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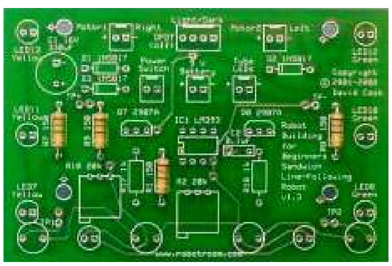
AP Physics C / 2* / Philhour

DC Circuits Lab

Abstract

The purpose of this laboratory was multi-faceted. At its core, we sought to experimentally verify Georg Simon Ohm's Law that the electric potential of a circuit or resistor equals the product of the current flow and the electrical resistance to that flow. More specifically, we familiarized ourselves with the techniques of measuring the resistance of a circuit, physically constructing a circuit with voltmeters in parallel and ammeters in series, and providing conclusive evidence that the resistance of a light bulb increases with the temperature of and power provided to that resistor.

I. Introduction



The practicality of understanding how circuits, electric potential, electricity, resistance, and power interrelate is overtly evident. Whether by watching television, using a cell phone, or typing on the laptop I am currently using, harnessing the power of circuitry and the flow of electrons is an integral component of our everyday lives. Pioneered by one of the premier scientists of the early 19^{th} century (Georg Simon Ohm, shown above), our current fundamental understanding of electricity relies heavily on the relation that $\Delta V = IR$. In conjunction with the derivation of $P = I(\Delta V)$, Ohm's Law is a powerful tool in predicting potential difference, resistance, current, and power in a given circuit. But the question must be asked: just how valid is it? Is there experimental data to verify its correctness?

In order to support the theory, we engaged in four individual, yet related, experiments: 1) Physically measure the resistance of three resistors as the slope of a best-fit line for the graph of electric potential versus current; 2) With the generic schematic given in class, plug in the three resistors and predict the current and potential difference at two given points and compare it to experimentally derived values; 3) To make a plot of electric potential versus current for a light bulb to demonstrate that its resistance varies with its temperature; and 4) To graph the resistance versus power dissipated through the same light bulb as in 3). The materials we used were one analog voltmeter, one analog ammeter, a number of wires with alligator clips, a DC voltage supply, and the program Graphical Analysis 3. We are confident that the methods and results obtained, especially when illustrated graphically, conclusively affirm the validity of the relation $\Delta V = IR$. We hope you become as convinced as we are!

II. Results

Experiment 1: Determining the resistance of three different resistors
(Note: Each of these were produced by placing a voltmeter in parallel and an ammeter in series with a single resistor and then varying the potential difference and current.)

Resistor 1:

	Data Set	
	Current (A)	V (V)
1	0.0290	5.0
2	0.0530	7.5
3	0.0810	10.0
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5		
6		
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8		
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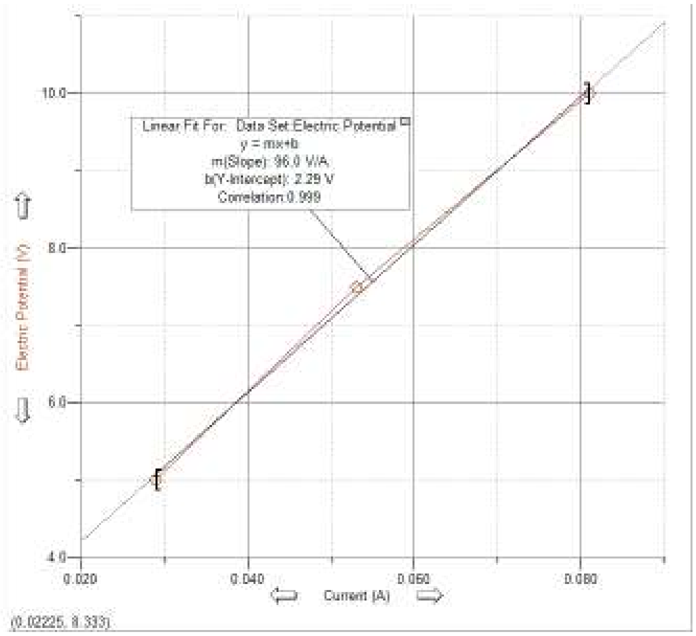

Through the methods outlined above, we experimentally deduced that a 5 V potential difference produced a .029 A current through the resistor, while 7.5 V induced .053 A and 10 V caused .081 A. Using the slope of best-fit line, we observe that the resistance is about 96 Ω (V/A) with very negligible error (.999 correlation).

