Multi-Meter Measurements

1. Pick 6 resistors with different color codes. If your resistors have 5 bands, consider only the first four bands. Measure their values with your DMM. Compare their stated values and tolerances (color code) with your measured multimeter results.

WORK SHEET HERE: $\frac{\text{MEASURED-MARKED}}{\text{MARKED}}(100\%)$

Resistor #	Marked	DMM Measured	% Deviation from Marked
R_1	3300, 5% tolerance	3230	2.12
R_2	1000, 5% tolerance	990	1
R_3	6800, 5% tolerance	6700	1.47
R_4	100, 2% tolerance	100.4	0.4
R_5	47 000, 10% tolerance	50400	7.2
R_6	15 000, 5% tolerance	14800	1.3

Is the % Deviation greater or less than the indicated tolerance?

ANSWER HERE:

The % Deviation is always less than the indicated tolerance.

2. If you look at a standard list of 20% resistors available, you will see 1000 ohms and 1500 ohms but not 1200 ohms. Why? If you look at 5% resistors, would the results be different? Why? [A listing of resistor values can be found on the wall of the laboratory.] Hint: Think about what tolerance means and how it differs from measurement error.

ANSWER HERE:

1200 is within the 20% deviation of the 1000 Ohm resistor and the 1500 Ohm resistor, making a standalone 1200 Ohm resistor unnecessary. With 5% resistors, the range of resistance values would look like this: 950-1050, 1425 - 1575. Since 1200 is now excluded from the deviation range, 1200 should be its own resistor.

3. Pick two resistors that are approximately two orders of magnitude different, i.e. 1,000 Ω and 100,000 Ω, or 22 Ω and 2,200 (See Figures 1-2, 1-3, and 1-4.)
   a. Measure them carefully. Note their actual values rather than the color code indicated value.

WORK SHEET HERE:

R_1 Color Code Value: 100 000 Ohms R_1 Measured Value: 99, 000 Ohms

R_2 Color Code Value: 1000 Ohms R_2 Measured Value: 990 Ohms

b. Measure them in series and parallel connections.

WORK SHEET HERE:

R_{Series} Value: 100 000 Ohms $R_{Parallel}$ Value: 981 Ohms

c. Compare your measurements with the calculated values. Your calculated values should be calculated using the individually measured values from part a. Note: in series, the larger value dominates the measurement.

WORK SHEET HERE:

R Series Resistance Calculated: 99, 990 Measured: 100000 % difference 0.01

R Parallel Resistance Calculated: 980.2 Measured: 981 % difference 0.082

d. In the parallel connection, which resistor dominates and why?

e. In the series connection, which resistor dominates and why?

ANSWERS HERE:

d. The 990 Ohm resistor, because it offers the path of least resistance so most of the current flows through it, and so the DMM registers a resistance that is very close to 990.
e. The 99 000 Ohm resistor, because it accounts for a vast majority of the resistance that the current encounters and thus the DMM registers.

