Introduction:

In this lab, we observed the ohmic and non-ohmic behaviors of certain conductors by experimentally measuring the resistance of each device to verify whether they obey Ohm's Law or not. The term "***ohmic***" refers to a conducting device that obeys Ohm's Law whereas a ***non-ohmic*** device does not obey Ohm's Law.

Ohm's Law is an assertion that the current (i) through a device is always directly proportional to the potential difference (V) applied to the device (Halliday) – Equation [1]. The proportionality constant of Ohm's Law is related to the material's resistance (R) – Equation [2]. Electric resistance is a property of an object that measures the ability to impede an electric current.

[1] $i \propto V$

[2] $i = (\frac{1}{R})V$ or $V = iR$

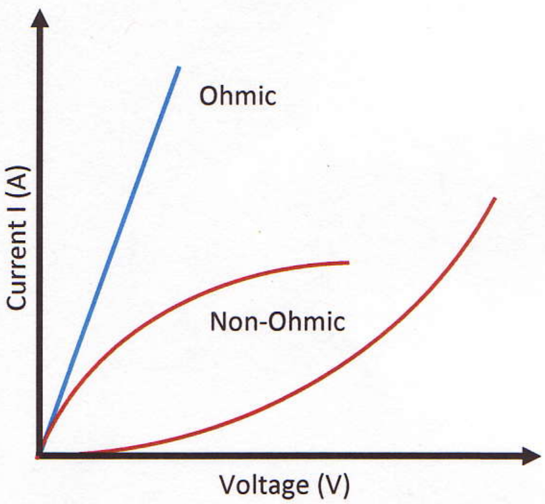
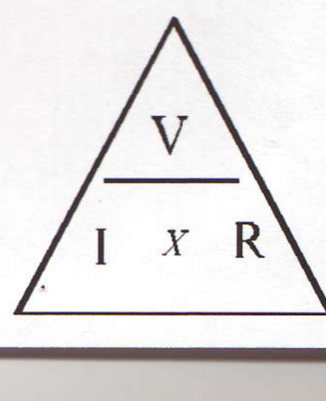


Figure 1: Ohmic vs. Non-Ohmic

When an element is ohmic, the resistance of that material is constant for all values of V. This means that the resistance is independent of the applied potential difference. As a result, a voltage vs. current graph will yield a linear curve like the one displayed in figure 1.

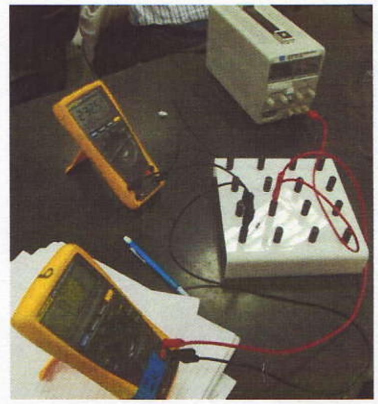
By contrast, a non-ohmic material possesses a resistance that is not constant; the resistance depends upon the value of V and changes. This will yield a non-linear curve like the ones displayed in figure 1.

Throughout this lab, we investigated the ohmic behavior of 2 different resistors, a light bulb and a diode. For each device, we measured the current at different voltages and then we compared the resistance in order to determine whether or not they followed Ohm's Law.



Equipment:

- Power supply
- 1 kΩ resistors (four)
- 22 Ω resistor
- 6.3 V light bulb
- Diode
- Breadboard
- Wires
- Digital multimeters(2)



Procedure:

