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**Lab 3: Ohm’s Law**

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PHYS 262 – 001

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**Objective**

The objective of this lab is to confirm Ohm’s Law by passing an electrical signal through resistors in series and in parallel and measuring that signal’s current, and the voltage drop and measured resistance across the resistors.

**Theory**

The theory being tested is the ability to describe an electrical signal and its interactions using Ohm’s law, which is given by:

Eq. 3-1

Eq. 2-1 conjects that an electrical signal can be described by three fundamental properties. These properties are the voltage, or voltage drop, of the signal *V*, the current *I* of electricity passing through the system, and the total resistance *R* of the current’s governing medium.

**Procedure**

The verification of this lab’s predictions was performed in three separate procedures. Each procedure included an RLC board, on which we concerned our focuses on its 100 Ω and 33 Ω resistors that shared a common circuit, an adjustable DC power supply with display for output voltage and current magnitudes, an integrated ammeter, a handheld and an integrated voltmeter, and the clips/leads required to assemble the desired circuits. Readings for the integrated ammeter and voltmeter were interpreted by a LabPro signal interface.

**Procedure A**

For this procedure, the power supply was set in series with both resistors (33/100 Ω) separately. Starting at a low output voltage, the source voltage was increased in an increment. In increment was ~0.5 V for the 33 Ω resistor, and ~1.0 V for the 100 Ω resistor. At each increment, the LabPro-integrated voltmeter and ammeter were used to take voltage drop and passing-current readings.

**Procedure B**

This procedure was focused on the effects of setting the two resistors in series. After setting up such a scenario, readings were taken for voltage drop and current across the entire circuit in the same manner as Procedure A. For the second part of this procedure, the power supply was set to a steady 5 V output. In this state, voltage drop, and current were measured for each resistor component individually.

**Procedure C**

This procedure was performed similarly to Procedure B, but the two resistors were set in parallel rather than in series. The same measurements were taken with this configuration, though the power supply voltage output was lowered to 3 V.

**Data**

Shown below are the tables of incremental voltage and current measurements taken across all procedures.

|  |  |  |
| --- | --- | --- |
| Procedure A - 33 Ω | | |
| Voltage(v) | Current(A) | Resistance(Ω) |
| 0.5 | 0.012 | 41.66666667 |
| 1 | 0.034 | 29.41176471 |
| 1.5 | 0.04 | 37.5 |
| 2 | 0.065 | 30.76923077 |
| 2.5 | 0.0762 | 32.80839895 |
| 2.9 | 0.0889 | 32.62092238 |
| 3.4 | 0.1204 | 28.23920266 |
| 3.9 | 0.1277 | 30.5403289 |

**Table 3-1.** The table of output voltages for each increment compared to its respective measured current and calculated resistance for the 33 Ω resistor.

|  |  |  |
| --- | --- | --- |
| Procedure A - 100 Ω | | |
| Votage(V) | Current(A) | Resistance(Ω) |
| 1 | 0.012 | 83.33333333 |
| 2 | 0.02 | 100 |
| 2.8 | 0.03 | 93.33333333 |
| 3.8 | 0.0411 | 92.45742092 |
| 4.9 | 0.052 | 94.23076923 |
| 6.1 | 0.065 | 93.84615385 |

**Table 3-2.** The table of output voltages for each increment compared to its respective measured current and calculated resistance for the 100 Ω resistor.

|  |  |  |
| --- | --- | --- |
| Procedure B - Series | | |
| Votage(V) | Current(A) | Resistance(Ω) |
| 1.1 | 0.015 | 73.33333333 |
| 2.4 | 0.0233 | 103.0042918 |
| 3.8 | 0.038 | 100 |
| 4.9 | 0.038 | 128.9473684 |
| 5.3 | 0.0425 | 124.7058824 |
| 5.9 | 0.055 | 107.2727273 |

**Table 3-3.** The table of output voltages for each increment compared to its respective measured current and calculated resistance for both resistors configured in series.

|  |  |  |
| --- | --- | --- |
| Procedure C - Parallel | | |
| Votage(V) | Current(A) | Resistance(Ω) |
| 0.5 | 0.0216 | 23.14814815 |
| 1 | 0.045 | 22.22222222 |
| 2.1 | 0.084 | 25 |
| 2.9 | 0.1131 | 25.64102564 |
| 3.384 | 0.138 | 24.52173913 |
| 4.1 | 0.167 | 24.5508982 |

**Table 3-4.** The table of output voltages for each increment compared to its respective measured current and calculated resistance for both resistors configured in parallel.

