Name/NetID: Teammate:

Module: Writing a Report

Laboratory Outline:

Now that we have looked at how to properly record measurements and generate graphs, we need to pull it all together in a well-written report.

Recall that within the lab procedure, you will

- Setup the hardware needed in the experiment
- Record measurements
- Visualize the data through the use of graphs
- Analyze the data extracting information about the behavior of the circuit under test
- Document the experimental setup and record what was seen during the experiment
- Draw conclusions as to why these results will aid in completing the semester's tasks in ECE110.

To get an idea of what constitutes a good report and a poor report, we can observe the reports of two fictional students for a fictional laboratory procedure that mimics functions of our own lab. The following fictional ***Experiment X*** is just an example. Do not attempt to answer the **Questions** presented there.

Experiment X: An Example Lab Procedure

Notes:

Learning Objectives:

In this experiment, you will characterize the current-voltage relationship of a standard DC motor. As you will see the behavior of the motor being driven with different voltages is interesting and complex. As a device that can convert electrical energy from a battery to mechanical rotation or vice versa the current-voltage relation is highly nonlinear. When including motors in a design, an understanding of the response of the motor to a range of voltages is crucial when designing the circuitry that drives the motor.

Procedures

Connect the circuit as shown in

Figure 1.

- ✓ Use the box with alligator clips (test box) to connect the power supply with your motor.

Notes:

- ✓ Make sure that the output on the power supply is set to “off” when you are constructing or making changes to your circuit.

Figure 1: Circuit schematic and photo of the variable voltage source motor drive method.

Before you begin taking measurements using your motor, it’s good practice to perform a quick test run. The motors respond nonlinearly so you need observe, qualitatively, how the motor reacts to different voltages. This will allow you to chose your data points carefully to capture the interesting behavior.

Question 1: Draw a schematic of your test setup.

Notes:

Question 2: Starting at zero volts, sweep the voltage of the power supply from 0 to 5V, and make note of the approximate voltage at which the motor begins to spin.

Notes:

Motors exhibit **hysteresis** meaning that *the current state of the motor depends on its history*. You will find that when the supply voltage is too low, the motor will not turn because static friction and electromagnetic forces initially oppose the motion. When driven with sufficient voltage the motor will begin to turn. Once the motor is turning if the voltage is decreased, the motor will not "stall" at the same turn-on voltage level because kinetic friction is smaller than static friction so the rotational kinetic energy is dissipated more slowly and the electromagnetic forces again oppose the change.

Question 3: Starting from 0V again, measure the voltage and current of the motor at increments no larger than 0.5V. Be sure to use smaller increments before and after the turn-on voltage you recorded in 0. Record measurements in the table below. Make sure to note when you see a change in behavior in the motor (i.e. "motor whines audibly but doesn't move", "motor starts to spin", etc.). **NOTE:** Since the motor behavior exhibits hysteresis it is important that you collect your data in a *forward direction*. If you need to go back and collect a certain data point, you need to start over from 0V

Voltage (V)	**Current**	**Notes:**

Table 1: Current flow for the motor for increasing DC voltage with comments.

Question 4: Use MATLAB to generate a plot for the IV characteristics using the data you collected.

Notes:

Notes:

Question 5: Describe in words the behavior of the motor when the voltage is increased. Explain all of the interesting features shown by the graph.

Question 6: If your graph was done properly the resulting curve should have two regions where the current-voltage relations in approximately linear. Draw two lines that fit the data in these two regions.

As an engineer designing a circuit to control a motor there are two important issues: 1) power consumption, and 2) keeping the motor operating using voltage levels that keep it as far as possible from the turn on and stall voltages. These next few questions aim to help you determine the optimal operating range for these motors that will be an integral part of your designs.

Question 7: Determine a linear equation (slope-intercept form) corresponding to each of the lines you drew on the graph in question 6.

Question 8: Using these two linear equations, determine the equivalent circuit for a motor in these two regions – the stall region where the motor is not turning but drawing current, and the region where the motor turns freely.

Notes:

In the regions of the current-voltage relation that are linear the motor behaves (and can be modeled) as a resistive device. The linear relationship that describes the current-voltage behavior while the motor is spinning also shows that as an electromagnetic device it can be source.

Optimal use of battery resources dictates that you not expend energy in the regions where the motor draws power but does not turn.

Question 9: How much power is drawn from the power supply just below the turn-on voltage?

