 (Part 1) and 25.4-5 (Part 2).

Part One: Set up the circuit shown below with a power supply, three resistors, and two decade resistance boxes; use the digital multimeter (DMM) to measure the resistances (which may be slightly different from the nominal values of resistance as given in the figure). Note that this circuit cannot be analyzed by means of simple rules for resistors in series and parallel. Set the output of the power supply at 4.0 V. Use the digital voltmeter (DVM) to measure the potential differences across each of the five resistors; keep track of which side is at higher potential in each case. Test Kirchhoff's Loop Rule for loops $abcd$, $cdef$, and $abcfed$. Next, use the ammeter capability of the DMM to measure the currents through each resistor; keep track of the current direction in each case. Test Kirchoff's Junction Rule for junctions c and d. Report the results of your five tests; be sure to report your agreement or disagreement in a careful scientific manner.
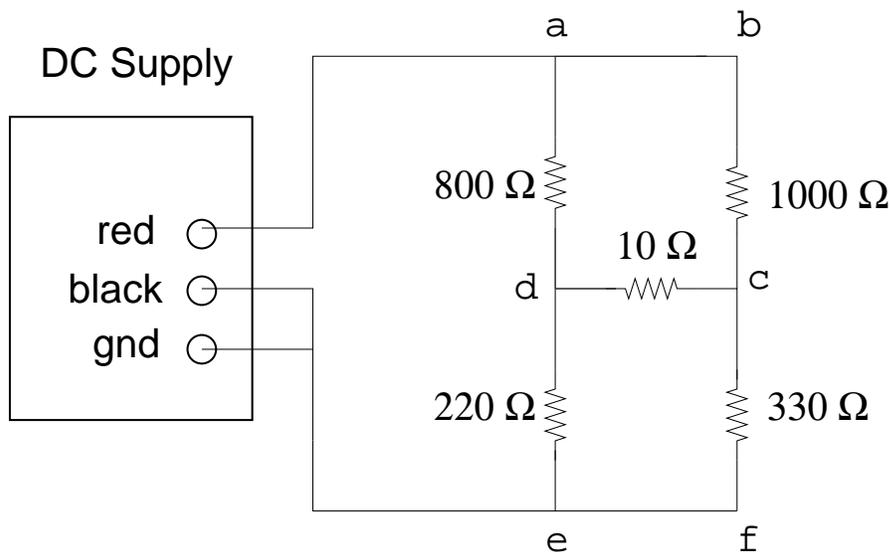

Part Two: Set up the circuit shown on the next page with a power supply and two decade resistance boxes. Set R_0 to 100 Ω and set the output of the power supply to 10.0 V. Use the DMM as your ammeter and the DVM as your voltmeter. The combination of the power supply plus R_0 plays the role of a battery with internal resistance (the internal resistance of the power supply is negligible); therefore, we will use the symbol $\mathcal{E}$ for the power supply voltage. Now vary the load resistance R_L from 10 Ω to 1280 Ω, increasing the resistance by a factor of two each time. For each value of R_L, record the resulting values

of I (from the DMM) and V_{R_L} (from the DVM). Check your measurements by varying R_L from 1280 Ω to 10 Ω, decreasing the resistance by a factor of one-half each time.

We are interested in the power dissipated by R_L, as a function of R_L; you now have the required data to plot such a function (use your measured values of I and V_{R_L} to calculate the dissipated power, as the nominal values of the decade resistance box are not to be trusted). Enter your values in Graphical Analysis (GA) and plot the function of interest; you will increase the accuracy of your plot if you measure the values of R_L with your DMM instead of using the nominal values from the decade box. From your plot, read off the value of R_L for which the dissipated power is a maximum and compare with R_0 (again measure the value of R_0 instead of trusting the decade box setting of 100 Ω).

To explain your result, some calculus is required. Using symbols, write P_{R_L}, the power dissipated in R_L, as a function of R_L (your other symbols are R_0 and the power supply voltage $\mathcal{E}$, both of which are constant) and then take the derivative of this function with respect to R_L and set that derivative equal to zero; solving for R_L will determine the value of R_L for which P_{R_L} has an extreme value, in this case a maximum. Show this work in your analysis.

To quantify the comparison from your plot, use the curve-fitting capability of GA. You have derived a theoretical equation for P_{R_L} as a function of R_L; fit your plot to this theoretical equation, and compare the resulting constants with your measured values of R_0 and $\mathcal{E}$ (again, measure $\mathcal{E}$ with the DVM instead of trusting the power-supply meter). Report these comparisons in your conclusions.
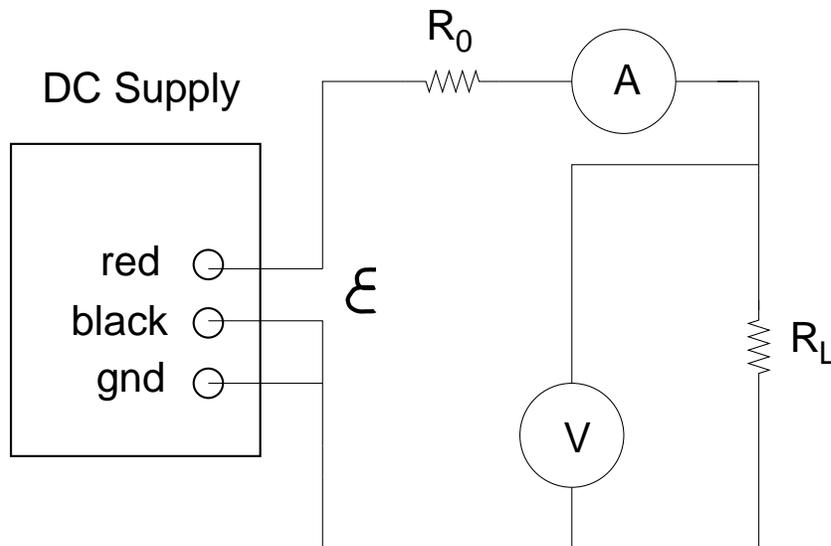
Name

Section Time and Day

1. A 6.0 V flashlight battery has an internal resistance of 1.0 Ω when new, and 10.0 Ω when old. (Imagine this as a resistor in series with the battery mounted INSIDE the battery itself, which describes the chemical degradation of the battery with age). Calculate the voltage across a 10.0 Ω lamp (the load) and the current through the lamp when the battery is new and when it is old. Does this explain why battery lamps go dim?

2. For the circuit in Part Two of this lab, algebraically find P_{R_L}, the power dissipated by R_L, as a function of R_L; consider R_0 and $\mathcal{E}$ to be constants. Then, working in GA, calculate $P_{R_L} = I*V_{R_L}$ from the table below, and plot P_{R_L} versus R_L. Fit this plot to your algebraic equation for P_{R_L} as a function of R_L, and in doing so determine the parameters R_0 and $\mathcal{E}$. State the best-fit values for both R_0 and $\mathcal{E}$.

R_L	I	V_{R_L}
Ω	mA	volts
2	22.32	0.04
4	21.93	0.09
6	21.19	0.17
16	19.84	0.32
32	17.61	0.56
64	14.37	0.92
128	10.50	1.34
256	6.83	1.75
512	4.02	2.06
1024	2.20	2.26