EE 220/220L Circuits I (Fall 2019)
Laboratory 2 Using the Digital Multimeter and Ohm's Law and Laboratory 3 Voltage and Current Division

<u>Background</u>

Digital multimeters (DMMs) measure three main electrical quantities: current, resistance, & voltage. Many DMMs also measure other quantities. Each measurement requires special consideration.

a) **Resistance** is measured with the DMM (functioning as an *ohmmeter*) connected in **<u>parallel</u>** with the circuit element(s). Before measuring resistance, **de-energize** the circuit (i.e., turn-off any voltage or current sources) and **isolate** (disconnect from rest of circuit) the circuit element(s) being measured! The symbol for an ohmmeter is a circle with an "Ω" inside. Resistance does not have a polarity or direction, i.e., DMM **red** & **black** test leads may be connected either way.

b) **Voltage** is measured with the DMM (functioning as a *voltmeter*) connected in **<u>parallel</u>** with the circuit element(s), i.e., same voltage **<u>across</u>** it. The symbol for a voltmeter is a circle with a "*V*" inside. On the DMM, the **red** test lead/terminal is connected to the assumed "+" polarity and the **black** is connected to the assumed "-" polarity to get a measurement with the correct sign.

c) **Current** is measured with the DMM (functioning as an *ammeter*) connected in **<u>series</u>** with the circuit element, component, or branch, so it has the same current flowing **<u>through</u>** it. Note, the symbol for an ammeter is a circle with an "*A*" inside. On the DMM, the current should <u>enter</u> through the **red** test lead/terminal (exits **black** lead) to get a measurement with the correct sign.

Warning! As an ammeter, DMMs have very low input resistances. Connecting it in parallel is like introducing a short circuit into the larger circuit, resulting in large current flows & a blown ammeter fuse. Set DC power supply current limit to **1.5 A** (i.e., 50% of max).

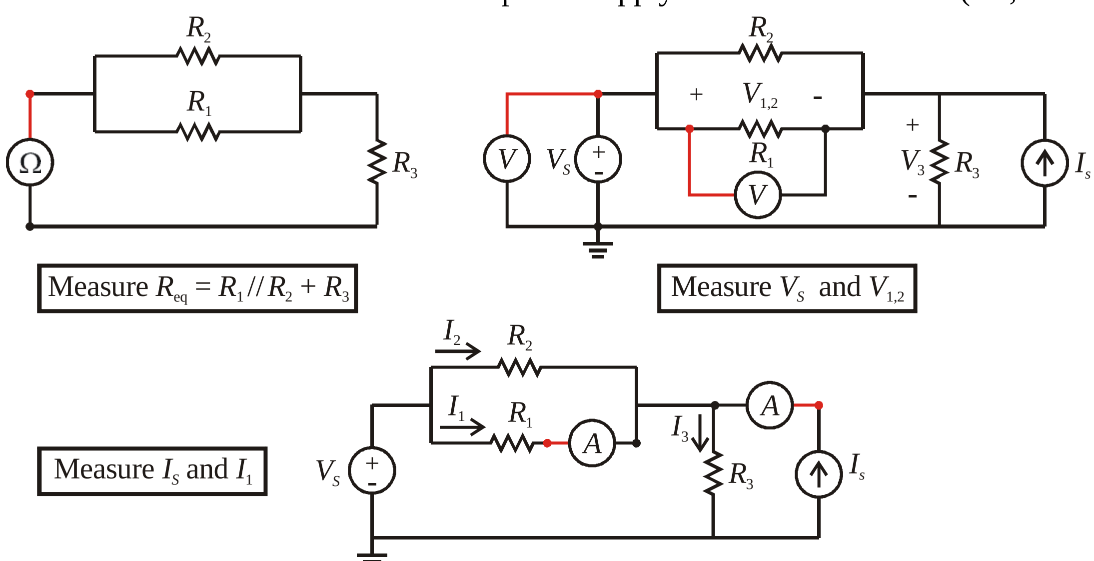

Figure 1 DMM measurement connection examples (This is **<u>NOT</u>** the circuit used in lab.)

