

Name/NetID:

# Experiment 1: A Lab-Course Introduction

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Teammate/NetID:

## Laboratory Outline

In each lab experiment, you will generally be asked to read a little background material (often in a pre-laboratory exercise) and work your way through a well-defined set of lab procedures. Within the lab procedure, you will generally

- Setup the hardware needed in the experiment.
- Record measurements.
- Visualize the data through the use of graphs.
- Analyze the data to extract information about the behavior of the “circuit under test”.
- Document the experimental setup using circuit schematics, equations, and tables.
- Record what was observed during the experiment.
- Draw conclusions as to why these results will aid in completing the semester’s tasks in ECE110.

This list is especially important as these items are the key components of your **grading rubric** (*a scoring sheet used to provide consistent criteria for grading*). You will be asked to perform a self-assessment of each lab using a table provided to you. This is an exercise that will aid your understanding of how your labs are graded and help you learn to produce well-written reports.

In today’s experiment, the TAs will guide you through exercises that will develop good habits ensuring that your data is accurately and unambiguously recorded and reported. In addition, you will learn the important role technical discussions with other classmates can have on your own ability to understand the lab procedures and your results. Ask questions freely and learn from your TAs as you will be expected to be able to follow their example with less guidance in future labs.

*Please use the Notes margin on the right for both notes to yourself about the experiment as well as for feedback to your TA on the quality or clarity of the lab procedure. Thanks!*

## Learning Objectives

- Walk through the paces of a typical lab (as outlined above) with the TA as a guide.
- Use software (MATLAB) as a tool in data analysis.
- Build a car chassis and experiment with driving via “pulsed” signals to the wheels.

Section AB/BB:

0	1	2	3	4	5	6	7
8	9	A	B	C	D	E	F

(circle one)

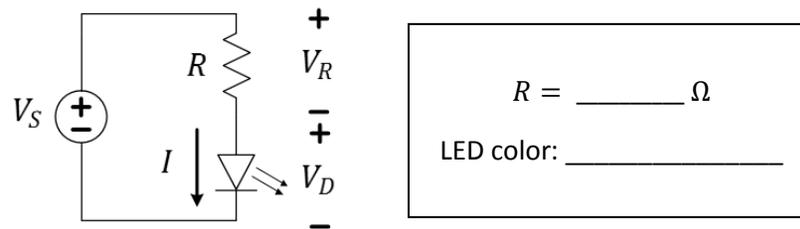
Notes:

## Introduction

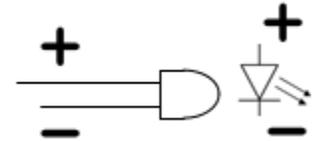
The TA will guide you through the characterization of a light-emitting diode. This characterization is very characteristic of some of the measurements you, yourself, will be required to make throughout the semester. There will be a circuit schematic implemented by your TA on a breadboard, measurements recorded in a table, calculations on those measurements accomplished, data graphed, and a mathematical model applied to that graph. You will use your kit to follow along during the construction of the circuit. The main goal of today's lab is to introduce you to the lab environment and to assist you in learning how to draft well-written reports that will help you accumulate the maximum knowledge from the lab as well as obtain the maximum credit for doing so. Do not be concerned that you may not fully understand the meaning of the measurements taken nor the function of the devices used today. These are skills you will gain in future laboratory exercises.

## Experimental Setup

**Question 1:** Examine the schematic of the circuit to be measured (Figure 1). Ask your TA to read the resistor value from the color code to provide you the value of  $R$  and which color LED is being used.



**Figure 1:** Illuminating an LED safely using a current-limiting resistor.



All diodes have an anode (top) and a cathode (bottom). If the LED is inserted in reverse, it will not illuminate as the voltage is increased.



How to read the resistor color code:

[http://en.wikipedia.org/wiki/Electronic\\_color\\_code](http://en.wikipedia.org/wiki/Electronic_color_code)

Notes:

## Measurements

**Question 2:** Your TA will now demonstrate how to measure data. Complete the column for  $V_D$  in the table below with values from your TA's measurements.