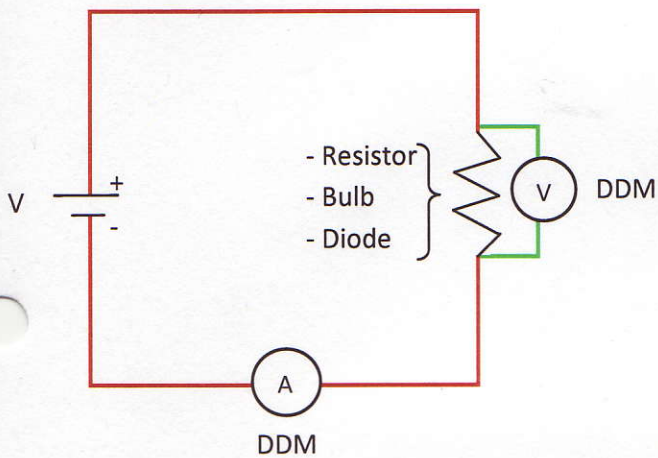


Figure 2: Electric Circuit

Building the Circuit

For each part of the lab you must construct the simple circuit that is displayed in figure 2. Using the breadboard, the power supply is connected to the device by a series of wires. Two digital multimeters (DDM) are also attached to the circuit: One is attached to the device and is set on voltmeter; this records the potential difference (V) of the device. The other DDM is attached into the circuit and set in amp-meter; this records the current.

Part 1A: 1 kΩ Resistor

a) Construct the circuit above using a 1 kΩ resistor

b) Adjust the power supply to an initial voltage of 1.0V. While record both voltage and current through the resistor, increase the voltage by increments of 1.0V until you reach 10.0 V.

c) At a 10V potential difference, watch the current meter for 30s. Q: Does the current through the resistor change? What does this tell you about the temperature of the resistor?

d) Reverse the polarity and check the current for a few different voltages. Q: Does the polarity of the voltage across the resistor make any difference in the current through the resistor?

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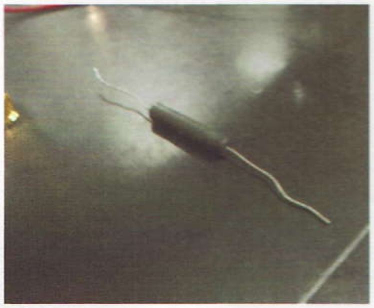
e) Q: Is the resistor ohmic or non-ohmic? How do you know?



f) Calculate Resistance (R_{exp}). Use a percent difference to compare R_{exp} to R_{theor}.

Part 1B: 22 Ω Resistor

a) Construct the circuit above using a 22 Ω resistor.

b) Starting at 0.5V, record both the voltage and current at increments of 0.5V until you reach 5.0V

c) Increase to 10V and observe for 30s. Q: Does the current through the resistor change during the 30s? What does this tell you about the temperature of the resistor?

d) Q: When lowering the voltage down to 1.0V, is the current the same? Why or why not?

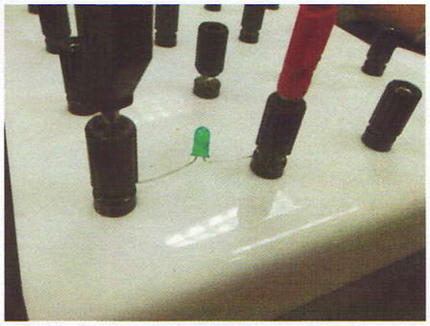
e) Q: From your results, can you conclude that all resistors obey Ohm's law? Is the resistance of all resistors constant? If not, when can you assume that the resistance of a resistor is constant?

Part 2A: 6.3V Light Bulb

a) Construct the circuit above using a 6.3V Light bulb.

b) Starting at 0.5V, record both the voltage and current at increments of 0.5V until you reach 5.0V.

c) Q: Is the light bulb ohmic or non-ohmic? How do you know? Does the light bulb filament have a constant resistance? Why or why not?



Part 2B: Light Emitting Diode (LED)

a) Construct the circuit above using an LED

b) Starting at a voltage of 1.75V, is there any current flowing through the LED? When polarity is reversed, is there any current?

c) Adjust the voltage so that an initial current flows through the LED.

d) At increments of 0.5V, record the voltage and current for about 10-20 values between 1.5V and 2.0V. Q: What is the turn-on voltage of the LED?

e) Q: Is the LED ohmic or non-ohmic? How do you know?

