Ohm's Law and Electrical Resistance

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Physics 210L
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CONTENTS

I. INTRODUCTION

THIS experiment will investigate and important property common to all electrical circuits known as resistance. The relationship between resistance, current, and potential difference will be examined and utilized.

Purpose

1) To verify Ohm's Law for a simple resistive DC circuit.
2) To calculate the resistance of an incandescent light bulb from current and voltage measurements, and to compare this to the directly measured value.
3) To measure the current-voltage characteristics of a diode.

II. THEORY

Ohm found that the ratio $R = V/I$ was nearly constant and **nearly independent of the applied voltage** V for many materials. This fact is now called **Ohm's Law**, and is predicted by theory. Note that Ohm's Law is *not* $R = VI$ as is often claimed. This is the **definition of resistance** and is true for all materials. Ohm's Law, on the other hand, makes a strong claim that this ratio is **constant and independent of** V for many (but not all) materials, at least over a limited range of applied current.

Part 1 measures a resistor that behaves linearly and thus obeys Ohm's Law. **Part 2** uses an identical setup to investigate a resistive element whose resistance changes as a function of applied voltage and temperature. **Part 3** examines the IV characteristics of a diode by varying the voltage across it and measuring the current through it.

III. METHODOLOGY

Part 1

1) The resistance of a known resistor was measured with a DMM and recorded, as was the resistance given by its color code.
2) The included circuit was constructed using the known resistor as R.
3) The maximum possible current was calculated to be no more than $150mA$ at the highest possible voltage delivered by the power source, and it was determined that it was safe to set the ammeter to the $430mA$ mode.
4) The power supply was set to a minimum output, and the circuit was activated. 10 ordered pairs for (V, i) were collected for the resistor R over the power supply's voltage range.

Part 2

1) The circuit shown in **Part 1** was rewired to a $60V$ power supply, using a light bulb as the resistor R.
2) The resistance of the light bulb was measured and recorded.
3) The current was slowly increased to find the maximum voltage supplied by the power supply, and then reset to zero volts.
4) Starting from the lowest voltage reading, ordered pairs (V, i) were collected over an approximately $60V$ range.
5) The resistance of the heated light bulb was disconnected from the circuit and again measured and recorded.

Part 3

1) The circuit shown was wired to a $12V$ power supply.
2) With the potentiometer set to the fully counter-clockwise position, ordered pairs for (V, i) were collected as the potentiometer was slowly rotated clockwise. Extra data points were taken over particularly nonlinear regions.
3) The leads from the power supply were reversed, and the voltage was varied in order to obtain values for the diode's reverse current and potential difference.

IV. Data

Part 1

Table I
VOLTAGE AND CURRENT THROUGH KNOWN RESISTOR

Trial	Voltage (V)	Current (mA)
1	2.347	11.7
2	2.400	12.0
3	3.824	19.1
4	6.82	34.0
5	8.53	42.6
6	11.19	55.8
7	13.36	66.7
8	16.89	84.2
9	21.29	106.1
10	22.92	114.2

Measured Resistance (Before Trials): 200.7Ω
Measured Resistance (After Trials): 198.6Ω
Color Code Resistance: 201Ω

Part 2

Table II
VOLTAGE AND CURRENT THROUGH INCANDESCENT LIGHT BULB

Trial	Voltage (V)	Current (mA)
1	2.031	17.2
2	4.56	27.5
3	6.56	34.1
4	9.31	41.9
5	12.81	50.7
6	16.51	58.9
7	20.78	68.2
8	25.96	77.6
9	29.78	84.4
10	34.19	91.7
11	38.38	98.3
12	43.2	105.5
13	48.7	113.3
14	53.8	120.4
15	58.5	126.6

Measured Resistance (Before Trials): 48.2Ω
Measured Resistance (After Trials): 64.3Ω

Part 3

Table III
VOLTAGE AND CURRENT MEASUREMENTS OF DIODE

Trial	Voltage (V)	Current (mA)
1	0.725	29.6
2	0.724	29.0
3	0.723	28.7
4	0.722	28.0
5	0.721	27.6
6	0.720	27.1
7	0.719	26.1
8	0.718	25.5
9	0.717	25.1
10	0.716	24.5
11	0.715	23.6
12	0.714	23.2
13	0.712	22.3
14	0.710	21.5
15	0.708	20.6
16	0.705	19.2
17	0.702	18.2
18	0.700	17.3
19	0.698	16.7
20	0.696	16.1
21	0.695	16.0
22	0.693	15.0
23	0.692	15.2
24	0.690	14.3
25	0.687	13.5
26	0.685	12.9
27	0.682	12.2
28	0.680	11.6
29	0.678	11.1
30	0.675	10.6
31	0.673	10.0
32	0.670	9.5
33	0.667	9.6
34	0.665	8.4
35	0.663	8.1

Table IV
DIODE CIRCUIT MEASUREMENTS WITH REVERSED VOLTAGE

Trial	Voltage (V)	Current (μA)
1	-1.467	-0.1
2	-2.167	-0.2
3	-3.165	-0.3
4	-4.51	-0.4
5	-5.09	-0.5
6	-6.18	-0.6
7	-7.24	-0.7
8	-8.12	-0.8
9	-9.37	-0.9
10	-10.67	-1
11	-12.07	-1.1
12	-13.57	-1.3

