

18-100: Intro to Electrical and Computer Engineering

LAB01: Circuits Lab

Writeup Due: Thursday, September 8th, 2022 at 10 PM

Name:

Bing Bhakdibhumi

Andrew ID:

barameeb

How to submit labs:

Download from this file from *Canvas* and edit it with whatever PDF editor you're most comfortable with. Some recommendations from other students and courses that use Gradescope include:

pdfescape.com

A web-based PDF editor that works on most, if not all, devices.

Preview

Pre-installed default MacOS PDF Editor.

iAnnotate

A cross-platform editor for mobile devices (iOS/Android).

*If you have difficulties inserting your image into the PDF, simply append them as an extra page to the END of your lab packet and mark the given box. **Do NOT insert between pages.***

If you'd prefer not to edit a PDF, you can print the document, write your answers in neatly and scan it as a PDF. (*Note: We do not recommend this as unreadable lab reports will not be graded!*). Once you've completed the lab, upload and submit it to *Gradescope*.

Note that while you may work with other students on completing the lab, this writeup is to be completed alone. Do not exchange or copy measurements, plots, code, calculations, or answer in the lab writeup.

Your lab grade will consist of two components:

1. Answers to all lab questions in your lab handout. The questions consist of measurements taken during the lab activities, calculations on those measurements and questions on the lab material.
2. A demonstration of your working lab circuits and conceptual understanding of the material. These demos are scheduled on an individual basis with your group TA.

Question:	1	2	3	4	Total
Points:	3	7	8	12	30
Score:					

Lab Outline

The purpose of this lab is to help students become familiar with the lab equipment and measurements (specifically, the breadboard, multimeter and power supply) as well as give a practical understanding of Ohm's Law and LEDs in circuits (both skills that will be heavily used/tested in future labs).

1. Introduction
2. Ohm's Law and Resistor Fundamentals
3. Resistor Networks and Sensors
4. LED Circuits

Equipment Required

- Breadboard
- Breadboard Power Supply
- 9 Volt battery
- Digital Multimeter w/ Probes
- Wire Strippers
- Diagonal Cutters
- Needle-nose Pliers

Bill of Materials

1x  47Ω Resistor
3x  100Ω Resistors
2x  470Ω Resistors
4x  1kΩ Resistor
2x  4.7kΩ Resistor

5x Red LEDs
1x Light-dependent resistor (CdS cell, Box 2)
Jumper Wire

Introduction

Welcome to 18-100 labs! These assignments are meant to be the hands-on component to material covered in lecture. The labs are also a great opportunity to get familiar with some of the equipment you will use in future lab course and through your entire career as an electrical and/or computer engineer!

Each lab will come with a handout (a.k.a. what you're reading right now!) that contains the exercises that you are to complete each week. You will be asked to generate data from each experiment and draw conclusions from it. **Make sure to thoroughly read the handout before attempting the lab!**

Following the completion of the lab, you will submit a writeup to **Gradescope** (instructions are on the cover of every lab) and then complete a demonstration to a TA. These demonstrations consist of explaining your completed circuit and then answering a few high-level conceptual questions on the lab material. These questions are *not* meant to trick you and, if you completed the lab, you should not have to “study” for them. The circuits you will be asked to demo will be clearly marked in the lab packet with a message that looks similar to this:

⚠ Do NOT take your circuit apart yet! You will need it for lab checkoff!

These labs, writeups, and demonstrations are meant to be completed on your own. We want you to collaborate and discuss the labs with other students however, come time to submit/demo, **all work must be your own! Students found building other students' circuits, copying data, or plagiarizing answers to writeup questions will be found in violation of the course's policy on academic integrity (see the Syllabus for more information).**

With that said, we wish you the best on your future laboratory endeavors in 18-100! If you get stuck on any of the parts of the lab or don't feel you can finish the lab before the due date, reach out to your group TA; they're here to help!

1. Setup

Take a moment to ensure you have all the necessary equipment in your lab kit. A list of each component and where to find it in the lab kit can be found on *Canvas*.