Data:

Part 1A: 1 kΩ Resistor

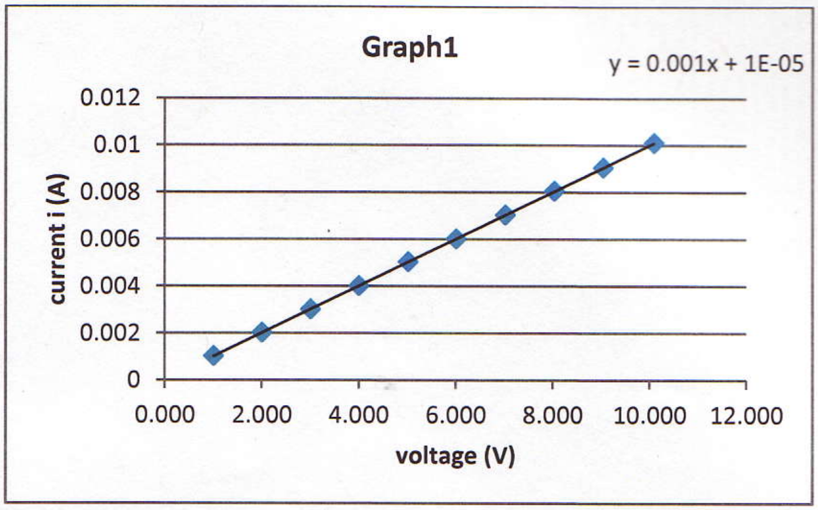
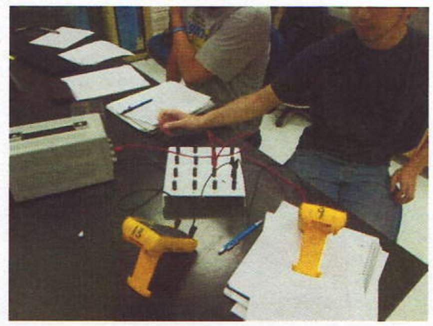
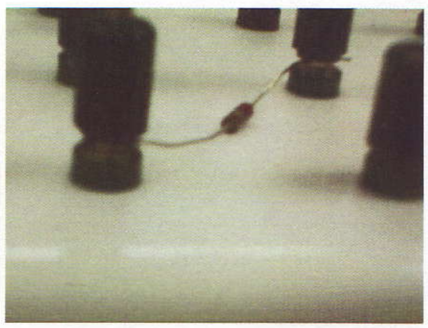


Table 1

Voltage(V)	Current i (A)
1.006	0.00102
2.003	0.00202
3.004	0.00301
4.003	0.00401
5.015	0.00503
6.005	0.00601
7.020	0.00703
8.030	0.00805
9.040	0.00904
10.090	0.01010

R_{exp} = 1000.00Ω = 1kΩ
% Diff = 0%

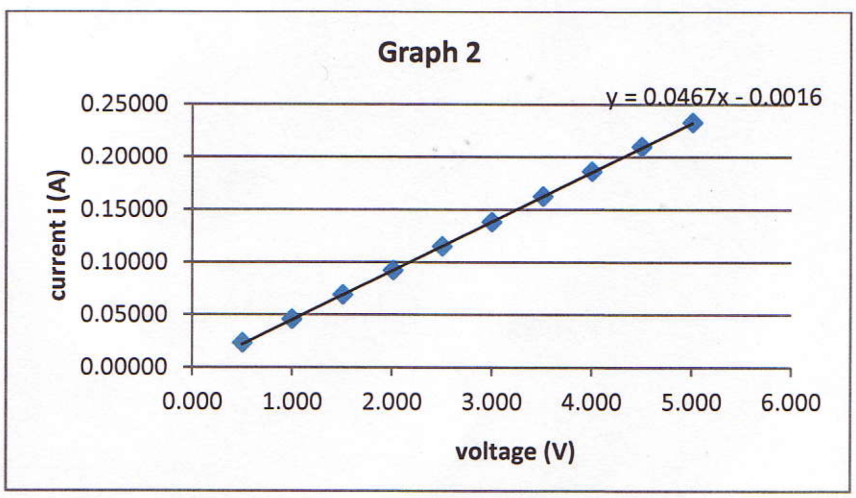




Part 1B: 22 Ω Resistor

Table 2

Voltage(V)	Current i (A)
0.501	0.02272
0.997	0.04523
1.507	0.06860
2.010	0.09170
2.503	0.11460
2.998	0.13790
3.510	0.16220
4.002	0.18580
4.500	0.20950
5.009	0.23240