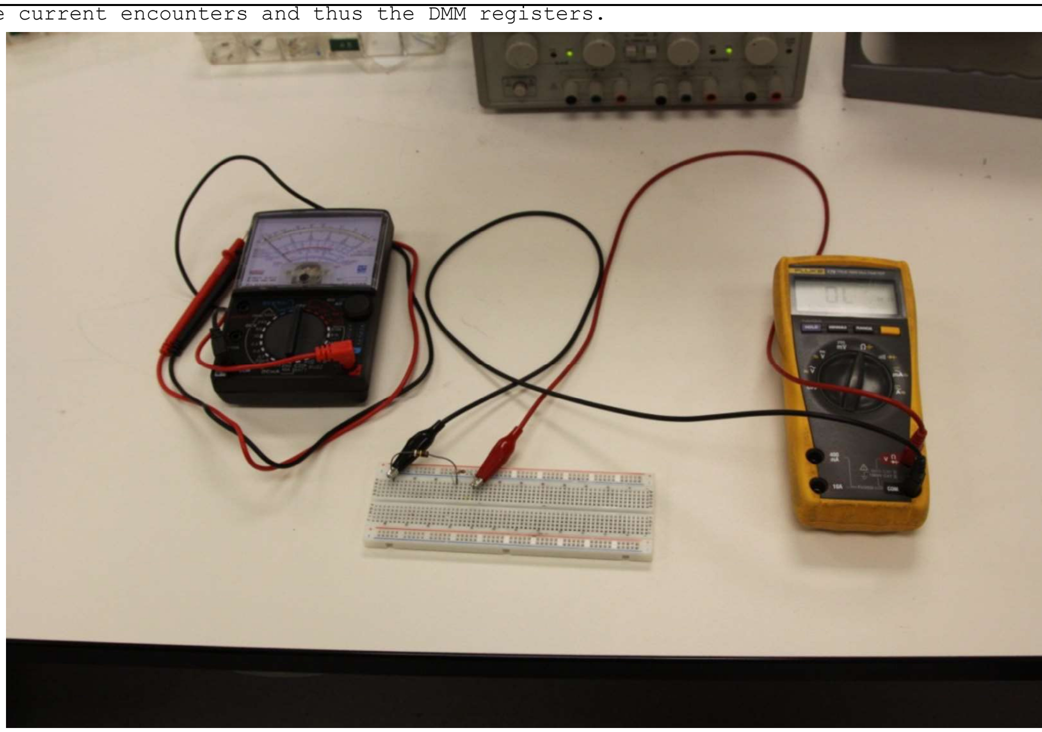


FIGURE 1-1. MULTIMETERS CONNECTED
TO RESISTOR ON PROTO-BOARD
[Left side: Analog Multimeter Right side: Digital Multimeter]