Breadboard Setup

The breadboard is a prototyping device that consists of rows of 5 holes are connected by a metal strip underneath. In addition to these, the power rails (the leftmost and rightmost 2 columns) are connected across their entire length. In order to set up the breadboard, remove it from its packaging and install the terminal plugs. Then connect the $\pm$ supply rails to each other and then to the terminal plugs. In the end your breadboard should look like this:

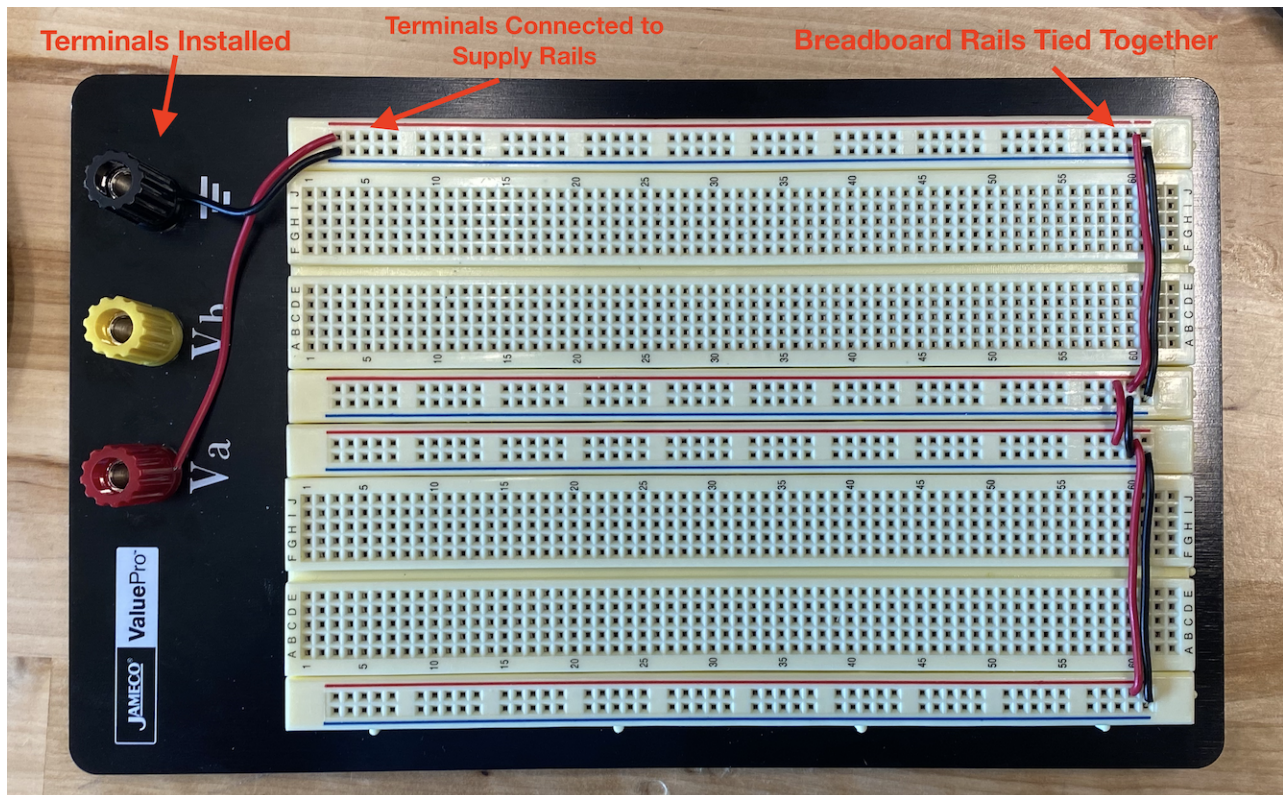


Figure 1: Breadboard setup complete

3 pts

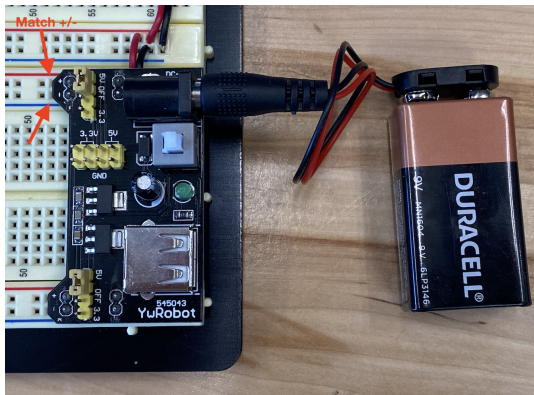
- 1.1 Setup your breadboard as described above. Make sure to install the breadboard terminals, connect them to the breadboard rails using jumper wire, and tie all the breadboard rails together.¹

If you need assistance setting up your breadboard, feel free to reach out to your group TA!