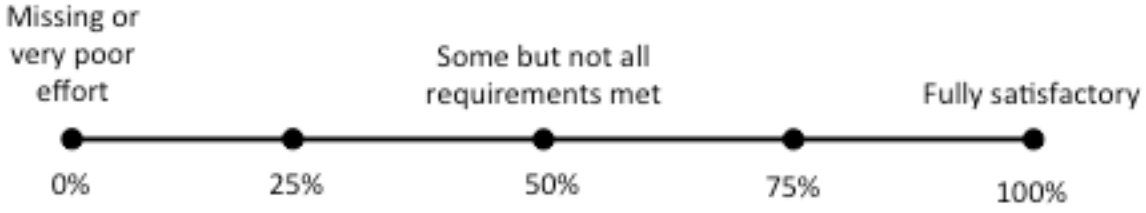
But now suppose the design requirements dictate that the motors must be turned on and off. In addition, it might be imperative that the speed be controlled as well – the speed of the vehicle driven by the motors, once the motors are freely rotating, is approximately, linearly related to the voltage. To satisfy these two requirements while conserving battery life a strategy that you will experiment with extensively in up-coming labs called Pulse Width Modulation (PWM) is commonly used for these applications. Instead of changing the voltage linearly at a voltage above the turn-on voltage, PWM uses only two voltage levels 0V and some voltage below that maximum rated voltage but way above the turn-on voltage alternately.

Question 10: Discuss what would happen if the voltage applied to the motor varied between 0 and 5V very slowly. What would happen if the voltage varies quickly? How might this be used to control the speed?

Notes:

Lab Report Rubric

Your lab reports will be graded by assigning a consistent amount of points to each type of questions. Each week you will encounter each category in all the labs. The number of points assigned to each question by your lab TAs grading is based on how well the answer satisfies the requirements.



Section	Points per question	Ques.	Total points	Criterion
Experimental Setup and/or Design Description	2	1	2	Circuit Schematics are drawn neatly, accurately, and properly labeled. All important decisions regarding experimental setup or project design are clearly explained.
Measurements	2	2-3	4	Tables include units and proper precision. Any *new device* introduced should be characterized using measurements!
Computations	1	9	1	Computations performed on raw data are *explicitly* described and follow rules for significant figures.
Analysis	2	4-5	4	Observations and graphs that have title, labels, units, scale, legend; Lines for curve-fitting appear in the graph when needed and parameters like the intercepts and slope are labeled.

Modeling	1	6-8	3	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.
Conclusion	1	10	1	Conclusions are drawn from your experimental results to support the reason(s) for completing the experiment. Closes the loop on the Introduction.
General Formatting (1 pt. total)		1-10	1	Answers to questions clearly labeled. The overall appearance of the report is professional.

Notes:

Looking at Example Reports

Take a moment to read through the sample reports found in the appendix at the end of your lab book and use the report grading rubric to grade each report. Pay special attention to the concepts discussed earlier in this week's experiment.

Once again, feel free to discuss these reports with your classmates.

Notes:

Task 1: Fill out the following "grading rubric" for Nick Tesla's lab report using the lab report rubric below. Two of the categories are fill in with comments explaining the assignment. Fill in all of the other categories. Explain your reasoning for each grade.

Section	Ques.	Total points	Criterion	Comments:
Experimental Setup and/or Design Description	1	2	Circuit Schematics are drawn neatly, accurately, and properly labeled. All important decisions regarding experimental setup or project design are clearly explained.	Nice labeling of variable voltage source and motor
Measurements	2-3		Tables include units and proper precision. Any *new device* introduced should be characterized using measurements!	
Computations	9	1	Computations performed on raw data are *explicitly* described and follow rules for significant figures.	Nice including gird lines on plots to make computing the power easier
Analysis	4-5		Graphs have title, labels, units, scale, legend; Lines for curve-fitting appear in the graph when needed and parameters like the intercepts and slope are labeled.	
Modeling	6-8		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.	
Conclusion	10		Conclusions are drawn from your experimental results to support the reason(s) for completing the experiment. Closes the loop on the Introduction.	
General Formatting	1-10		Answers to questions clearly labeled. The overall appearance of the report is professional.	

Notes:

Task 2: Fill out the following "grading rubric" for Tommy Edison's lab report using the lab report rubric below. Two of the categories are fill in with comments explaining the assignment. Fill in all of the other categories. Explain your reasoning for each grade.