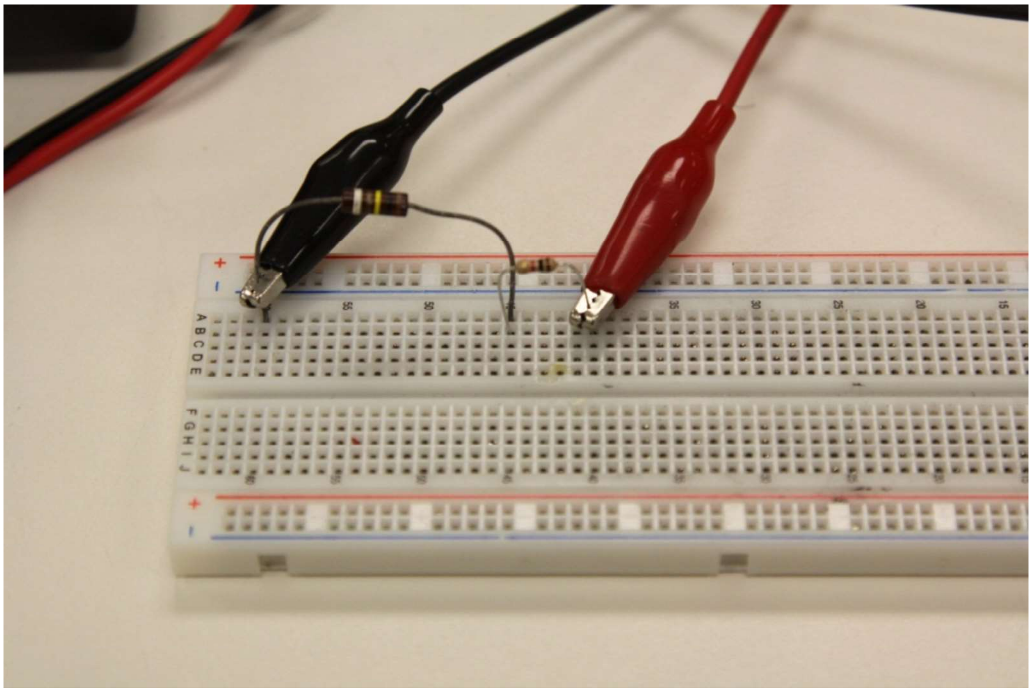


FIGURE 1-2. RESISTORS CONNECTED IN SERIES ON PROTO-BOARD

