

## OHM'S LAW – Sample Report

NAME

SECTION #

Group Members:

### OBJECTIVE

To experimentally verify Ohm's Law through measurement and to confirm findings by comparing measured values with prediction.

### THEORY

Ohm's law states that in a resistive circuit, when the resistance is kept constant, the current through the resistor is directly proportional to the voltage across the resistor.

This is given by the formula:

$$V = I \times R$$

This can also be written as:

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

Thus, if voltage was plotted as a function of the current (voltage on ordinate and current on the abscissa), an ohmic resistor would yield a linear plot with slope equal to the resistance value. Ohm's law may be easily verified in the lab by setting up a simple circuit consisting of a power supply that will supply the voltage, a non-variable resistor and connecting wires. An ammeter can be added in the circuit, in series with the resistor, to measure the current flowing *through* the circuit. A voltmeter can be added parallel to the resistor in order to measure the voltage *across* the resistor. The current and reading measurements taken by the ammeter and voltmeter can be plotted as described and if the graph obtained is linear, with slope close to the resistance value, then Ohm's law will be verified for  $R_1$ .

### MEASURING INSTRUMENTS

Instrument	Least Count	Instrumental Uncertainty	Other Sources of Uncertainty
Voltage Sensor	N/A	N/A	The Voltage readings were read on the computer using DataStudio that had an option to change precision, hence Least Count cannot be established
Current Measurement Unit	N/A	N/A	Showed excessive fluctuation and would not stabilize. Current measurements were taken based on human judgment of stability.
Digital Multimeter (Ohmmeter)	$\pm 0.1 \Omega$	$\pm 1 \Omega$	The measurement was taken by pressing the leads to the ends of the resistor. This method may not have created the best contact, compromising accuracy.

DATA

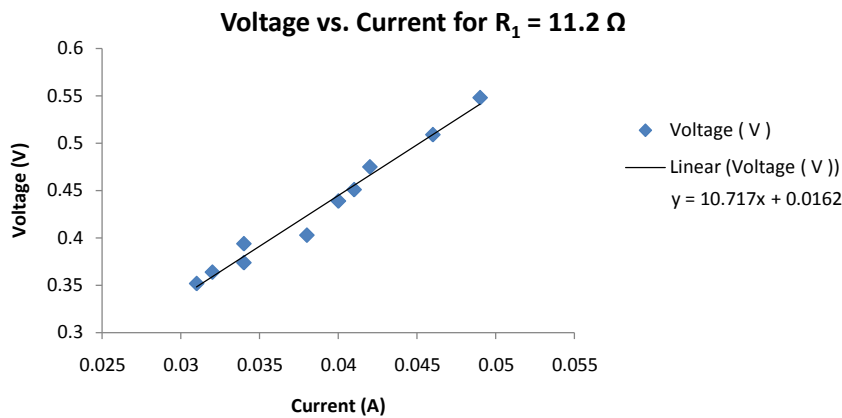
Part 1 Resistance = $11.2 \pm 0.1 \Omega$		Part 2 Resistance = $21.1 \pm 0.1 \Omega$			
DataStudio Slope: $10.8 \pm 0.59 \Omega$		DataStudio Slope: $20.6 \pm 0.61 \Omega$			
Measured Values		Predicted Values		Measured Values	
Voltage (Volts)	Current (Amps)	Voltage (Volts)	Current (Amps)	Voltage (Volts)	Current (Amps)
0.352	0.031	0.352	0.01668246	0.553	0.026
0.364	0.032	0.364	0.01725118	0.621	0.029
0.374	0.034	0.374	0.01772512	0.631	0.03
0.394	0.034	0.394	0.01867299	0.685	0.033
0.403	0.038	0.403	0.01909953	0.715	0.034
0.439	0.04	0.439	0.02080569	0.727	0.034
0.451	0.041	0.451	0.02137441	0.751	0.036
0.475	0.042	0.475	0.02251185	0.793	0.038
0.509	0.046	0.509	0.02412322	0.808	0.038
0.548	0.049	0.548	0.02597156	0.866	0.042

**NOTE:** DataStudio took measurements of time along with measurements of voltage and current. Since these measurements are not time dependent, the column with the time values have not been used in the analysis and have not been included in the data tables.