Section	**Ques.**	**Total points**	**Criterion**	**Comments:**
Experimental Setup and/or Design Description	1	.25	Circuit Schematics are drawn neatly, accurately, and properly labeled. All important decisions regarding experimental setup or project design are clearly explained.	Correct connections but could not recreate experiment with just this schematic. Poor labeling.
Measurements	2-3		Tables include units and proper precision. Any *new device* introduced should be characterized using measurements!	
Computations	9	1	Computations performed on raw data are *explicitly* described and follow rules for significant figures.	Correct formula but difficult to read values from graph.
Analysis	4-5		Graphs have title, labels, units, scale, legend; Lines for curve-fitting appear in the graph when needed and parameters like the intercepts and slope are labeled.	
Modeling	6-8		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.	
Conclusion	10		Conclusions are drawn from your experimental results to support the reason(s) for completing the experiment. Closes the loop on the Introduction.	
General Formatting	1-10		Answers to questions clearly labeled. The overall appearance of the report is professional.	

Appendix A: Good Report Example

Name/NetID: ntesla2 Teammate: Georg Ohm

Notes:

Learning Objectives:

In this experiment, you will characterize the current-voltage relationship of a standard DC motor. As you will see the behavior of the motor being driven with different voltages is interesting and complex. As a device that can convert electrical energy from a battery to mechanical rotation or vice versa the current-voltage relation is highly nonlinear. When including motors in a design, an understanding of the response of the motor to a range of voltages is crucial when designing the circuitry that drives the motor.

Procedures

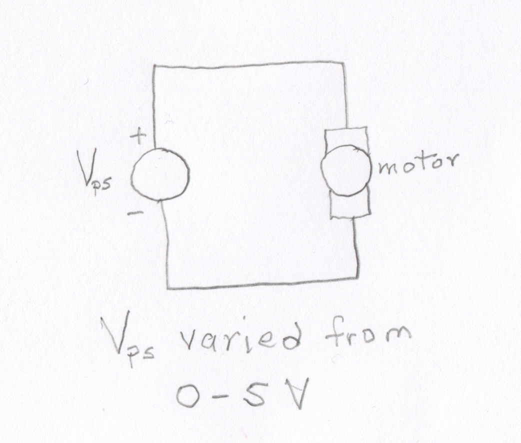
- ✓ Connect circuit as shown in Figure 1.
- ✓ Use the box with alligator clips (test box) to connect the power supply with your motor.
- ✓ Make sure that the output on the power supply is set to “off” when you are constructing or making changes to your circuit.

Notes:

Figure 1: Circuit schematic and photo of the variable voltage source motor drive method.

Before you begin taking measurements using your motor, it’s good practice to perform a quick test run. The motors respond nonlinearly so you need observe, qualitatively, how the motor reacts to different voltages. This will allow you to chose your data points carefully to capture the interesting behavior.

Question 1: Draw a schematic of your test setup.



V_{ps} varied from 0 – 5 V

Question 2: Starting at zero volts, sweep the voltage of the power supply from 0 to 5V, and make note of the approximate voltage at which the motor begins to spin.

The motor starts to spin at ~1.4V though is sounds like it is trying to spin at lower voltages. After turn-on the motor speed increased as the voltage increased until it seemed to max out as we approached 5V.

Motors exhibit **hysteresis** meaning that *the current state of the motor depends on its history*. You will find that when the supply voltage is too low, the motor will not turn because static friction and electromagnetic forces initially oppose the motion. When driven with sufficient voltage the motor will begin to turn. Once the motor is turning if the voltage is decreased, the motor will not “stall” at the same voltage level because kinetic friction is smaller than static friction so the rotational kinetic energy is dissipated more slowly and the electromagnetic forces again oppose the change.

Question 3: Starting from 0V again, measure the voltage and current of the motor at increments no larger than 0.5V. Be sure to use smaller increments before and after the turn-on voltage you recorded in 0. Record measurements in the table below. Make sure to note when you see a change in behavior in the motor (i.e. “motor whines audibly but doesn’t move”, “motor starts to spin”, etc.). **NOTE:** Since the motor behavior exhibits hysteresis it is important that you collect your data in a *forward direction*. If you need to go back and collect a certain data point, you need to start over from 0V

Voltage (V)	**Current (A)**	**Comments:**
0.000	0.000	Power supply is off
0.300	0.034	
0.601	0.067	
0.902	0.101	
1.202	0.134	Motor is starting to make noise
1.301	0.143	Smaller increments to catch the turn on voltage

Notes:

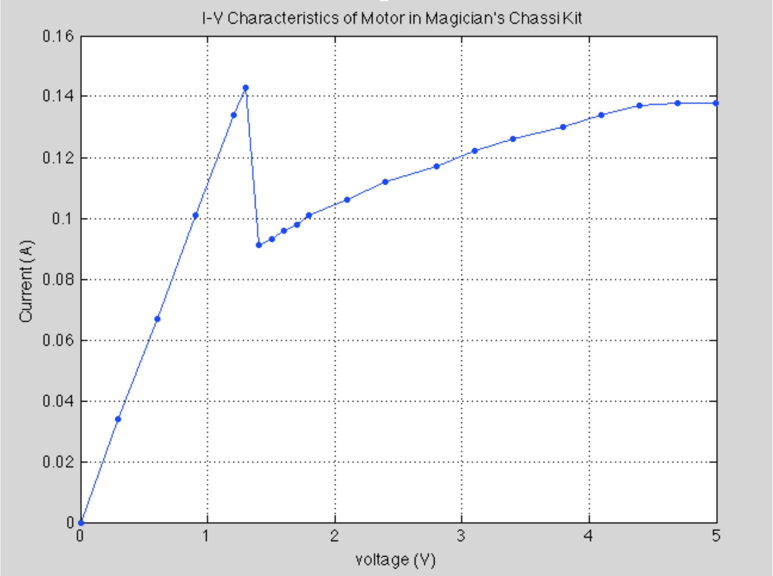
While we were turning the voltage up we could hear the motor trying to turn. After finding the turn on voltage we started over and found that we could get the motor turning at a lower voltage if we spun it by hand.

1.401	0.091	Motor begins to spin slowly
1.501	0.093	Motor speed begins to increase with voltage
1.601	0.096	
1.701	0.098	
1.801	0.101	
2.101	0.106	
2.401	0.112	
2.801	0.117	Accidentally took a larger increment
3.101	0.122	
3.400	0.126	
3.799	0.130	Accidentally took a larger increment
4.098	0.134	
4.397	0.137	
4.696	0.138	Motor speed seems to have maxed out
4.995	0.138	

Table 2: Current flow for the motor for increasing DC voltage with comments.

Question 4: Use MATLAB to generate a plot for the IV characteristics using the data you collected.

Notes:



MatLab code used to create plot

```
%enter data into arrays

>>voltage=[0,0.3,0.601,0.902,1.202,1.301,1.401,1.501,1.601,1.701,1.801,2.1,2.4,2.8,3.1,
3.4,3.799,4.098,4.397,4.696,4.995];

>>current=[0,0.034,0.067,0.101,0.134,0.143,0.091,0.093,0.096,0.098,0.101,0.106,0.112,0.
117,0.122,0.126,0.130,0.134,0.137,0.138,0.138];

%plot current as a function of voltage using a blue line with blue dots

>>plot(voltage,current,’b.’)

>>hold on
```

Notes:

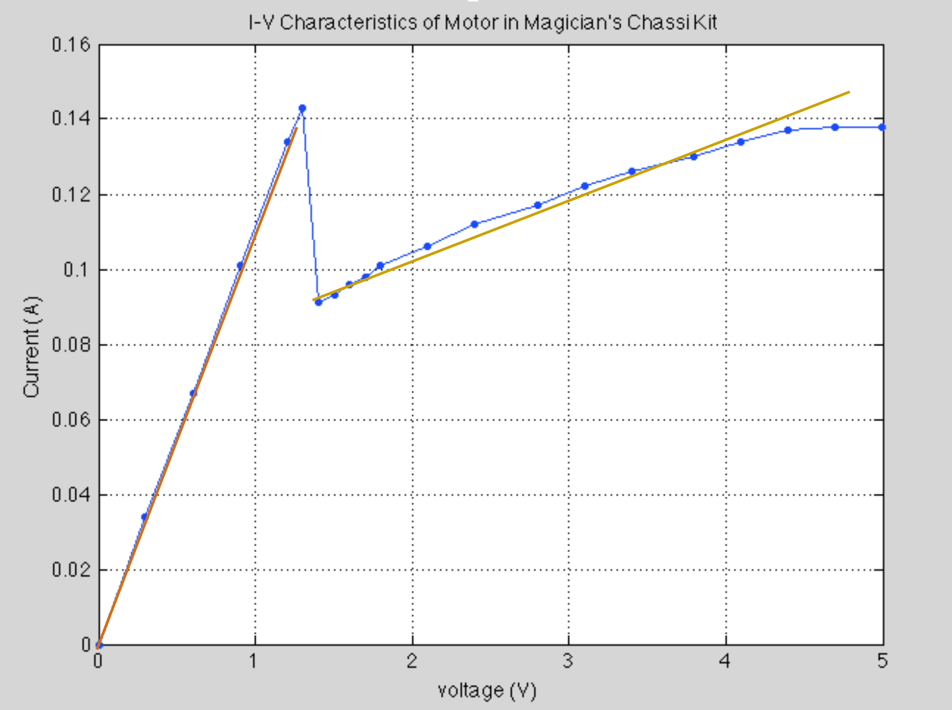
```
>>plot(voltage,current,'b')

>>xlabel('Voltage (V)')

>>ylabel('Current (A)')

>> title('I-V Characteristics of Motor in Magician's Chassis Kit')
```