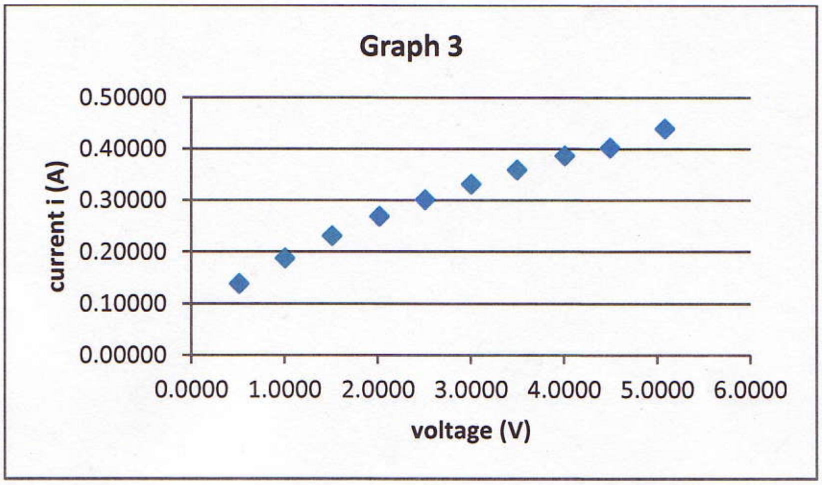


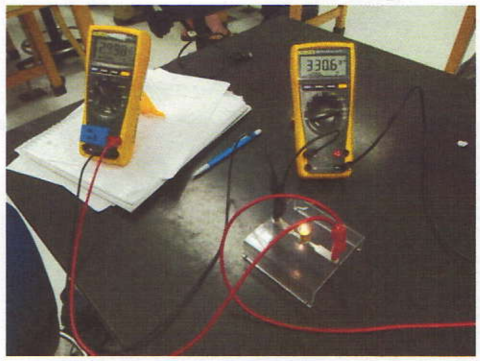
R_{exp} = 21.41 Ω
%Diff = 2.68%

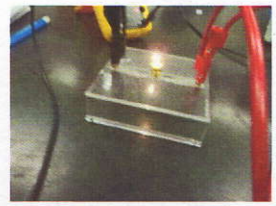
Part 2A: 6.3V Light Bulb

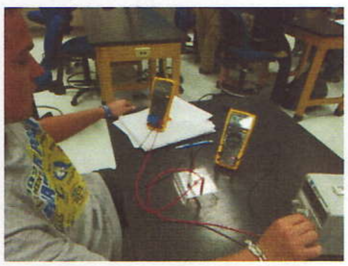
Table 3

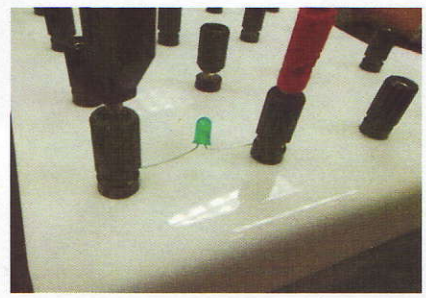
Voltage(V)	Current i (A)
0.5100	0.13790
1.0030	0.18700
1.5080	0.23000
2.0160	0.26780
2.5060	0.30050
3.0000	0.33080
3.4920	0.35870
4.0050	0.38620
4.4910	0.40130
5.0800	0.43850