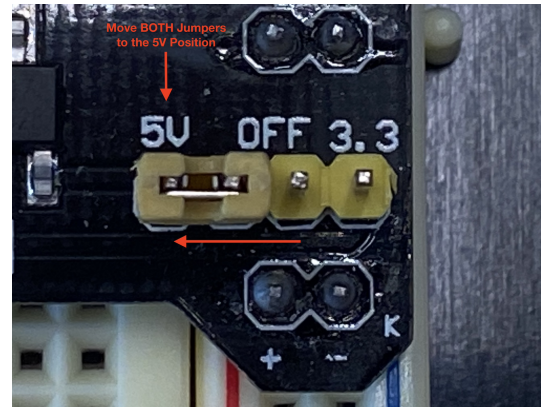
¹That's right! A whole three points just for setting it up correctly!

Power Sources

There are two main branches of ways to supply power to your circuit: fixed and adjustable. In this course we provide one of each: an adjustable power supply that plugs into the terminals on your breadboard and a fixed 5V supply that is inserted directly into the breadboard power rails.



(a) Power Supply Installed



(b) Switch Jumpers to 5V!

Insert the prongs into the rails (the 2 columns on both sides of the breadboard marked with red and blue lines). It's a tight fit so don't be afraid to use a little force.

The breadboard power supply is useful when you simply need 5V, like you will in Labs 1-3.

2. Resistance

In this section we'll take a look at resistors and their behavior in circuits.

2 pts

- 2.1** Based on the gold tolerance band on the resistor, what are the minimum and maximum values each resistor can have to be within tolerance? Measure the actual resistance using your Digital Multimeter (DMM).

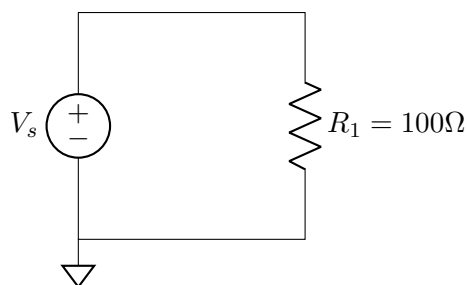
Resistor	Minimum Value (Ω)	Measured Value (Ω)	Maximum Value (Ω)
47 Ω	44.64	46.4	49.35
100 Ω	95	99.1	105
470 Ω	446.5	469	493.5
1k Ω	950	989	1050
4.7k Ω	4465	4650	4935

1 pts

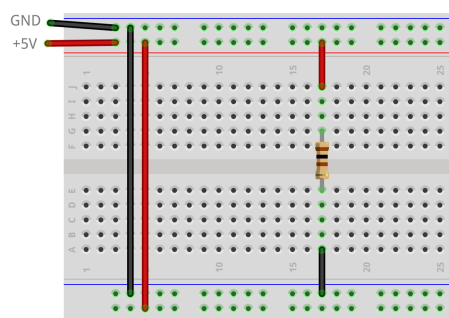
- 2.2** Do any of the measurements you took in 2.1 change if you flip the probes?

no.

Connect a 100 Ω resistor to the breadboard by placing one of the leads in a row of five holes and the other lead in a separate row. Use the breadboard power supply to set the rails to 5V. Connect each end of the resistor to a power rail, as shown in the diagram.



Simple Resistor Circuit (Schematic)



Simple Resistor Circuit (Breadboard)

Figure 3: Measuring Voltage across Resistor

1 pts

2.3 What voltage do you measure across the resistor?

Measured Value =

4.96

V

1 pts

2.4 Using Ohm's law, what should the current be flowing through the circuit? Show all work.

$$I = \frac{V}{R} = \frac{4.96V}{100\Omega} = 49.6mA$$

$I =$ 49.6 mA

Measure and record the current through the resistor using the multimeter. This involves physically breaking the circuit and connecting the meter in series as discussed in class. Before measuring current, verify that you've connected the multimeter correctly in series.

**⚠ Measuring current incorrectly can damage your multimeter!
Always check your probes before powering on a circuit!**

1 pts

2.5 What is the actual current flowing through the circuit?

Measured Value =

48.9

mA

1 pts

2.6 Using the measurements collected in 2.3 and 2.5, calculate the power consumed by the resistor

$$P = IV = (48.9mA)(4.96V)$$

$P =$ 242.5 mW

3. Resistor Networks

Series Resistors / Voltage Divider

Build the circuit shown below in Figure 4 which features a pair of $1\text{k}\Omega$ resistors wired in series.