Question 5: Describe in words the behavior of the motor when the voltage is increased. Explain all of the interesting features shown by the graph.

Initially, before the voltage across the motor terminal reach ~1.4 volts the motor did not spin. We could hear it trying to spin around 1V. Though the motor was not moving it was still drawing current from the battery with the voltage and current linearly related. We did try to get it to spin when we were doing question 2 at lower voltages and we were successful. Once the motor started moving the current-voltage relationship was monotonically increasing in a linear manner.

Notes:

Question 6: If your graph was done properly the resulting curve should have two regions where the current-voltage relations in approximately linear. Draw two lines that fit the data in these two regions.



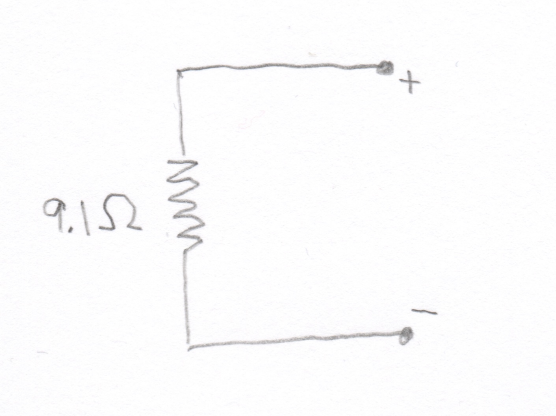
As an engineer designing a circuit to control a motor there are two important issues: 1) power consumption, and 2) keeping the motor operating using voltage levels that keep it as far as possible from the turn on and stall voltages. These next few questions aim to help you determine the optimal operating range for these motors that will be an integral part of your designs.

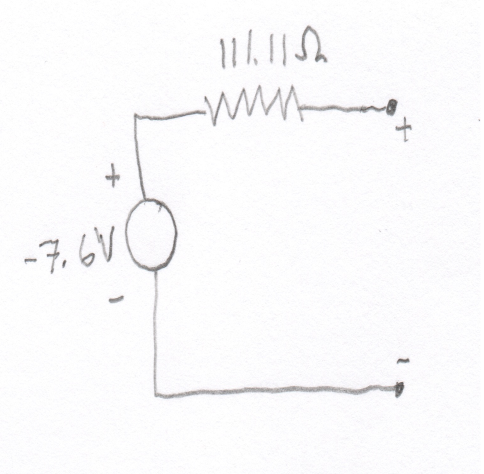
Question 7: Determine a linear equation (slope-intercept form) corresponding to each of the lines you drew on the graph in question 6.

Stalled (0-1.14V) $I = 0.11V$

Freely turning (1.14-5V) $I = 0.009V + 0.068$

Question 8: Using these two linear equations, determine the equivalent circuit for a motor in these two regions – the stall region where the motor is not turning but drawing current, and the region where the motor turns freely.





In the regions of the current-voltage relation that are linear the motor behaves (and can be modeled) as a resistive device. The linear relationship that describes the current-voltage behavior while the motor is spinning also shows that as an electromagnetic device it can be source.

Optimal use of battery resources dictates that you not expend energy in the regions where the motor draws power but does not turn.

Notes:

Question 9: How much power is drawn from the power supply just below the turn-on voltage?

Near the point where the motor begins turning V=1.14V and I=.143A therefore the power P=V*I=.1630W.