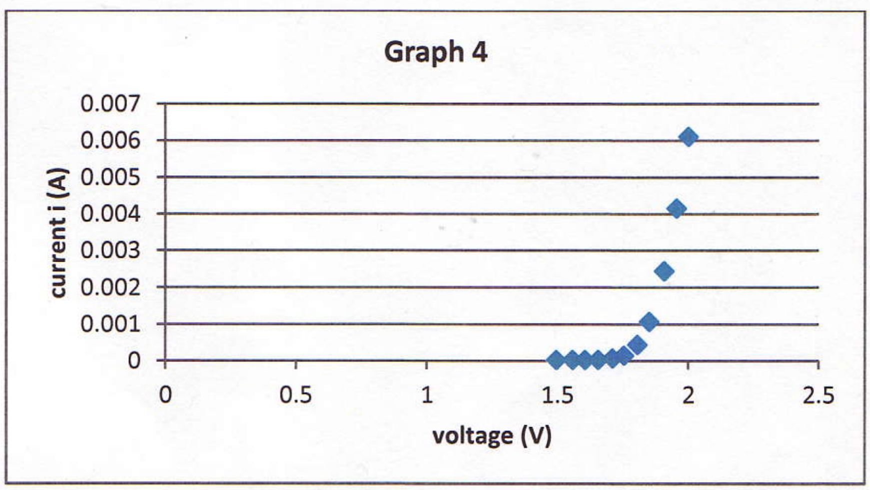




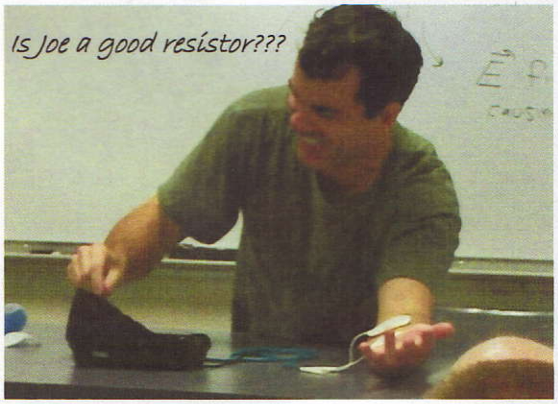
Part 2B: Light Emitting Diode (LED)

Table 4

Voltage(V)	Current i (A)
1.494	0.00002
1.557	0.00002
1.604	0.00002
1.654	0.00002
1.709	0.00006
1.754	0.00014
1.805	0.00044
1.850	0.00106
1.907	0.00244
1.955	0.00415
2.000	0.00610



Data Analysis:



Sample Calculations

Resistance (Part 1A) $R_{exp} = \frac{1}{slope} = \frac{1}{0.001} = 1000\Omega = 1k\Omega$

% Diff (Part 1A) $\%Diff = \frac{|actual| - |exp|}{|actual|} = \frac{1k\Omega - 1k\Omega}{1k\Omega} = 0\%$

Questions

- *Part1A.c): Does the current through the resistor change? What does this tell you about the temperature of the resistor?* The current does not change after waiting 30s at a constant 10V through the 1kΩ resistor. This means that the temperature of this resistor is fairly constant even with a high potential difference being applied to it.
- *Part1A.d): Does the polarity of the voltage across the resistor make any difference in the current through the resistor?* When reversing the polarity of the voltage across the resistor, the magnitude of the current stayed the same, but the sign switched. This indicates that current has a direction and is now moving in the opposite direction.
- *Part1A.e): Is the resistor ohmic or non-ohmic? How do you know?* The resistor is clearly ohmic because the curve on the voltage/current graph is linear. A linear curve means the resistance is constant and therefore, the resistor is ohmic.
- *Part 1A.f): Calculate Resistance (R_{exp}). Use a percent difference to compare R_{exp} to R_{theor}.*

  R_{exp}=1kΩ → %Diff = 0%
- *Part1B.c): Does the current through the resistor change during the 30s? What does this tell you about the temperature of the resistor?* During the 30s, the current was decreasing. This indicates that the temperature of the resistor was increasing because a higher temperature would excite the atoms in the conductor; as a result, the atoms will impede some of the current. Resistance has increased.