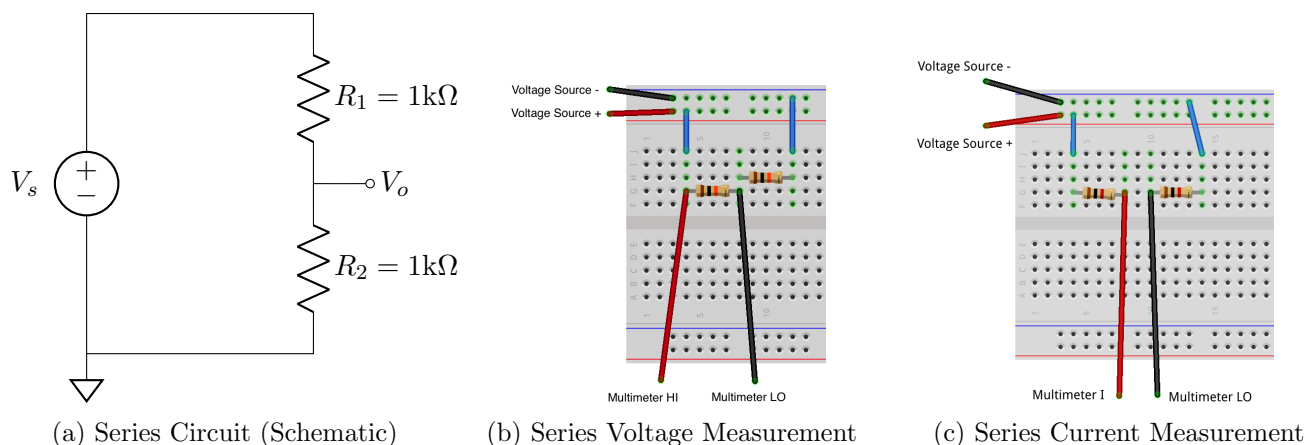


Figure 4: Measuring Series Resistors

- 1 pts** 3.1 Calculate the equivalent resistance, R_{eq} , of the circuit as seen from the voltage source, V_s .

$$R_{eq} = \underline{2} \text{ k}\Omega$$

- 1 pts** 3.2 Measure the voltage across, and current through, each resistor in Figure 4. Use Figures (b) and (c) to aid in your measurement process. The voltage source $V_s = 5\text{V}$. R_1 and $R_2 = 1\text{k}\Omega$

$$V_1 = \underline{2.49} \text{ V} \quad I_1 = \underline{2.4} \text{ mA} \quad V_2 = \underline{2.49} \text{ V} \quad I_2 = \underline{2.4} \text{ mA}$$

- 1 pts** 3.3 Using Ohm's Law and KVL/KCL, what can one expect the voltage across, and current through, each resistor in Figure 4 to be? The voltage source $V_s = 5\text{V}$. R_1 and $R_2 = 1\text{k}\Omega$

$$I_1 = I_2 = \frac{V_s}{R_{eq}} = \frac{5\text{V}}{2000\Omega} = 2.5 \text{ mA}$$

$$R_1 = R_2 \quad V_1 = V_2 = IR_1 = 2.5 \text{ mA}(1000\Omega) = 2.5 \text{ V}$$

$$V_1 = \underline{2.5} \text{ V} \quad I_1 = \underline{2.5} \text{ mA} \quad V_2 = \underline{2.5} \text{ V} \quad I_2 = \underline{2.5} \text{ mA}$$

1 pts

3.4 Replace the resistor R_2 in Figure 4 with a $4.7\text{k}\Omega$ resistor. Measure the voltage across, and current through, each resistor in Figure 4.

$$V_1 = \underline{0.87} \text{ V} \quad I_1 = \underline{0.8} \text{ mA} \quad V_2 = \underline{4.11} \text{ V} \quad I_2 = \underline{0.8} \text{ mA}$$

1 pts

3.5 Using Ohm's Law and KVL/KCL, what can one expect the voltage across, and current through, each resistor in Figure 4 to be? The voltage source $V_s = 5\text{V}$. $R_1 = 1\text{k}\Omega$ and $R_2 = 4.7\text{k}\Omega$

$$I_1 = I_2 = \frac{V}{R_{\text{eq}}} = \frac{5\text{V}}{5700\Omega} = 0.877\text{ mA}$$

$$V_1 = IR_1 = 0.877\text{ mA}(1000\Omega) = 0.877\text{ V}$$

$$V_2 = V_s - V_1 = 5 - 0.877$$

$$V_1 = \underline{0.877} \text{ V} \quad I_1 = \underline{0.877} \text{ mA} \quad V_2 = \underline{4.123} \text{ V} \quad I_2 = \underline{0.877} \text{ mA}$$

Light Dependent Resistor

Now let's make something a little more interesting. First, find your kit's light dependent resistor (LDR, Figure 5). The resistivity of the red material changes with the intensity of light striking it.