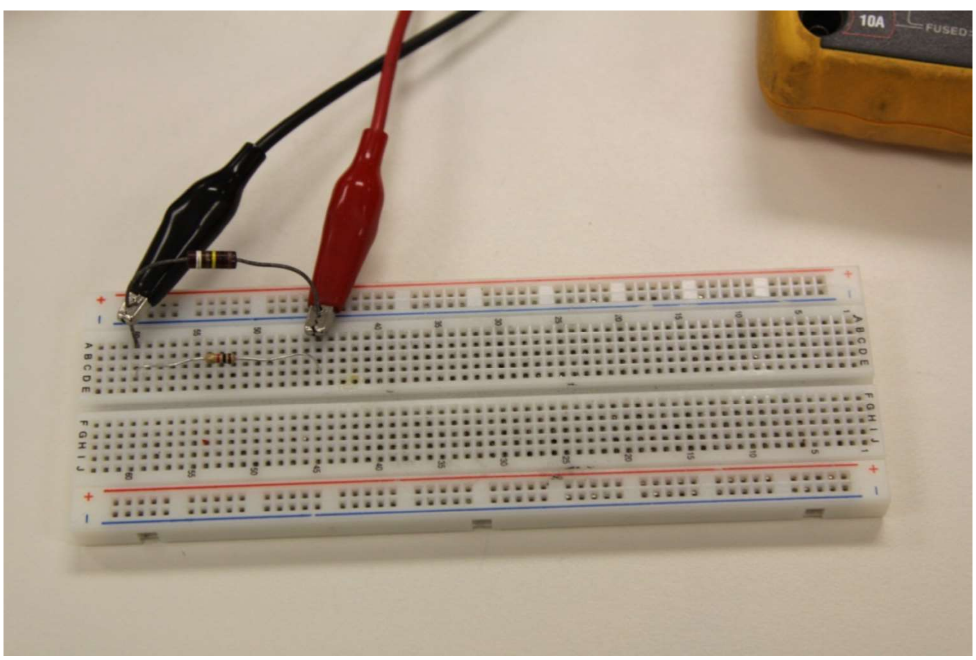
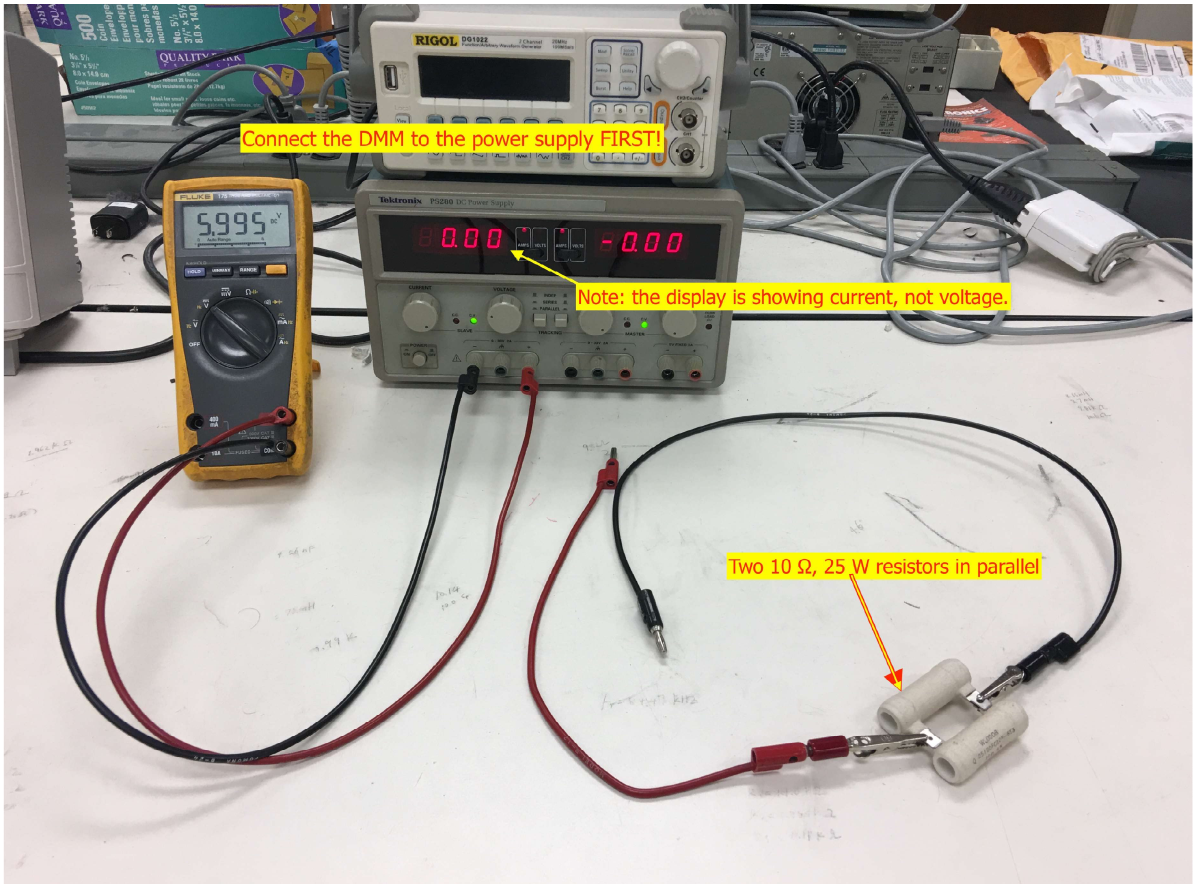