**Comment [ag1]:** In this section, the complete data has been provided, as was collected during the experiment. But there was extra data collected which was not used anywhere (time data). In this case I have decided to leave it out. This is not always an easy decision to take. So, if in doubt, don't leave it out!

## ANALYSIS

PART 1:



Graph 1: A plot of Voltage as a function of Current, for the circuit with  $R_1 = 11.2 \Omega$  (Part 1). Also shown is a linear fit to the plot.

The slope from the line of best fit of this plot is the measured value of  $R_1$  in the circuit, as analyzed by the excel graphing software. This analysis was also done in the lab using DataStudio which also yielded a value of the slope, as analyzed by the DataStudio graphing software. These values are tabulated below.

Measuring Method	Resistance Value
Ohmmeter	$11.2 \pm 0.1 \Omega$
DataStudio Graphical Analysis	$10.8 \pm 0.59 \Omega$
Excel Graphical Analysis	$10.7 \Omega$

Ideally, all three processes of calculating  $R_1$  should have given the same value. If we consider the ohmmeter reading as most accurate, then any variation from the ohmmeter reading can be due to errors in the experiment when *collecting data*. This is expected because the current values were not entirely stable, which may be because the current sensor was not operated at its optimum current measurement range. This may be seen as a slight spread in the points in graph 1.

Both DataStudio and Excel plotted identical data points and should ideally give the exact same linear fits. Any variation in the slope values from DataStudio and Excel indicates slight differences in the way each software processes the data and calculates the slope. It is not easy to say which software is correct hence the ohmmeter reading of the resistance was considered as the "correct" value of  $R_1$ . Thus, percentage error analysis was done with the ohmmeter reading of  $R_1$  as the reference.

**Comment [ag2]:** For this section, I have followed the lab manual in how I organized the report and then I confirmed with the checklist at the end that I have everything that is necessary.

This checklist is the minimum required and will not tell you to analyze at each point. If you have been asked to plot / calculate / tabulate / compare any data or results, it goes without saying that you must explain what you see in the analysis section and summarize it in the conclusion section.

**Comment [ag3]:** We have purposely not included an error for the excel data because we feel that the  $R^2$  value quoted by excel is not exactly what we understand to be the statistical  $R^2$  value. So till we understand it, we would like to not use it.

Percentage Error Calculations:

$$\frac{|Inaccurate - Accurate|}{Accurate} \times 100 = \% \text{ extent of inaccuracy}$$

DataStudio Analysis :  $\frac{|10.8 - 11.2|}{11.2} \times 100 = 3.57\%$

Excel Analysis :  $\frac{|10.7 - 11.2|}{11.2} \times 100 = 4.46\%$

It is seen that the slopes derived from the DataStudio analysis and Excel analysis are both less than 5% off from the ohmmeter reading.

**Analysis Question 1: Do these Readings fall within the experimental error margin from the instrumental uncertainty?**

Since the ohmmeter reading was selected as the "correct" reading of the resistance, the uncertainty from the ohmmeter ( $\pm 0.1 \Omega$ ) is selected as the instrumental uncertainty for this comparison. The DataStudio slope value and the Excel Slope value fall within  $\pm 0.1 \Omega$  of each other, indicating that the error due to using different graphing softwares is still within our most stringent margin of error. But the slope values still fall well outside the  $\pm 0.1 \Omega$  error margin of the ohmmeter reading. This could either mean that our method of verifying ohm's law and the instruments we used did not give us correct results. It could also mean that we have selected an error margin that is too precise to account for expected experimental errors. If we consider the experimental error margin from the DataStudio analysis ( $\pm 0.59 \Omega$ ), we find that all the readings do fall within this error margin. This error margin accounts for experimental variations due to fluctuations while taking readings so this may be a more reasonable experimental error margin to consider for this experiment.