Resistor 2:

	Data Set	
	Current (A)	V (V)
1	0.011	2.5
2	0.026	5.0
3	0.040	7.5
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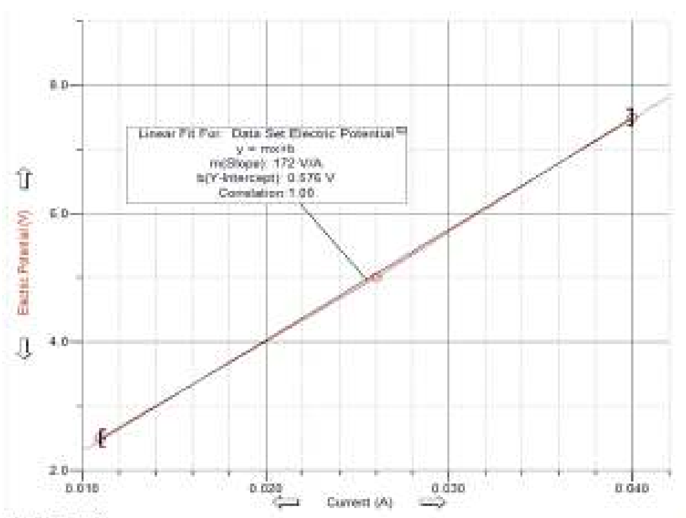
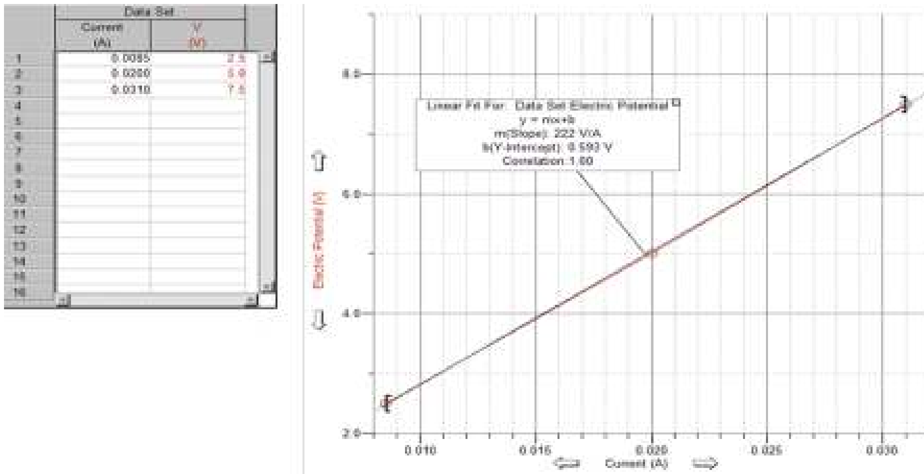


The best-fit line shows this resistance to be 172 Ω (V/A), as compared to the 180 Ω it was listed at.

Resistor 3:

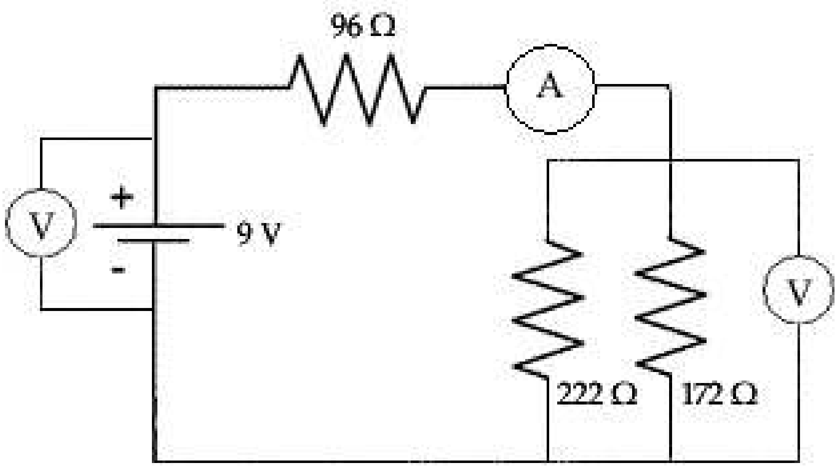


	Current (A)	V (V)
1	0.0085	2.5
2	0.0200	5.0
3	0.0310	7.5

This time, the slope observed is 222 Ω (V/A), with a correlation of 1.00 (sweet!).