Figure 5: A light dependent resistor

Measure the LDR's resistance with your Ohmmeter. Cover the face of the LDR with your hand. This is its dark resistance R_{dark} . Now shine a light into the LDR. This is its light resistance R_{light} .

1 pts

3.6 What are the dark and light resistances that you measured?

$$R_{\text{dark}} = \underline{21.4 \text{ k}} \Omega \quad R_{\text{light}} = \underline{467} \Omega$$

Now replace the resistor R_2 in Figure 4 with your LDR as shown in the schematic in Figure 6. Use your voltmeter to measure V_o in the dark (V_{dark}) and in the light (V_{light}).

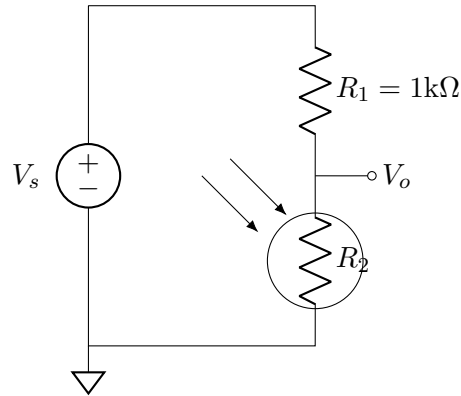


Figure 6: Light-dependent voltage divider circuit

1 pts

3.7 What are the dark and light voltages that you measured?

$$V_{dark} = \boxed{4.83} \text{ V} \quad V_{light} = \boxed{1.49} \text{ V}$$

1 pts

3.8 Is the output voltage higher in the dark or in the light? Why?

Higher in the dark since the resistance is greater.
Due to Ohm's law, $>R$ means $>V$ since I remains constant.

4. LED Circuits

Create the following circuit (Figure 7) on your breadboard using a red LED. Note: the **longer** wire is the **anode** (positive end) and the **shorter** wire is the **cathode** (negative end).

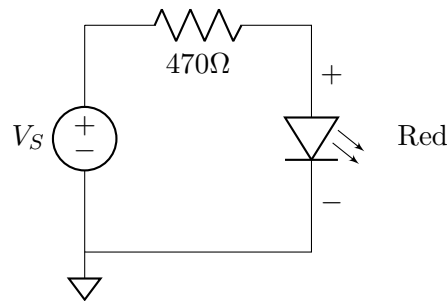


Figure 7: Single-LED Circuit

Hint: It should light up

1 pts

4.1 Once the LED lights up, flip the LED's direction. Does the LED continue to emit light?

no.

Assemble the following circuit (Figure 8) on your breadboard.