Thus, considering a reasonable error margin, we have experimentally deduced that V is indeed proportional to I where the proportionality constant is the constant R in the circuit. This was concluded because the plot of V vs. I yielded a straight line with slope that equaled the resistance in the circuit (within an acceptable margin of error).

## PART 2

Calculations: The predicted values for part 2 were calculated using the formula for Ohm's Law, as deduced from part 1:

$$V = I \times R$$

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

Where R was measured using the ohmmeter and voltage values from part 1 were considered for this calculation.

Sample Calculation:  $I = \frac{V}{R} = \frac{0.352V}{21.1A} = 0.016682 \Omega$

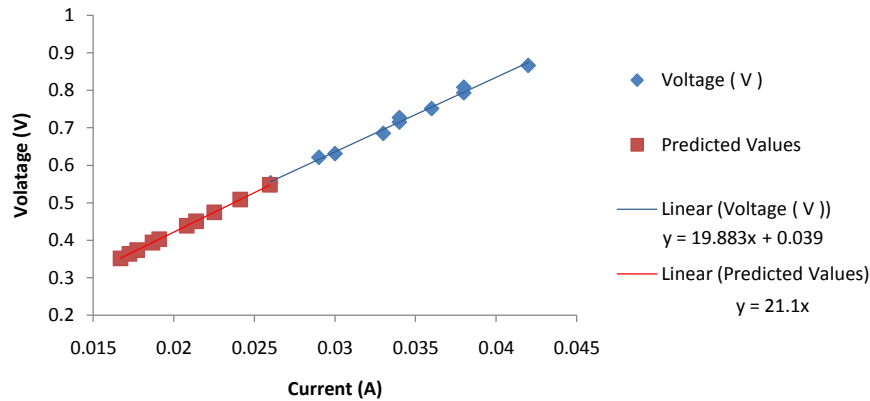
These calculated values have been presented in the data table, to make comparison with the measured readings easier.

**Comment [ag4]:** Calculations: Show formula and then sample calculations. Here I have used a generic form for percentage error. The more specific formula is in your manual. Either may be used.

**Comment [ag5]:** Answer analysis questions where they are found in the lab manual

**Comment [ag6]:** Give the formula used and show sample calculations

### Voltage vs. Current for $R_1 = 21.1 \Omega$ - Predicted and Measured Values



Graph 2: A plot of Voltage as a function of Current, for the circuit with  $R_1 = 21.1 \Omega$  (Part 2). Predicted and measured values along with linear fits are shown in this graph.

From the graph, it is seen that the predicted curve using Ohm's law almost exactly coincides with the experimentally obtained curve. This confirms our understanding of Ohm's law as deduced from Part 1 of the experiment.

**Comment [ag7]:** Comment on the predicted and measured values from the graph

Before beginning this experiment I had predicted that it would not matter which values of voltage were used to calculate the predicted graph. The final graph confirms that what I expected was true. The slope is key in confirming Ohm's law. The slope should be the same irrespective of which data points are selected on the line. In this experiment, the measured values and predicted values selected different ranges of voltage and currents. Nevertheless they all fell on almost the same line, indicating almost the same slopes and almost the same resistance measurements. (Ideally it should have been exactly the same, not almost the same).

The value of the resistor was measured directly by using the ohmmeter and was derived experimentally from the graphical analysis done in DataStudio and in Excel. These readings are tabulated below.

Measuring Method	Resistance Value
Ohmmeter	$21.1 \pm 0.1 \Omega$
DataStudio Graphical Analysis - Predicted	$21.1 \pm 0.08 \Omega$
DataStudio Graphical Analysis - Measured	$20.6 \pm 0.61 \Omega$
Excel Graphical Analysis - Predicted	$21.1 \Omega$
Excel Graphical Analysis - Measured	$19.9 \Omega$

It is seen that the predicted graph slopes match exactly with the ohmmeter reading (confirming the checkpoint 1 in the lab manual). This is expected since the predicted graph data points were calculated

specifically using the ohmmeter value of the resistor. So the slope from the predicted has shown the value used to create the predicted curve.