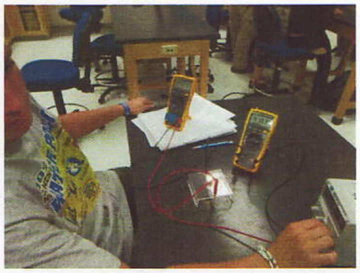
- *Part1B.d): When lowering the voltage down to 1.0V, is the current the same? Why or why not?* The current stayed the same when we lowered the voltage back down to 1.0V. This is because there was not enough voltage (energy) to heat up the atoms and increase the resistance.
- *Part1B.e): From your results, can you conclude that all resistors obey Ohm's law? Is the resistance of all resistors constant? If not, when can you assume that the resistance of a resistor is constant?* From our results, we concluded that the resistance of all resistors is constant to a certain degree. They seem to obey Ohm's law at low voltages when there is not enough voltage to heat up the conductor. Once the temperature of the resistor increases, then the resistance increases and less current passes through.
- *Part2A.c): Is the light bulb ohmic or non-ohmic? How do you know? Does the light bulb filament have a constant resistance? Why or why not?* The light bulb is non-ohmic because the curve on the voltage/current graph is non-linear. It seems as though less current is able to pass through as we increased the voltage. This indicates that the resistance is not constant and increases as more voltage is added and the light bulb heats up.
- *Part2B.b): Starting at a voltage of 1.75V, is there any current flowing through the LED? When polarity is reversed, is there any current?* There was no current flowing through the LED at 1.75V. Even when the polarity was reversed, no current was present in the LED.
- *Part2B.d): What is the turn-on voltage of the LED?* The turn-on voltage was about 1.7V
- *Part2B.e): Is the LED ohmic or non-ohmic? How do you know?* The LED was non-ohmic because the curve on the voltage/current graph was non-linear. There was no current going through the LED for small amounts of voltage. As more voltage was added, more and more current was passing through. The current was exponentially increasing and therefore, the resistance was decreasing.

Discussion/Conclusion:

Throughout the lab, we were successful in mapping out the ohmic and non-ohmic behaviors of 2 different resistors, a light bulb and a diode. For each conductor, we plotted the current with respect to different values of potential difference. By doing this, we were able to determine the resistance and whether or not they obeyed Ohm's Law. We also looked at polarity and heat as factors that affect resistance.

When testing the 1 kΩ resistor, we determined it does in fact obey Ohm's law; the linear curve that it formed indicates that the current is directly proportional to the potential difference and therefore, the resistance of the device is independent of the applied potential difference. Furthermore, when switching the polarity, the sign of the current and voltage changed, but this will still yield the same resistance. Therefore, this resistor is independent of the direction of the applied E-field.

By contrast, we tested a 22 Ω resistor and it produced similar results. The linear curve indicated ohmic behavior, but after a long period of time, the current began to decrease as the resistor heated up. From this, we concluded that most resistors are ohmic until a certain point when there is enough voltage to heat up the resistor. More energy in the resistor will excite the atoms of the conductor and impede the electric current – resistance increases.



When testing the light bulb, we more noticeably saw a non-ohmic behavior. Less current was able to pass through as voltage increased. This resulted in a non-linear curve and the resistance was increasing.

The Light-Emitting Diode was also an example of a non-ohmic conductor. A diode is a device that only allows current to flow in one direction, so when we switched the polarity, we noticed that no current was flowing. A diode also requires a forward voltage. Once this forward voltage is established, more and more current is able to flow through. We determined that the turn-on voltage of the green diode was 1.7V. The current increased exponentially as the potential difference increased; this created a non-linear curve and thus, a non-ohmic behavior. Since the current was increasing exponentially, the resistance was decreasing.

In conclusion, we witnessed the characteristics of ohmic and non-ohmic conductors and we determined that most conducting devices are NOT completely ohmic. Even for seemingly ohmic resistors, there is a point where the resistance changes and Ohm's law no longer applies. Heat plays a big factor in the resistance of a device because as more energy heats up the conductor, less current is able to pass through. The direction in current also plays a factor in some devices like the diode. Therefore, Ohm's Law is a useful tool to use under the right conditions.