Now suppose the design requirements dictate that the motors must be turned on and off. In addition, it might be imperative that the speed be controlled as well – the speed of the vehicle driven by the motors, once the motors are freely rotating, is approximately, linearly related to the voltage. To satisfy these two requirements while conserving battery life a strategy that you will experiment with extensively in up-coming labs called Pulse Width Modulation (PWM) is commonly used for these applications. Instead of changing the voltage linearly at a voltage above the turn-on voltage, PWM uses only two voltage levels 0V and some voltage below that maximum rated voltage but way above the turn-on voltage alternately.

Question 10: Discuss what would happen if the voltage applied to the motor varied between 0 and 5V very slowly. What would happen if the voltage varies quickly? How might this be used to control the speed?

If the motor is turned on and off slowly enough the motor would come to a complete stop. The vehicle would move but very slowly. As the rate at which the voltage is turned on and off increases the motor will no longer stop completely moving the vehicle at a steady rate. The rate must be fast enough so that the motor remains running all the time. To change the speed of the vehicle the amount of time the voltage remains high must change. If the voltage were high all of the time the motor would run a full speed al the time.

Notes:

Appendix B: Poor Report Example

Name/NetID: Tom Edison/tedison Teammate: none

Learning Objectives:

In this experiment, you will characterize the current-voltage relationship of a standard DC motor. As you will see the behavior of the motor being driven with different voltages is interesting and complex. As a device that can convert electrical energy from a battery to mechanical rotation or vice versa the current-voltage relation is highly nonlinear. When including motors in a design, an understanding of the response of the motor to a range of voltages is crucial when designing the circuitry that drives the motor.

Procedures

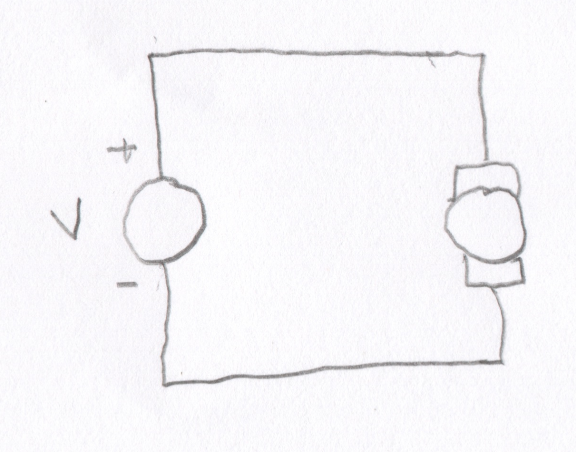
- ✓ Connect the circuit as shown in Figure 1.
- ✓ Use the box with alligator clips (test box) to connect the power supply with your motor.
- ✓ Make sure that the output on the power supply is set to “off” when you are constructing or making changes to your circuit.

Figure 1: Circuit schematic and photo of the variable voltage source motor drive method.

Notes:

Before you begin taking measurements using your motor, it's good practice to perform a quick test run. The motors respond nonlinearly so you need observe, qualitatively, how the motor reacts to different voltages. This will allow you to chose your data points carefully to capture the interesting behavior.

Question 1: Draw a schematic of your test setup.



Notes:

Question 2: Starting at zero volts, sweep the voltage of the power supply from 0 to 5V, and make note of the approximate voltage at which the motor begins to spin.

The motor starts to spin at ~1.4V.

Motors exhibit **hysteresis** meaning that *the current state of the motor depends on its history*. You will find that when the supply voltage is too low, the motor will not turn because static friction and electromagnetic forces initially oppose the motion. When driven with sufficient voltage the motor will begin to turn. Once the motor is turning if the voltage is decreased, the motor will not "stall" at the same voltage level because kinetic friction is smaller than static friction so the rotational kinetic energy is dissipated more slowly and the electromagnetic forces again oppose the change.

Question 3: Starting from 0V again, measure the voltage and current of the motor at increments no larger than 0.5V. Be sure to use smaller increments before and after the turn-on voltage you recorded in 0. Record measurements in the table below. Make sure to note when you see a change in behavior in the motor (i.e. "motor whines audibly but doesn't move", "motor starts to spin", etc.). **NOTE:** Since the motor behavior exhibits hysteresis it is important that you collect your data in a *forward direction*. If you need to go back and collect a certain data point, you need to start over from 0V