Conclusion: Our three resistors are of the order of 96 Ω, 172 Ω, and 222 Ω. Henceforth, we shall use these values in the context of our experiment.

Experiment 2: For a given schematic, comparing the predicted and measured potentials and currents at a given point in the circuit.



The above schematic represents the schematic used in the lab. The notation agrees with standard convention, with V denoting the voltmeter (notice that it is in parallel), A meaning the ammeter (notice that it is hooked up in series), the longer and shorter length plates representing the electric potential source, and the squiggly lines designating the resistors. It is important, prior to the commencement of our calculations, that the 222 Ω and the 172 Ω resistors are in parallel with each other, with their equivalent resistance attached in series to the 96 Ω resistor. This fact will be implied and exploited in the ensuing theoretical calculations.

Theoretical:
Given: $\Delta V_{Tot} = 9$ V; The resistors as shown, with values as indicated.
Firstly, we will find the current through the ammeter. The current through it is equal to the total current of the circuit, so we need the equivalent resistance of the circuit.
$R_{Eq} = 96\ \Omega + [1/(222\ \Omega) + 1/(172\ \Omega)]^{-1} = 96\ \Omega + 96.9\ \Omega = 192.9\ \Omega$
Therefore, the current through the ammeter must be $I_{Tot} = \Delta V_{Tot} / R_{Eq} = 9\ V / 192.9\ \Omega = .047$ A

Now to find the drop in electric potential drop across the two resistors in parallel. To figure this out, note that the total potential drop must equal the potential drop across the 96 Ω resistor plus the potential drop across the parallel component of the circuit. Therefore, if we find $\Delta V_{96\ \Omega}$, we can subtract it from nine and find the potential drop across the 172 Ω and 222 Ω resistors, which will equal the potential across the voltmeter. We proceed as follows:
$\Delta V_{96\ \Omega} = I_{96\ \Omega} R_{96\ \Omega} = (.047\ A)(96\ \Omega) = 4.512$ V, which means the potential we want is:
$\Delta V_{Voltmeter} = \Delta V_{Tot} - \Delta V_{96\ \Omega} = 9\ V - 4.512\ V = 4.488$ V

To determine the percent difference between our theoretical and measured values, we use the formula Percent Difference = | Theoretical – Actual | / ½(Theoretical + Actual) x 100 and the fact that $I_{Measured} = .045$ A and $\Delta V_{Measured} = 4.35$ V
Percent Difference in I = |.047 A - .045 A| / ½(.047 A + .045 A) x 100 = 4.35 %
Percent Difference in ΔV = |4.488 V – 4.35 V| / ½(4.488V + 4.35 V) = 3.12 %

These percent differences are well within the acceptable boundary.

Experiment 3: Verifying that the resistance of a light bulb depends upon temperature.

To demonstrate this point, we will not only show that the electric potential versus current graph for a circuit just containing a light bulb is not linear, but also that the data curves upward. This curvature shows that the slope of the tangent line to the curve will increase as we move from left to right. The slope, which literally represents the resistance, therefore increases. Also note that the error for the quadratic fit is much lower than the constants themselves.

	Data Set	
	Current (A)	Electric Potential (V)
1	0.000	0.0
2	0.050	1.5
3	0.069	2.5
4	0.081	3.5
5	0.095	4.5
6	0.105	5.5
7	0.119	6.5
8	0.129	7.5
9	0.132	8.5
10	0.141	9.5
11	0.152	10.5
12	0.161	11.5
13	0.170	12.5
14	0.179	13.5
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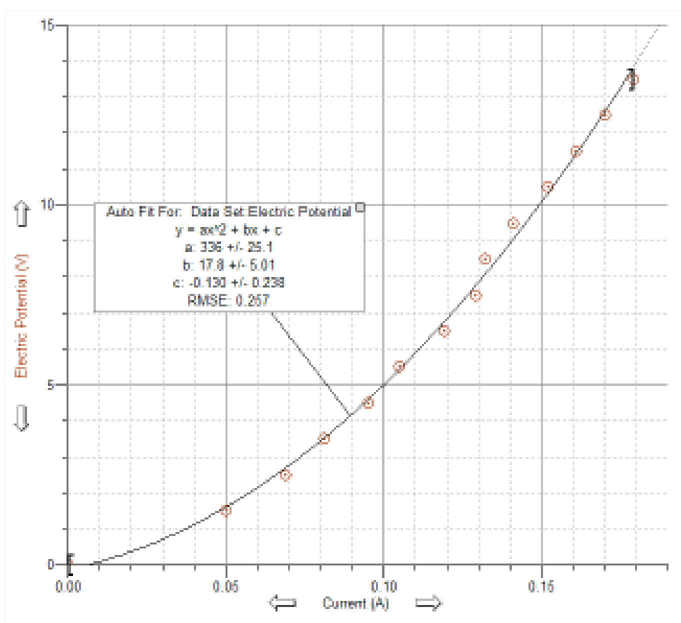