As with part 1, when doing the percentage error calculations, the ohmmeter reading was selected as the "correct" reading (which in this case is also equal to the predicted graph slope).

Percentage Error Calculations:

$$\frac{|Inaccurate - Accurate|}{Accurate} \times 100 = \% \text{ extent of inaccuracy}$$

$$\text{DataStudio Analysis : } \frac{|20.6 - 21.1|}{21.1} \times 100 = 2.37\%$$

$$\text{Excel Analysis : } \frac{|19.9 - 21.1|}{21.1} \times 100 = 5.69\%$$

The slopes derived from the DataStudio analysis is less than 5% off from the ohmmeter reading but the Excel analysis slope is slightly more than 5% off. This could mean that the excel method of analysis is not as trust worthy as the DataStudio method of analysis. But this can only be confirmed if we consistently see a larger percentage error for the excel values as compared to the data studio values.

If we select the uncertainty from the ohmmeter ( $\pm 0.1 \Omega$ ) as the instrumental uncertainty for comparing the data, then we find that none of the measured values fall within  $\pm 0.1 \Omega$  of each other. If we again assume that the ohmmeter defined error margin is too stringent and we consider the DataStudio defined error margin ( $\pm 0.61 \Omega$ ), the DataStudio derived slope matches the ohmmeter reading within this error of margin. But, the Excel derived slope does not match with either the ohmmeter reading or the DataStudio result. This is because, in addition to the slight differences in the way the 2 softwares analyze data, an obvious outlier point was excluded from the data studio analysis that was retained in the excel analysis which made a difference in the readings.

**Comment [ag8]:** Do these Readings fall within the experimental error margin from the instrumental uncertainty?

**Comment [ag9]:** This may not be true, but I have included it to indicate that when such variations occur in the, analysis they should be mentioned clearly in the report.

#### QUESTIONS:

1. **For a circuit with a constant resistance, what happens to the current as the voltage increases?**

If there is a constant resistance in the circuit, the current is directly proportional to the voltage and will increase as the voltage increases.

2. **For a circuit with a constant resistance, what kind of relationship (e.g., inverse, linear) does the current have to the voltage?**

For a circuit with a constant resistance, current will have a directly proportional and hence linear relationship with voltage. This can be proven by looking at Ohm's law  $V=I \times R$  and also by looking at the graphs of this experiment.

#### CONCLUSION

In this experiment Ohm's law was hypothesized and then confirmed on simple circuits consisting of a power supply, constant value resistors and an ammeter and voltmeter. Ohm's law states that when R is kept constant, V is directly proportional to I. We deduced this behavior in part 1 where we measured current as voltage was varied. A plot of V vs. I then yielded a linear graph whose slope ( $10.8 \Omega$ ) matched

with the resistance value determined using an ohmmeter ( $11.2 \Omega$ ), within an acceptable margin of error. This acceptable margin of error was determined to be the error quoted for the slope in the DataStudio analysis ( $\pm 0.59 \Omega$ ). Ohm's law that was deduced in part 1 was further verified in part two where a graph was predicted and almost exactly replicated (with a 2.37% error in slope) experimentally. This confirms that when R is kept constant, V is indeed proportional to I, given by:

$$V = I \times R$$

While doing this analysis, we also had the opportunity to compare 2 graphing soft-wares and it was discovered that there is an additional source of uncertainty which comes from slight variations in the analysis procedures followed by each software. We could only perform a cursory analysis and have a preliminary conclusion that DataStudio graphical analytic software may be more accurate as compared to Excel. But it may be too early to conclude this from just one experiment.

**Comment [ag10]:** This section is going a little beyond the scope of this lab but I thought it would be an interesting find to comment on. It also serves to illustrate that error is truly an in-exact field and there are many ways in which error can be analysed. It is only important that you understand which method you are selecting and why.