$V_S$ (V)	$V_D$ (V)	$V_R$	$I$	Comments
0.0				
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				

Table 1: *Students, please give this table a title! TAs, take extra data points around turn-on.*

**Question 3:** In the circuit schematic of Figure 1,  $V_S$  is the voltage provided by the voltage source (power supply) in the lab. The power supply controls the voltage across the resistor/diode combination, forcing it to take on the value of  $V_S$ . Looking at the other side of the schematic, we see that the voltage drop across the resistor,  $V_R$ , and the voltage drop across the diode,  $V_D$ , must sum to the value of  $V_S$ . Write the relationship between  $V_S$ ,  $V_R$ , and  $V_D$  as a simple mathematical formula in the space below. Your table should support this formula.

$$V_S =$$

In the table,  $V_S$  is set and  $V_D$  is measured.  $V_R$  and  $I$  are to be computed from formulae in Questions 4 and 5; they are not measured.

Later, we will formalize this observation as Kirchhoff's Voltage Law (KVL).

Notes:

## Computations

**Question 4:** Provide the equation that describes the voltage across the resistor,  $V_R$ , in terms of  $V_S$  and  $V_D$ .

$$V_R =$$

**Question 5:** Provide an equation that describes the current through the (Ohmic) resistor,  $I$ , in terms of  $V_R$  and  $R$ .

$$I =$$

**Question 6:** Complete the table above, filling in the calculated values of  $V_R$  and  $I$ . Be sure to provide a descriptive name for your table and add the units for these two variables to the top of the columns.

For an “Ohmic” device (like a resistor), the ratio of the voltage across the device to the current through the device should be roughly constant. We call this constant the resistance,  $R$ :

$$R = \frac{V}{I}$$

## Plotting graphs in MATLAB (students go to their own benches to complete the lab)

Throughout the semester you will be asked to perform mathematical operations on your data and to generate your own graphs based on data collected during an experiment. In general, it will be expected that you create these graphs using MATLAB (saving much time) and attach them to the end of your lab report. Given that your graph may be separated from its corresponding portion of the experiment, it becomes *very important* that you give each graph a useful title and make a note in that section of the experiment so the reader knows where to find it.

Below are the basic commands for generating a plot in MATLAB. Go ahead and enter these commands into the *Command Window* in MATLAB right now. At the command prompt '>' type each line and hit *Enter*. When the command prompt returns after each line is typed, enter the next line. Notice what changes when you hit *Enter* in the workspace and history windows.

Note: the semicolon is optional – try entering the first line without it.

```
x = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10];  
y = [0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100];  
  
figure(1);  
plot(x, y);  
title('Parabola');  
xlabel('X Axis (x units)');  
ylabel('Y Axis (y units)');
```

If you don't already have experience using MATLAB, these commands might be a little cryptic. To shed a little light on the issue, we've broken things down a little further.

### Creating variables

```
x = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10];
```

This line of the code creates a variable named "x". This particular variable is an *array*, meaning that it is a collection of variables.

Alternatively, you can create a variable in the same way you would enter data into a spreadsheet. You can do this by using the menu under the *Workspace* (upper left corner of the MATLAB window) to create new variable. Once you have created and named a variable you can simply double click the variable name in your *Workspace* and a spreadsheet will open displaying its contents. Once you have this spreadsheet open, you can edit or add to the content associated with that variable name by selecting a cell and entering the desired numbers.

## Creating Plots

```
figure(1);
```

This command generates a new window in which your plot (figure 1) will appear. This command is not strictly required for creating plots in MATLAB but it is good practice. If a figure is not open before you call the plot function, MATLAB will automatically open one for you – making this command unnecessary. If a figure window is already open, MATLAB will plot into that window and *overwrite any graph that may have been there*. Use this function to avoid overwriting your plots by accident.

```
plot(x, y);
```

This command calls a function and gives it two parameters. The first parameter, *x*, is used as the horizontal axis and the second parameter, *y*, is the vertical axis. It is important to note that in this case, the variable names were chosen to illustrate how the plot function works. When you're creating a plot for an experiment, you should give your variables meaningful names (in case you forget what they were for). For example, if our data represented voltage and current I might use the following variable names:

```
voltage = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10];  
current = [0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100];  
plot(voltage, current);
```

## Title and Labels

```
title('Parabola');  
xlabel('X Axis (x units)');  
ylabel('Y Axis (y units)');
```

These function calls should be pretty self-explanatory. Just remember that the text you want as a title or label must have single quotes around it.

## Making Your Graph Pretty

MATLAB provides a very robust graphical interface for changing virtually any parameters of your plots. You can access the *plot tools* by selecting the icon on the figure window that is shown in the figure below.