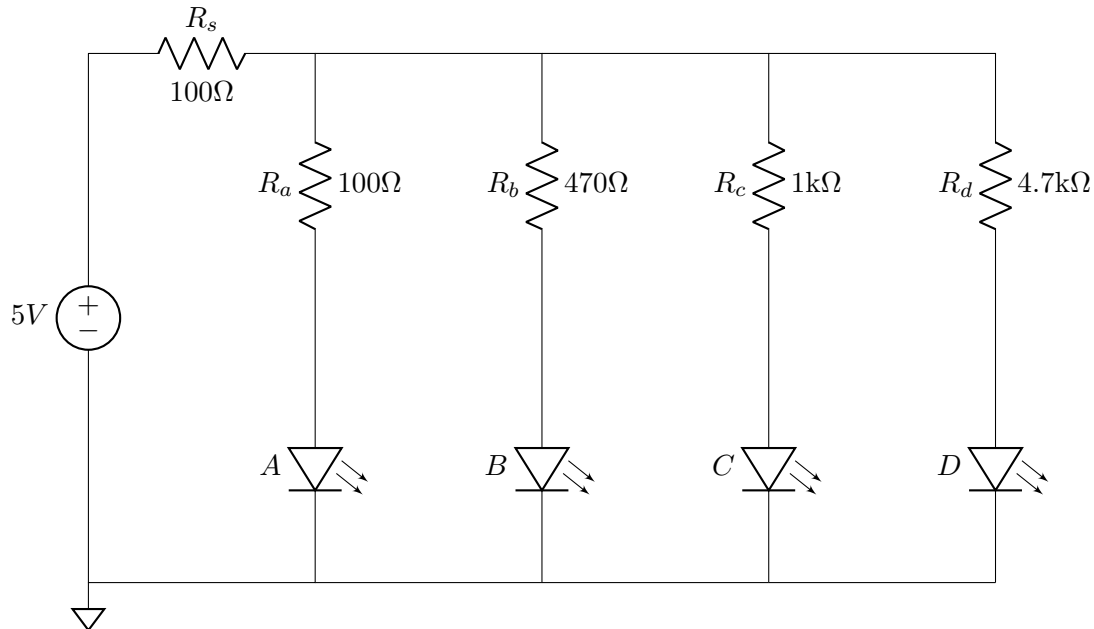


Figure 8: 4-LED Circuit

The figure below (Figure 9) shows the circuit connections on the breadboard. Refer to the diagram if you have difficulties wiring up the circuit.

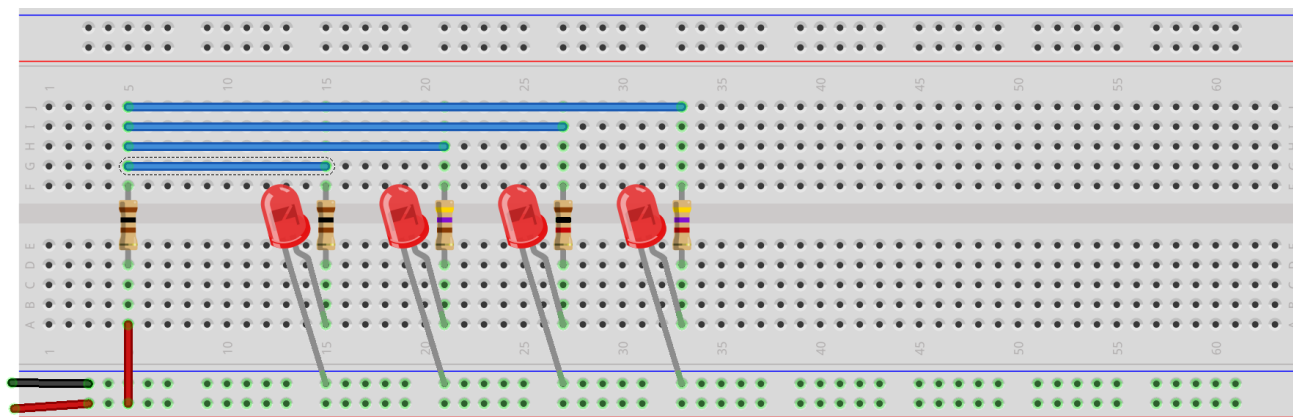


Figure 9: LED circuit breadboard diagram.

1 pts

4.2 Observe the light intensity of each LED and provide a ranking from the least bright to the brightest (e.g. $B < A < D < C$).

$D < C < B < A$

2 pts

4.3 Measure the voltages across the 100Ω , 470Ω , $1k\Omega$, and $4.7k\Omega$ resistors ($R_a - R_d$) as well as the voltage across each of the LEDs. Sum them together.

Branch	Resistor Voltage (V_{R_x})	LED Voltage (V_{D_x})	Total Voltage (V_x)
A	2.93 V	2.03 V	4.96 V
B	3.16 V	1.80 V	4.96 V
C	3.21 V	1.75 V	4.96 V
D	3.30 V	1.66 V	4.96 V

1 pts

4.4 What do you observe about the voltages across the LEDs?

they decreased as the corresponding resistance increased.
the voltage of each LED and its resistor summed up to 4.96 V.

1 pts

- 4.5 Measure the current through R_s (I_S) and the currents through LED A, B, C, and D (I_A , I_B , I_C , I_D). Remember that current is measured in series!

Quantity	Measured Current (mA)
I_S	39.1 mA
I_A	29.1 mA
I_B	6.6 mA
I_C	3.2 mA
I_D	0.7 mA

1 pts

- 4.6 What relationship do you hypothesize about the current through R_s (I_S), and the LED currents (I_a , I_b , I_c , I_d)? Write down the hypothesis and prove that it holds (roughly) with empirical data.

$$I_S = I_a + I_b + I_c + I_d$$

as seen in the table above : $29.1 + 6.6 + 3.2 + 0.7 \approx 39.1$

5 pts

- 4.7 Be prepared to demonstrate your working circuit to a TA.

▲ Do NOT take your circuit apart yet! You will need it for lab checkoff!