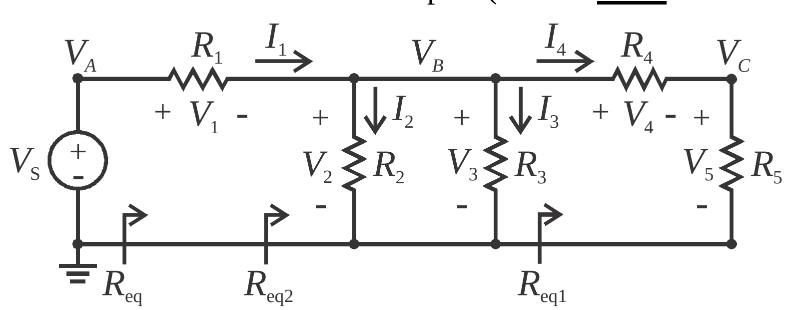

Figure 2 Experimental test circuit

Preliminary

For the test circuit shown in Figure 2, let V_s = 12 V, R_1 = 1 kΩ, R_2 = 3.3 kΩ, R_3 = 2.2 kΩ, R_4 = 1 kΩ, and R_5 = 1.5 kΩ.

1) Given that the resistors in the laboratory are rated for 2 W of power and ±10 % tolerance, what are the color bands for the resistors? Put answers in a table. Refer to course web page or internet for references on resistor color bands. Note: use the **four band code**- 1^{st}, 2^{nd}, multiplier, & tolerance [e.g., 250 Ω ± 5% resistor has Red (2) – Green (5) – Brown (x10) – Gold (±5%) bands].
2) Sketch the **portion** of the circuit (label all components in circuit sketches) showing the DMM connections (use symbol for an ohmmeter) to measure the equivalent resistance R_{eq2}.
3) Sketch the circuit showing the DMM connections (use symbol for a voltmeter) to measure the voltage V_S. Then, sketch **another** circuit showing DMM connections to measure the voltage V_5. Label the leads/terminals on the DMM, i.e., red "+" and black "-".
4) Draw the circuit showing the DMM connections to measure the current I_1. Then, sketch **another** circuit showing DMM connections to measure I_4. Label the terminals on the DMM (use symbol for an ammeter) to indicate where the current enters and leaves, i.e., enters red and exits black.
5) Use parallel/series resistance rules & Ohm's Law to find resistances R_{eq1}, R_{eq2}, & R_{eq}, and current I_1.
6) Use current division to find currents I_2, I_3, and I_4.
7) Use voltage division to find voltages V_1, V_2, V_3, V_4, and V_5. Also, find the node voltages V_A, V_B, and V_C using KVL (do NOT use Nodal Analysis).
8) Last, calculate the power **absorbed** by each circuit element (including source).
9) Have lab instructor/TAs initial your preliminary work before starting the experimental work.

Experimental (NO groups of more than 2)

1) Your lab instructor will explain the use of the DMM & DC power supply. Take notes in logbook.
2) Select resistors with values to match those given. Using a DMM, measure and record the resistance of R_1, R_2, R_3, R_4, & R_5. Then, starting at the right of the circuit shown in Figure 2, connect the resistors and measure & record R_{eq1} (R_4 & R_5 connected in series), R_{eq2} (parallel combination of R_2, R_3, & R_{eq1}), and the overall equivalent resistance R_{eq} seen by the voltage source.
3) Add a DC power supply to complete the circuit shown in Figure 2.
4) Using a DMM as a voltmeter, adjust DC power supply to specified V_s (record). Measure voltages V_1, V_2, V_3, V_4, & V_5 as well as node voltages V_A, V_B, & V_C. Record data in logbook.
5) Using a DMM as an ammeter, measure currents I_1, I_2, I_3, and I_4. You must disconnect wire(s) & insert ammeter in **series** to measure current. Be sure to **de-energize** the circuit when making and/or changing connections. Do **NOT** connect an ammeter in parallel! Record data in logbook.
6) Have the lab instructor or TA initial your experimental work. Then, disconnect circuit.

Analysis and Conclusions:

1) In **four** tables, tabulate the calculated/nominal & measured values for all <u>resistances</u>, <u>currents</u>, <u>voltages</u>, & <u>powers</u> as well as the % difference. Format: col. 1 list variable/quantity names, col. 2 list calculated/nominal values, col. 3 list measured values, and col. 4 list percent differences. Note: % difference = | measured - calculated/nominal | / | calculated/nominal | *100%.
2) Do the measured voltages, currents, and resistances follow Ohm's Law? <u>Tabulate</u> your check. Format: Col. 1 list voltages V_1 - V_5, Col. 2 measured voltages V_1 - V_5, col. 3 V_1 - V_5 calculated by Ohm's Law, e.g., $I_{x,\text{meas}} R_{x,\text{meas}}$ = (1.1 A)(5 Ω) = 5.5 V, and col. 4 list percent differences.
3) Discuss and make comparisons between expected and measured results.