*Figure 2: Finding Plot tools on the MATLAB taskbar.*

Once you have opened the plot tools, you can change the properties of most aspects of your graph by clicking on the thing you want to change and adjusting the properties displayed in the lower portion of the window. Alternatively, it is possible to adjust any of the plot properties from the command line but it is left to you to use the extensive documentation to find this information if needed.

## Multiple Plots in a Single Graph

Often times, we would like to compare two sets of data by plotting them on the same axes. You can do this using the “hold” command as shown below. You’ll need to use this information in order to finish today’s lab.

```
plot(time, voltage);  
hold on;  
plot(time, current);  
hold off;
```

Note: After entering “hold on”, MATLAB will put every curve you plot on the same axes until you enter “hold off”.

**Question 7:** What does the following line of MATLAB code do?

```
time = (0:9)*1e-3;
```

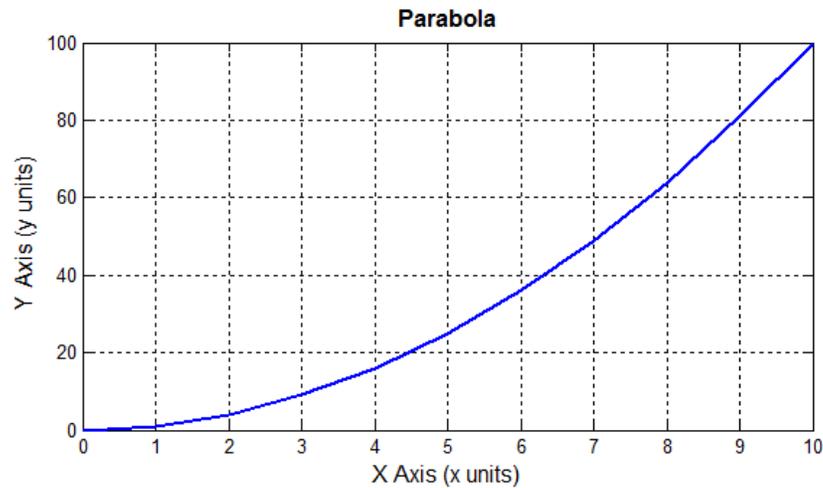
**Question 8:** What happens if you try to plot two variables that do not have the same number of elements in them? (Try it for yourself and see what MATLAB does.)

**Question 9:** Using the *plot tools* interface, adjust the settings on your parabola plot so that it looks just like Figure 3. To do this, you'll need to add grid lines, change the thickness of the curve and adjust the font sizes for the title and labels. **Enter your netID into the title** so that you can identify your printout at the printer. Once you have finished formatting your graph, print it out and attach it to the end of your lab.\*

*Hint: If you get stuck or can't find something, MATLAB has a very extensive help menu. If you still can't figure it out, talk to other students in the class, maybe someone else found it.*

\*IMPORTANT! ECE110 is now allowing online submission of MATLAB-generated graphs. If you wish to take advantage of this method and save printing fees, please load all graphs into an MS Word or pdf document titled *your\_name\_Lab1* and submit using SafeAssign at Compass2g. As with any graphs, you need to provide a descriptive, numbered title and reference that graph at the appropriate location in the lab report text. If your TA has difficulty matching the graphs to the text, points may be lost in the grading.

Alternately, you may wish to purchase a print queue from the College of Engineering so that you may print on the lab's printer.



*Figure 3: Example plot of a parabola*

## Analysis

**Question 10:** Create a graph that plots  $I$  (on the y-axis) and  $V_D$  (on the x-axis) from the data done earlier today. Label it properly in the manner just learned.

Notes:

Think about it...

While ECE110 doesn't require a "professional" lab notebook, you should learn to start good habits now. Never erase mistakes or remove "bad" data. Cross out mistakes with a simple line and make the correction nearby. If you can explain an "outlying" data point, do so, but never arbitrarily choose to remove an outlier to improve your data set.

## Modeling: Linear Approximation

After the LED has “turned on”, the flow of current through a diode can be modeled, mathematically, as a line.

**Question 11:** On the same graph as the previous plot, add a line. Under plot tools (Annotations), click on Line, then use the cursor to draw a line on your plot to match the turn-on region. Adjust the line until this model approximates your data. It is likely you may choose to have your line intersect at a positive value of  $V_D$ . That value might be used as a nominal “turn-on” voltage. Include both your plot and your MATLAB code with this report.