Experiment 4: Graphing Resistance versus Power for the same circuit as in Experiment 3
Based on the values given above, we can figure out the resistance of the bulb and power provided to the light based on the following two equations: R = ΔV / I and P = I(ΔV). Both current and change in electric potential are known from experiment three, so this becomes trivial number crunching. Luckily for you, I did all of that mindless calculator work so you do not have to! A graph of this data clearly demonstrates that as power increases, so too does the resistance of the bulb, which was what we wanted to demonstrate.

	Data Set	
	Power (Watts)	Resistance (Ohms)
1	0.000	0.000
2	0.076	30.000
3	0.173	36.200
4	0.284	43.200
5	0.428	47.400
6	0.578	52.400
7	0.774	54.600
8	0.968	58.100
9	1.122	64.400
10	1.340	67.400
11	1.596	69.100
12	1.852	71.400
13	2.125	73.500
14	2.417	75.400
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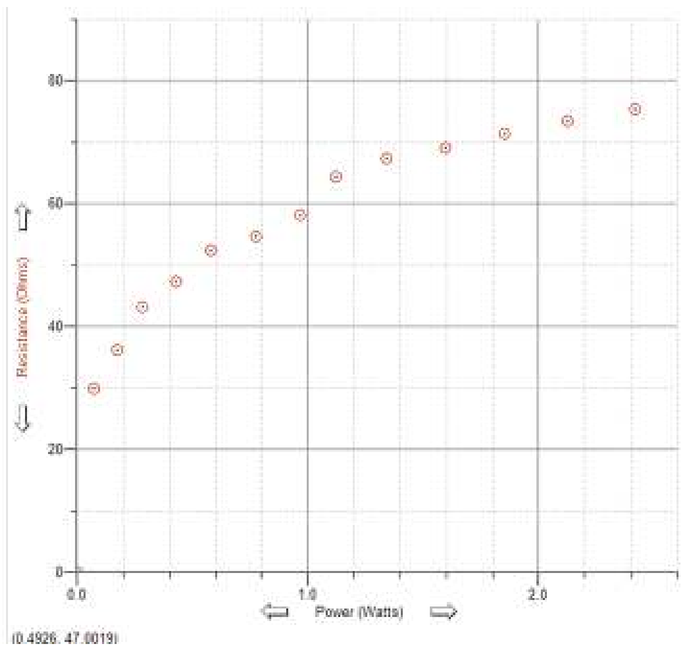

III. Sources Of Error
Significant Figures – As with any experiment, our results are only as reliable as the measuring capabilities of our tools. For the sake of scientific precision, we rounded our results regularly to two or three decimal places; however, this could have produced a slight problem in the accuracy of our data. To combat excessive inaccuracy, we only rounded at the end of a particular calculation, leaving the only approximation in the final answer.

Analog Voltmeter / Ammeter – One of the major disadvantages of using an analog voltmeter and ammeter is that the display does not provide an exact reading. With certain measurements, only good approximations are possible to extract. While we did our best to read out current and electric potential to the best of our ability, there is definitely some error introduced through human interpretation, although clearly the impact was only slight.

Resistance and Temperature – As we have demonstrated, the resistance of an object varies with the temperature of the surrounding environment. Due to a number of trial runs, our resistors may have heated up slightly, in turn altering our measured resistance. This may or may not have affected the resistance that we measured, but if it did, the effect would have been relatively miniscule.