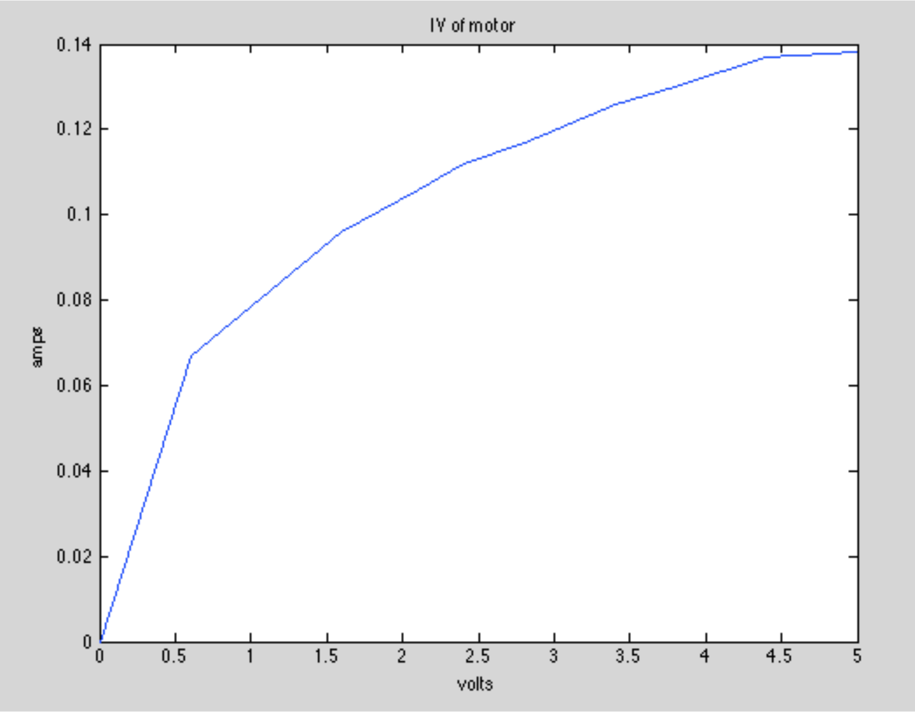
Voltage (V)	**Current (A)**	**Comments:**
0.000	0.000	Power supply is off
0.601	0.067	

Notes:

1.601	0.096	Motor is running
2.101	0.106	
2.401	0.112	
2.801	0.117	
3.400	0.126	
3.799	0.130	
4.397	0.137	
4.995	0.138	

Table 3: Current flow for the motor for increasing DC voltage with comments.

Question 4: Use MATLAB to generate a plot for the IV characteristics using the data you collected.



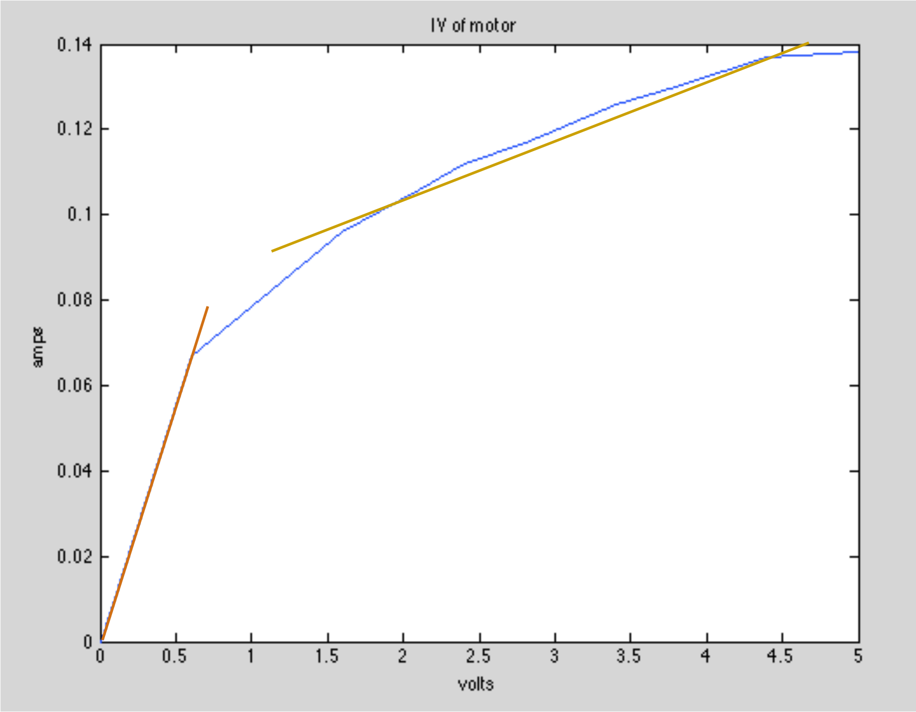
Question 5: Describe in words the behavior of the motor when the voltage is increased. Explain all of the interesting features shown by the graph.