## Conclusion

**Question 12:** Complete the comments section on the rubric (grading outline) on the last page of this lab. This rubric is provided to give you an opportunity to think about the grading process and allow you to self-assess your own work.

## Build the Car Chassis and Play!

If lab time remains, complete this section. Otherwise, jump to “What You Learned” and complete this section on your own building the chassis at home and bring it to the next lab session.

Our semester-long project will revolve around the construction and design of an autonomous robotic car. Our first step is to build the chassis – the plastic platform that holds the motors and the circuitry. Following the instructions provided by SparkFun at <https://learn.sparkfun.com/tutorials/assembly-guide-for-redbot-with-shadow-chassis>. Because the chassis is the dedicated platform of their RedBot, these instructions include some parts that you will not need right now. You can look through the whole set of instructions but you will leave out some portions.

- ✓ Make sure you have all of the chassis parts – the black plastic body, the motors with black and red wires to the terminals of the motors already soldered on, and the wheels.
- ✓ Navigate to the next page labeled – **2. Wheels and Motors**. Attach the wheels and motors to the bottom of the body.
- ✓ Skipping the instructions for loading the line-following sensors (you may need these instructions later) and mechanical bumpers move on to the section labeled – **5. Chassis**.

### Powering the Motors

The motors will start spinning when a high enough voltage is applied across the terminals. Let’s use the power supply to run the motors and see how fast the car moves when connected to a battery.

- ✓ Place the breadboard on top of the chassis. There are connectors available to hold it as shown in the photo on the right. A breadboard (sometimes called a protoboard) is the white board with lots of holes in it. This board helps with building prototypes– the first version of a design. The holes are connected in a useful way as shown in the diagram below.

You might want to borrow an already-built car chassis from your TA for today. Save valuable lab time and build yours at home as part of your prelab for lab 2. Better yet, meet up with other 110 students and build together!

Notes:

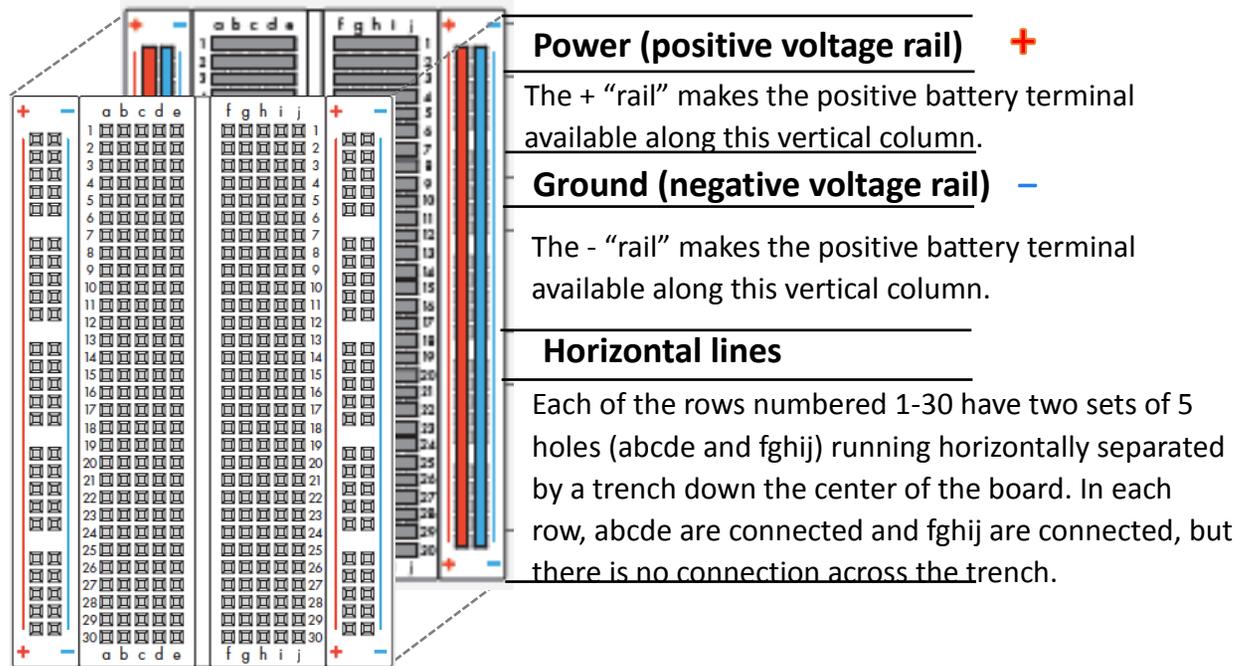


Figure 2: The breadboard “exploded” to show its internal connections.