FIGURE 1-3. RESISTORS CONNECTED IN PARALLEL ON PROTOBOARD

Source Measurements

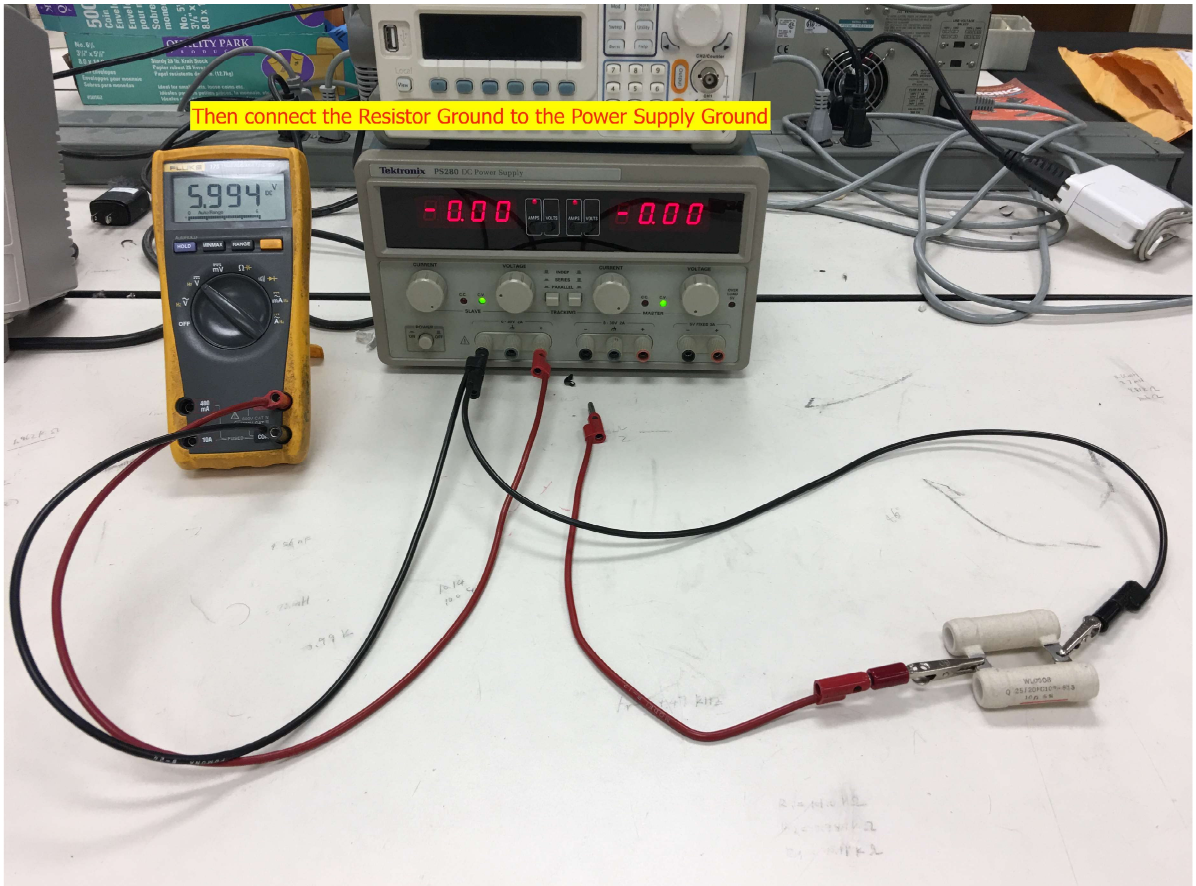
The Tektronix dual power supply you will be using can operate as a near ideal voltage source or a near ideal current source. When the green light is on (CV) it is a Controlled-Voltage source, and when the red light is on (CC) it is a Controlled-Current source.