At low voltages the motor did not turn but eventually started spinning once the voltage exceeded 1.4V. With increasing voltage it spins faster.

Notes:

Our plot seems to be missing some of the features described in the questions or in the other students' graphs. Our voltage increment might be too large.

Question 6: If your graph was done properly the resulting curve should have two regions where the current-voltage relations in approximately linear. Draw two lines that fit the data in these two regions.



As an engineer designing a circuit to control a motor there are two important issues: 1) power consumption, and 2) keeping the motor operating using voltage levels that keep it as far as possible from the turn on and stall voltages. These next few questions aim to help you determine the optimal operating range for these motors that will be an integral part of your designs.

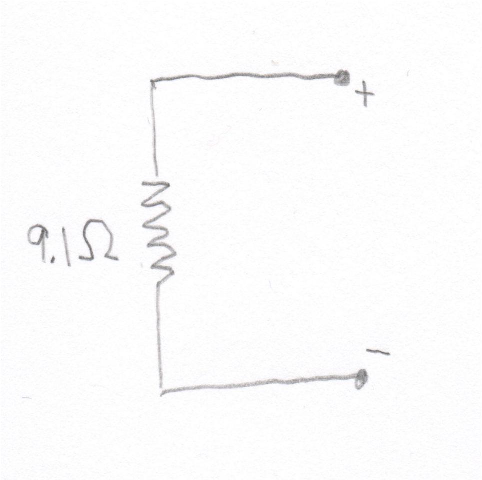
Notes:

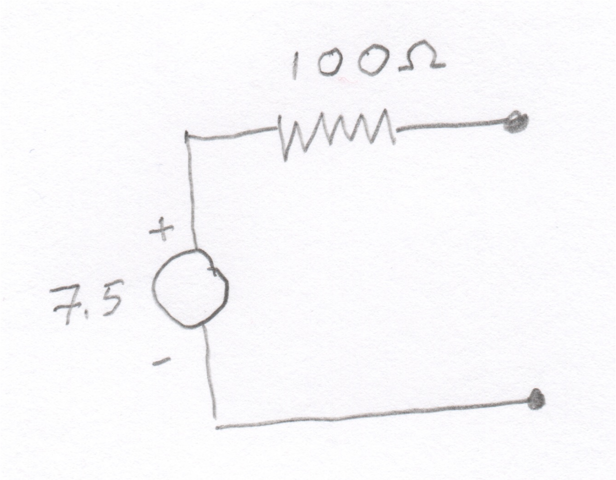
Notes:

Question 7: Determine a linear equation (slope-intercept form) corresponding to each of the lines you drew on the graph in question 6.

$$I = 0.11V \qquad I = 0.01V + 0.075$$

Question 8: Using these two linear equations, determine the equivalent circuit for a motor in these two regions – the stall region where the motor is not turning but drawing current, and the region where the motor turns freely.





In the regions of the current-voltage relation that are linear the motor behaves (and can be modeled) as a resistive device. The linear relationship that describes the current-voltage behavior while the motor is spinning also shows that as an electromagnetic device it can be source.

Optimal use of battery resources dictates that you not expend energy in the regions where the motor draws power but does not turn.

Question 9: How much power is drawn from the power supply just below the turn-on voltage?

Notes:

It is hard to tell from the graph - near the point where the motor begins turning V=1.14V and I=.090A therefore the power P=V*I=.1026W.

Now suppose the design requirements dictate that the motors must be turned on and off. In addition, it might be imperative that the speed be controlled as well – the speed of the vehicle driven by the motors, once the motors are freely rotating, is approximately, linearly related to the voltage. To satisfy these two requirements while conserving battery life a strategy that you will experiment with extensively in up-coming labs called Pulse Width Modulation (PWM) is commonly used for these applications. Instead of changing the voltage linearly at a voltage above the turn-on voltage, PWM uses only two voltage levels 0V and some voltage below that maximum rated voltage but way above the turn-on voltage alternately.

Question 10: Discuss what would happen if the voltage applied to the motor varied between 0 and 5V very slowly. What would happen if the voltage varies quickly? How might this be used to control the speed?

If the motor is turned on and off slowly enough the motor would come to a complete stop. The vehicle would move but very slowly. As the rate at which the voltage is turned on and off increases the motor will no longer stop completely moving the vehicle faster and faster.