- ✓ Insert the motor leads to the breadboard so they can be accessed individually – see figure below
- ✓ Quickly test each motor (without the control panel) to verify they are functional.

**CHALLENGE:** Use the DMM as an Ohmmeter (measuring resistance) to verify the breadboard construction detailed in Figure 2.

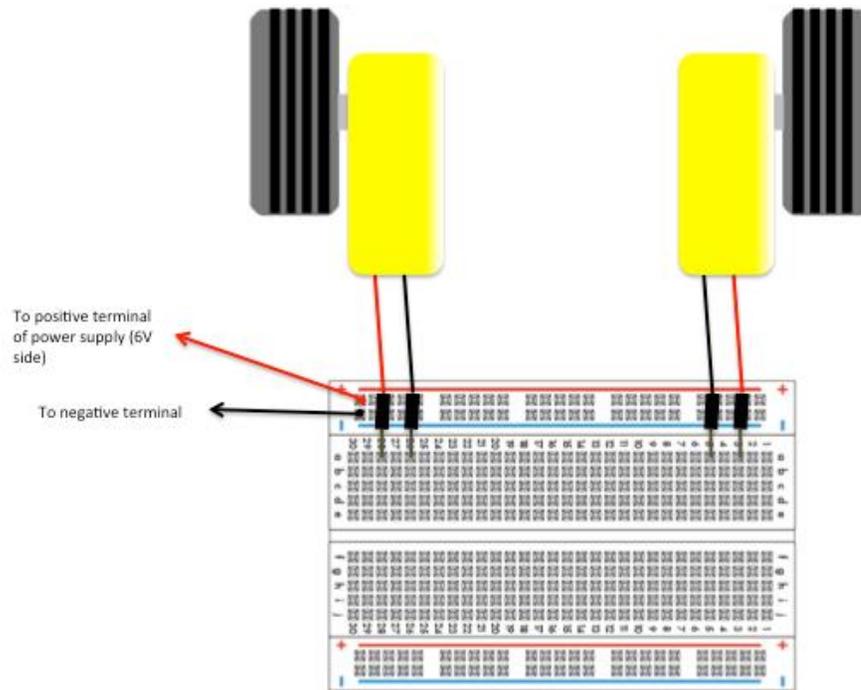
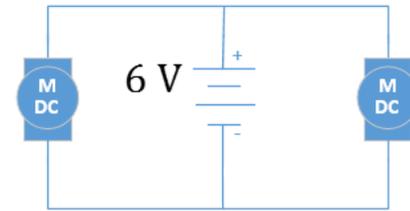


Figure: Using the breadboard to connect to the motors.

If you are doing this part from home, you can use your own batteries to power the motors. The battery options available to you are shown in the diagram below.

Notes:



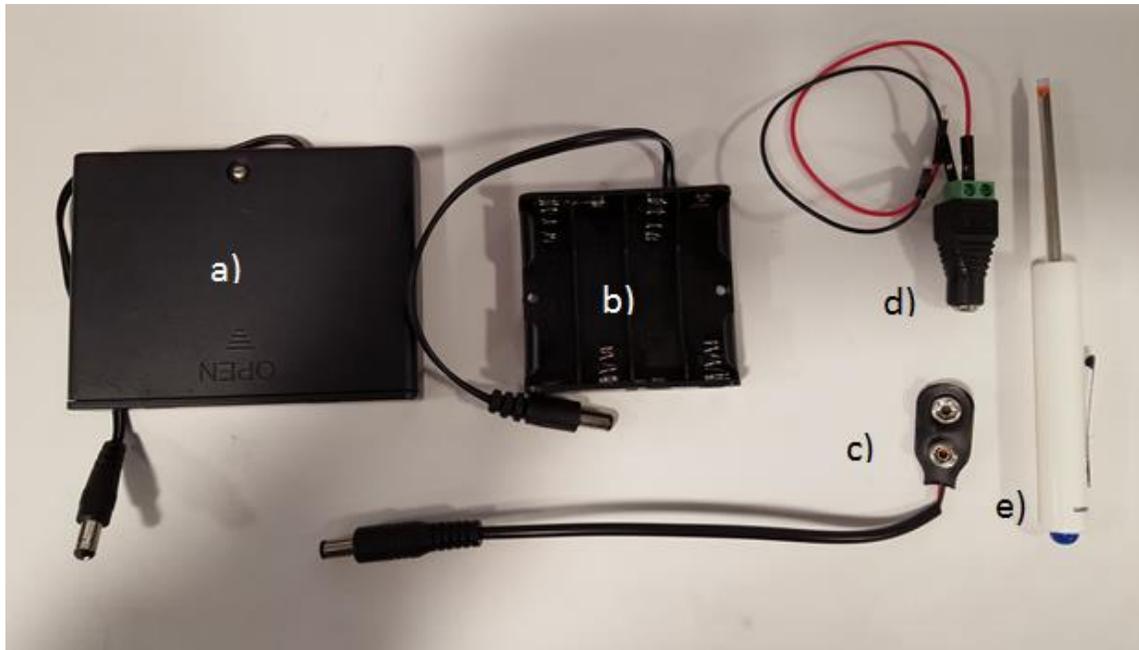


Figure: Battery options for ECE110 students. a) The 6x1.2-volt NiMH battery pack available in the lab only. b) The 4x1.5-volt battery back for home use (AA batteries not included). c) The 1x9-volt battery-to-barrel adaptor (9-v battery not included). d) The barrel-to-pin adaptor with wires added using the screwdriver. e) The reversible (flat blade and phillips) screwdriver available in your kit.

- ✓ Use the battery-powered, two-button control panel provided by the TA to drive your car. Make the connections as shown in the figure.
- ✓ Press each button separately. Each corresponding motor should rotate. Below is a physical diagram of the connections (for both motors – for now just connect one side) including the jumper wires and the equivalent schematic shown in the sidebar to the right.

Notes:

The selection of a battery is, of course, not an arbitrary matter when designing a project. Questions will arise such as “how long will this battery last?” and “how much power can this battery provide?” You will gain practical skills to answer these questions in ECE110!

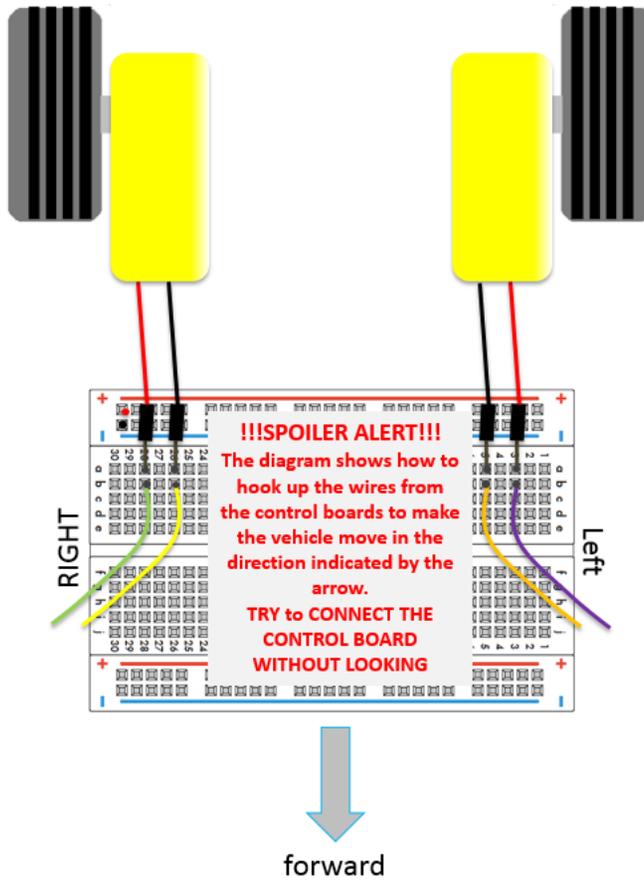
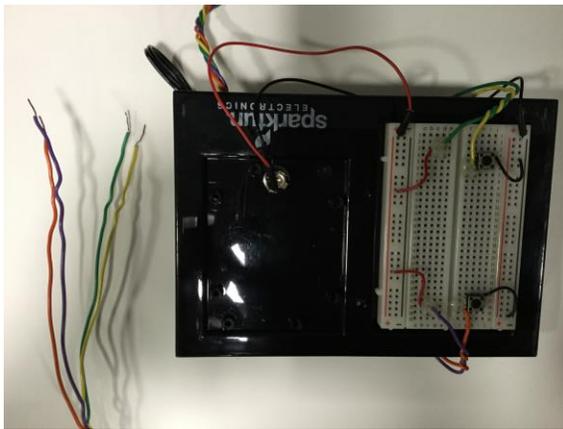
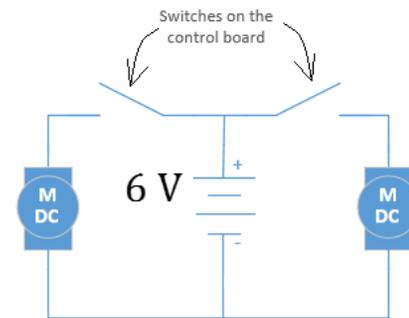