To test the voltage source, refer to the following figures:

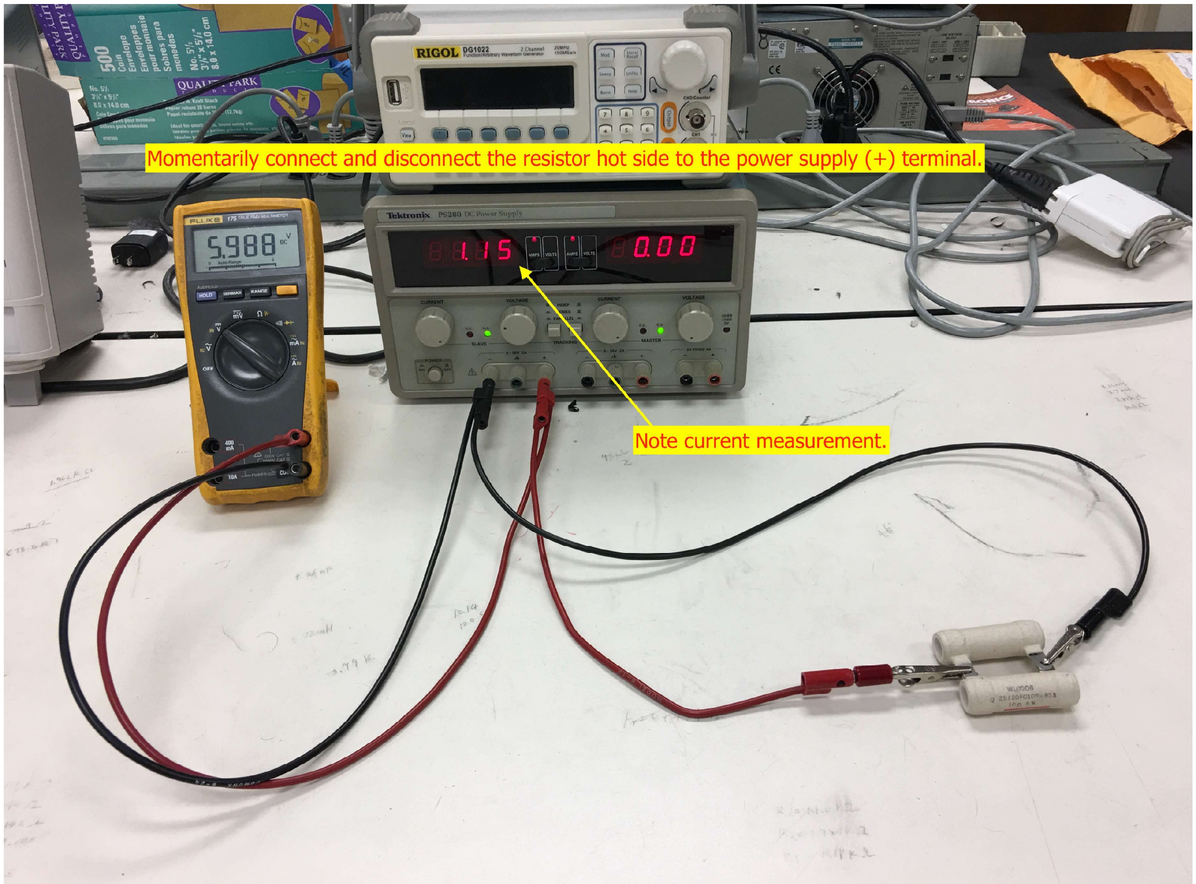


1. Set the DMM to read DC volts.
2. Using the left side of the power supply front panel, connect the positive terminal of the DMM to the positive terminal of the power supply. Do the same for the negative terminal.
3. Slide the switch on the power supply front panel to the left to display current.
4. Turn the current limit to full right (clockwise).
5. Set the output to ~6 volts as indicated on the DMM.
6. Be sure that the DMM display shows <u>three numerals to the right</u> of the decimal point.
7. Set up the 5 Ω resistor by connecting two 10 Ω resistors in parallel as shown in the above picture.

By observing the following picture, connect the 5 Ω resistor ground (black lead) to the power supply ground. Leave the resistor hot side (red lead) disconnected.

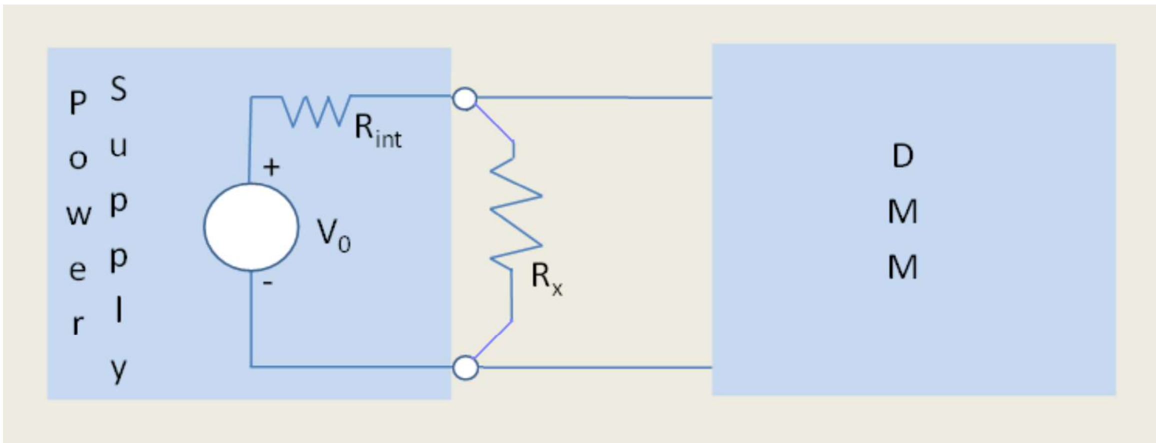


Now, by observing the following picture, momentarily connect and disconnect the resistor hot side (red lead) to the power supply (+) terminal. Note: the resistor will dissipate energy and could get quite HOT!! Take care not to burn yourself. Record the DMM readings in the worksheet below when connected and when disconnected. The difference between the two readings should be a few millivolts.



Measuring Internal Resistance of a Power Supply

Observe carefully the small change in the output voltage that occurs when the 5 Ω resistor (Rx) is connected as shown below. From the change in this voltage, calculate the internal resistance of the voltage source. The circuit equivalent to the above pictures is:



(The DMM input resistance is extremely large compared to R_x !)

<u>WORK SHEET HERE:</u>

Unloaded voltage (i.e. without 5 Ω resistor): 6.011 Volts

Loaded voltage (with 5 Ω resistor): 6.008 Volts

Voltage shift: 0.003 Volts

Calculate internal resistance: (Hint: The voltage divider equation will be useful here)

```
I = V/R = 6.008/5 = 1.202 Amps

V(shift) = IR(int)
R(int) = V(shift)/I
       = 0.003 V/ 1.202 A
       = 0.002 Ohms
```

Unloaded and Loaded Voltage Dividers

We will investigate the effect that loading has on a voltage divider circuit. Loading, as you recall from lecture, is the demand for current from a voltage source. That demanded current has an effect on the performance of the circuit. We will be measuring the amount of that performance change.