Applied Voltage: 11.97 V
Room Temperature: 22.5 °C

V. ANALYSIS, RESULTS, AND CONCLUSIONS

Part 1

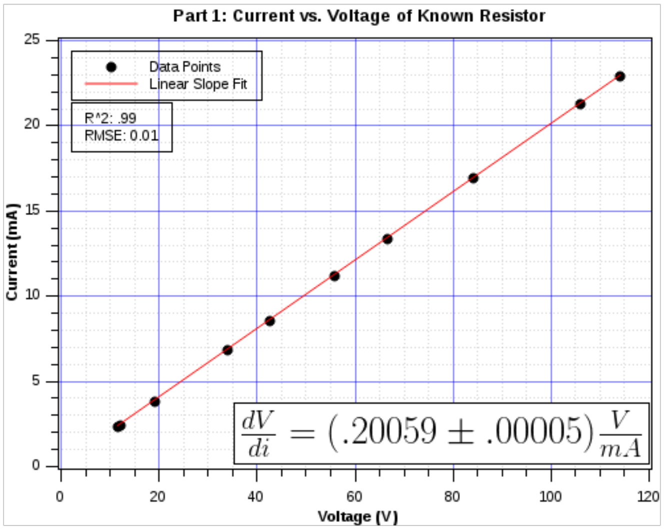

Figure 1. Plot and Linear Fit of Table I Data.

Measured R (Before Trials):	200.7Ω
Measured R (After Trials):	198.6Ω
Percent Change (Before/After):	-1.0%
Measured R_{avg} (Before/After):	199.7Ω
Color Code R:	201Ω
Percent Difference (Color/R_{avg}):	-0.65%
R From Linear Fit:	(200.59 ±.05)Ω
Percent Difference (Fit/R_{avg}):	0.45%

It was found that the measured value of R changed slightly over the course of this portion of the experiment, so two measurements were taken – one before running the trials, and one afterwards. As the resistor heated up, the resistance dropped, and so the average value of these two measurements was used as the measured value of R. In light of the results, the linear fit of current vs. voltage yielded a slightly more accurate value of the resistance R, despite the variance of the resistance while the measurements were taking place.

Part 2

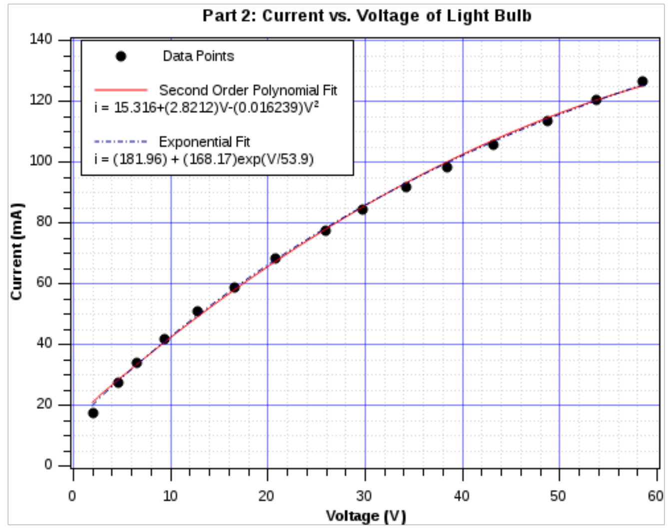

Figure 2. Plot and Various Fits of Light Bulb Voltage and Current

Measured R_{Bulb} (Before Trials):	48.2Ω
Measured R_{Bulb} (After Trials):	64.3Ω
Average R_{Bulb} (Before/After):	56.25Ω

The plotted data shows that the incandescent light bulb departed significantly from the linear relationship $R = i/V$. Line fits were attempted with polynomial and exponential functions, but neither yielded any information that correlated with any physical measurements that were taken. This indicates that the coefficients found may be dependent on a property that was not investigated in this experiment, or that the function that governs the resistive behavior of the bulb is more complicated than the functions used. It is possible that in non-ohmic materials, the resistance could a function of other variables, such as temperature or the rate of power dissipation. Further investigations might include performing similar plots for a wider variety of such materials, and searching for common elements among the resulting functions.

Part 3

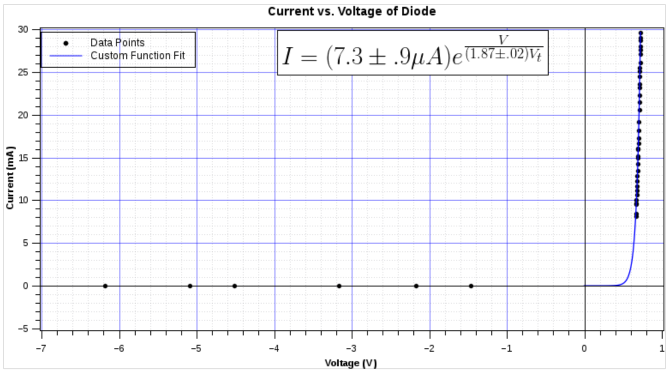

Figure 3. Plot and Custom Fit of Diode Forward and Reverse Voltage/Current

n (From Graph):	$\underline{1.87 \pm .02}$
I_s (From Graph):	$\underline{(7.3 \pm .9)\mu A}$

The diode's measurements were plotted and fitted according to the equation

$$i = I_s\left(e^{\frac{V}{nV_t}} - 1\right) \tag{1}$$

where V_T was set equal to the constant kT/e, while n and I_s were used as fitting parameters. It was expected that the experiment would yield a value for n between 1 and 2, and the results indicated that this was indeed the case. It was also expected that the saturation current would be relatively low, and the fit yielded a value of I_s in the μA range. From the data obtained for the negative voltage, however, it is clear that the current that runs backwards through the diode, while approximately 1000 times smaller than the current flowing through in forward-bias, is still non-zero and increases in proportion to applied voltage. Further experiments to test this behavior might involve increasing the reverse voltage to observe the continuation of the graph's behavior.