Figure: The two-button, 6-volt controller and how to connect it to the car chassis.

- ✓ You can drive the car around the lab for fun. Think about what is needed to make the car move continuously, but in a straight line.

Notes:



Can you “pulse” fast enough to control the direction of the car smoothly? This is exactly what will happen later this semester when you **automate** the car’s navigation!

## What You Learned

Each week, the core laboratory experiment will end with this “What You Learned” section. This section will outline the engineering skills developed during that laboratory exercise and provide emphasis on the skills in which you are expected to show proficiency in future tasks. Today’s experiment covered the fundamental skills needed for successfully completing laboratory procedures in the coming weeks. In the future, it will be assumed that you know how to:

- Include the characteristics necessary to make every lab a well-written report.
- Produce graphs using MATLAB.

Questions relevant to your lab experience are likely to occur on homework assignments and exams. Points will be deducted for failure to show proficiency in these skills in future lab exercises and lab reports.

## Explore More!

When you finish the main laboratory exercise each week and time remains in your lab session, you are not yet finished. You will spend the remainder of the time solidifying your understanding of the materials paying special attention to the skills outlined in the previous section. If you feel you have proficiency in those skills, you should move closer to mastery by challenging yourself with the suggested “module exercises” provided by the instructors. This week, we highly recommend **Explore More! Writing a Strong Report**, which will help you understand the grading process and enable you to take a metacognitive view of your lab performance through your own self-assessment each week.

At the end of the semester, you will earn points towards your total semester lab score by having completed many of these modules.

## Lab Report Rubric

The following page is the self-assessment Lab Report Rubric. It is a guide that the TAs will use for grading lab submissions. As a final step in preparing your lab report each week, you will use this same rubric to analyze your own performance. It is an opportunity for you to think about the teaching-and-learning process and to self-evaluate if you are placing adequate effort into your laboratory reports. For each category of the rubric, the assessment will follow the scale on this page. The TAs might help you determine which questions and sections of the lab pertain to the categories of the rubric. They might also help you determine how much of the total lab grade might be assigned to a particular category in a particular week. Note that some labs will have much greater emphasis on one category depending on the topic being covered.

Notes:

<b>Section</b>	<b>Criterion</b>	<b>Comments:</b>
<i>Experimental Setup and/or Design Description</i>	Circuit Schematics are drawn neatly, accurately, and properly labeled. Decisions regarding experimental setup and design are clearly explained.	
<i>Measurements</i>	Tables include units and proper precision. Any <i>new device</i> introduced should be characterized using measurements!	
<i>Computations</i>	Computations performed on raw data are <i>explicitly</i> described and follow rules for significant figures.	
<i>Analysis</i>	Graphs have title, labels, units, scale, legend; Lines for curve-fitting appear in the graph when needed and parameters like the intercepts and the slope are labeled.	
<i>Modeling</i>	A mathematical model for the curve-fit graph allows for more abstract references to the device's behavior. The expected behavior is explained in the context of the graph.	
<i>Conclusion</i>	Conclusions are drawn from your experimental results to support the reason(s) for completing the experiment. Closes the loop on the Introduction.	
<i>General Formatting</i>	Answers to questions clearly labeled. The overall appearance of the report is professional.	
<i>Self-assessment</i>	This table has been thoughtfully completed.	