You will need the following components:

1 KΩ resistors (2)

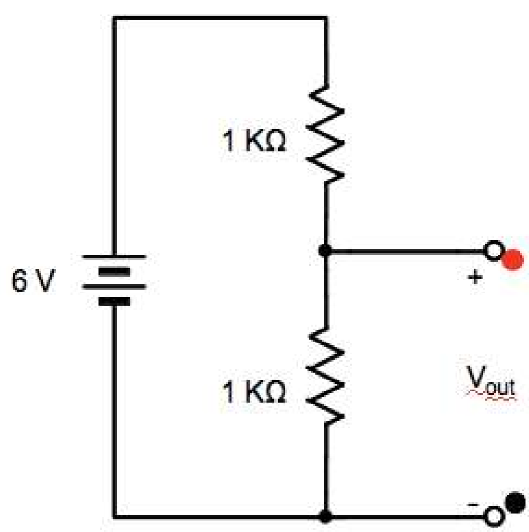
3.3 KΩ resistor

Breadboard

DMM

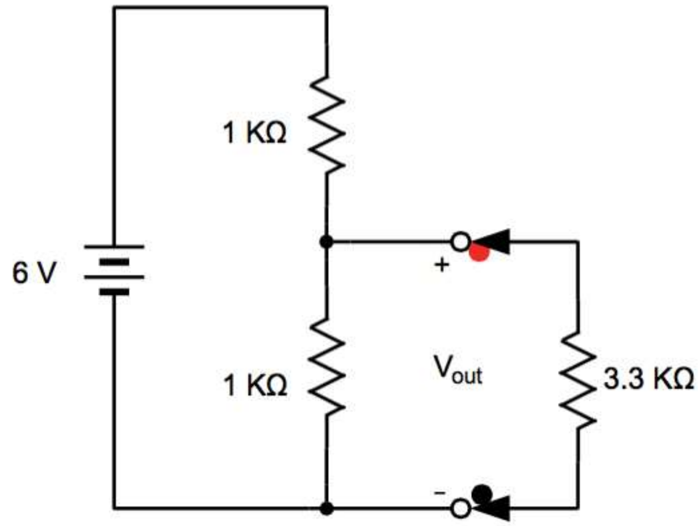
Tektronix DC Power Supply

1. Construct the voltage divider circuit as shown below. This is an <u>unloaded</u> voltage divider.



2. Measure V_{out} at the red and black dots. Record the value here __3.003 V__ .

3. Now load the circuit by attaching the 3.3 KΩ load resistor across the lower 1 KΩ resistor, as shown below. The 3.3 KΩ resistor is now demanding current from the voltage divider.



4. Measure the new V_{out} as in Step 2. Record the value here: 2.606 V
5. Fill out the following table:

	UNLOADED VOLTAGE DIVIDER	LOADED VOLTAGE DIVIDER
V_{out} (measurement)	3.003 V	2.606 V
$V_{upper1K}$ (calculation)	2.997 V	3.396 V
I_{total} (calculation)	0.003 A	0.0033 A

How does the increase in total current affect the output voltage of the loaded voltage divider circuit?

The increase in total current actually reduces the output voltage of the loaded voltage divider circuit.

Validation of Kirchhoff's Laws

In this lab, we will be showing that Kirchhoff's Laws are actually true with the Digital Multimeter (DMM).

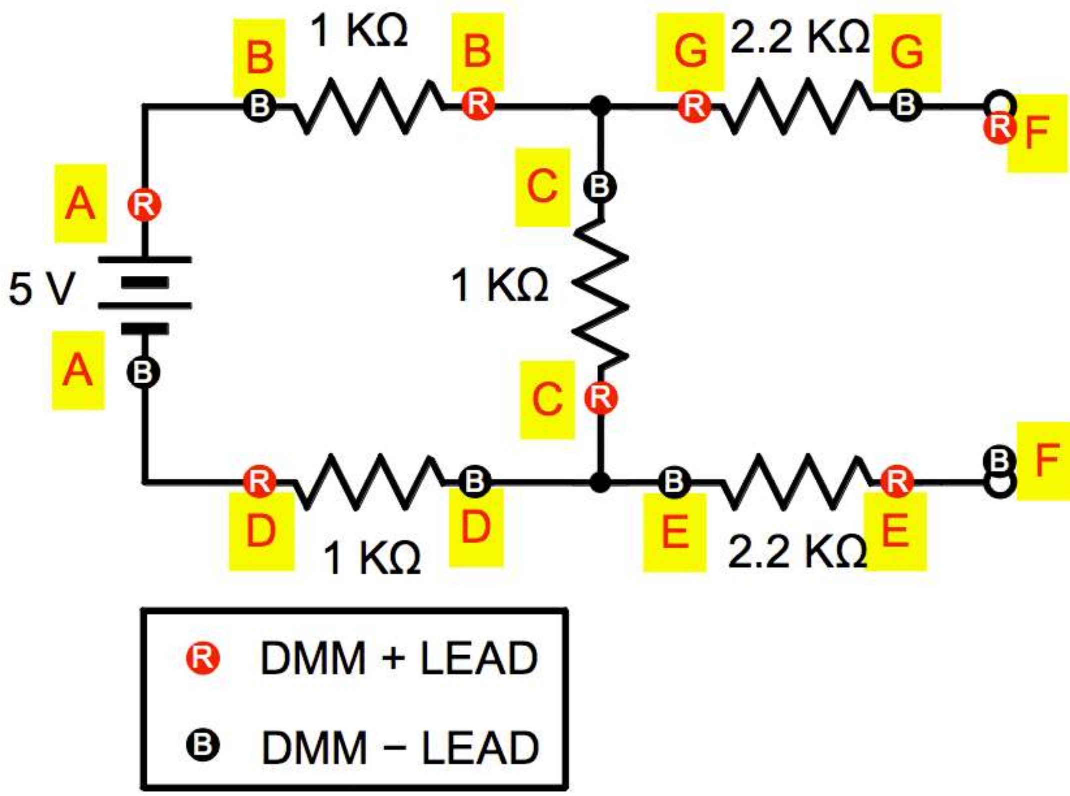
In addition to a DMM and the power supply, you will need the following components:

1 KΩ resistors (3)

2.2 KΩ resistors (2)

Breadboard

1. Construct the following circuit using the power supply, breadboard, and resistors:



2. Using the DMM, and following the polarities indicated, take DC voltage measurements A through G. Fill in the blanks on the next page.

MEASUREMENT	VALUE
A	5.00
B	-1.67
C	-1.67
D	-1.67
E	0
F	1.67
G	0

3. Add measurements A through D. Put your answer here: -0.01 V

4. Add measurements C, E, F, and G. Put your answer here: 0 V

5. Now, use a jumper wire to connect the two open circles (at Measurement F).

6. Repeat measurements A-G.

MEASUREMENT	VALUE
A	5.00
B	-1.78
C	-1.45
D	-1.78
E	0.72
F	0
G	0.72

7. Using Ohm's Law, calculate the ABSOLUTE VALUE of the current through resistors B, C, and G (answers in "CURRENT" column in the table below). Also, using the Passive Sign Convention, determine whether the current through each resistor is entering or leaving the B-C-G node connecting the three resistors ("CHOOSE ONE" column).

RESISTOR	CURRENT	CHOOSE ONE	
B	1.78 mA	☐ LEAVE	☒ ENTER
C	1.45 mA	☒ LEAVE	☐ ENTER
G	0.33 mA	☒ LEAVE	☐ ENTER

8. Using [a] the Passive Sign Convention rule** (see footnote) and [b] the NVA convention that currents leaving the node are positive, attach the + or – sign to the currents and **add them up to see if KCL holds**. NVA rule: currents leaving the node are marked +; currents entering the node are marked −.

9. Put your sum here: 0 Amps

Discuss your answers to Steps 3, 4, and 9. In particular, did you validate Kirchhoff's Laws?

Yes, we did validate Kirchoff's Laws. We observed that a closed loop will have a net voltage change of 0 Volts (or close to 0, there is room for measurement error here), and that the current entering and exiting at a node should sum up to 0 Amps.

Week 1 Lab End

** The Passive Sign Convention says, among other things, that the positive end of a resistor is where the current always enters. Conversely, the negative end of a resistor is where the current always leaves.