Shown below are the tables of voltage drops and calculated current, as well related as parametric data, measured for each resistor individually when assembled in series and in parallel.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Procedure B - Resistor Perspective Measurements | | | | |
| Resistor (Ω) | Measured Voltage (V) | Calculated Current (A) | Supplied Voltage (V) | 5 |
| 100 | 3.65 | 0.0365 | Ammeter Reading (A) | 0.03 |
| 33 | 1.275 | 0.038636364 |  |  |
| Total Voltage (V) | 4.925 |  |  |  |

**Table 3-5.** The table of individual resistances and measured voltage drops for each resistor in series, as well as the derived current. Also included are the parametric values for the circuit, which are the input voltage and from the power supply and the measured current accompanying that potential. The value at the bottom represents the total voltage drop across the circuit.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Procedure C - Resistor Perspective Measurements | | | | |
| Resistor (Ω) | Measured Voltage (V) | Calculated Current (A) | Supplied Voltage (V) | 3 |
| 100 | 3.02 | 0.0302 | Ammeter Reading (A) | 0.12 |
| 33 | 3.02 | 0.091515152 |  |  |

**Table 3-6.** The table of individual resistances and measured voltage drops for each resistor in parallel, as well as the derived current. Also included are the parametric values for the circuit, which are the input voltage and from the power supply and the measured current accompanying that potential. No total voltage drop is given because only one parallel node is present in this circuit, wherein the voltage drop should be equivalent across all paths and thus functionally equivalent to a single resistor in series.

**Analysis**

To produce an experimental resistance for each set of incremental measurements, the incremented voltage was plotted against the current measured by the ammeter for that run. Using regression tools, a best-fit equation can be derived. The slope of this trendline equation is the experimental resistance for that set of measurements. The graphs deriving this value for each set of measurements is given below:

**Procedure A**

**Figure 3-1.** Incrementally tuned output voltage plotted against the current measured at each increment across the 33 Ω resistor.

**Figure 3-2.** Incrementally tuned output voltage plotted against the current measured at each increment across the 100 Ω resistor.

**Procedure B**

**Figure 3-3.** Incrementally tuned output voltage plotted against the current measured at each increment across both resistors arranged in series.

**Procedure C**

**Figure 3-4.** Incrementally tuned output voltage plotted against the current measured at each increment across both resistors arranged in parallel.

These graphs and their trendlines provide an experimental resistance for each configuration of the two resistors. We can determine naturally that the expected resistances for the first and second configurations are **33 Ω** and **100 Ω**, respectively. For the second configuration, the total resistance must be determined based on the specific layout of the resistors. The total resistance of *N* effective resistors in series is given by:

Eq. 3-2

Where *Ri* is the resistance for any resistor in a collection of enumerated resistors configured in series. Using Eq. 3-2, the total resistance for the Procedure B configuration is calculated as **133 Ω**. For the final configuration, a separate equation is needed. The cumulative resistance for *N* individual effective resistors in parallel is given by:

Eq. 3-3

Where *Ri* is the resistance for any resistor in a collection of enumerated resistors configured in parallel. Using Eq. 3-3, the total resistance for the Procedure C configuration is calculated as about **24.812 Ω**. The comprehensive list of expected and actual resistances for all configurations is given below.

|  |  |  |  |
| --- | --- | --- | --- |
| Configuration Resistance Comparison | | | |
| Configuration | Expected Resistance (Ω) | Actual Resistance (Ω) | Percent Error |
| Single (33 Ω) | 33 | 24.478 | 25.824% |
| Single (100 Ω) | 100 | 94.459 | 5.541% |
| Series | 133 | 125.42 | 5.699% |
| Parallel | 24.812 | 25.144 | 1.338% |

**Table 3-7.** Expected and actual (measured) total resistance for each configuration.

The additional information gathered concerns the voltage drop and passing current across each resistor when in series and in parallel. The table below compares the measured voltage drops compared to the voltage drops expected by **Kirchoff’s Voltage Law**.

|  |  |  |  |
| --- | --- | --- | --- |
| Kirchoff's Voltage Law Comparison | | | |
| Configuration (Resistor) | Expected Voltage (V) | Actual Voltage (V) | Percent Error |
| Series (33 Ω) | 3.759398496 | 3.65 | 2.910% |
| Series (100 Ω) | 1.240601504 | 1.275 | 2.773% |
| Parallel (33 Ω) | 3 | 3.02 | 0.667% |
| Parallel (100 Ω) | 3 | 3.02 | 0.667% |

**Table 3-8.** Expected and actual (measured) voltage drop across each resistor for each configuration.

The next table compares currents measured using a handheld multimeter set to expect 2A DC current across each resister against the current for each configuration/resistor item expected by **Kirchoff’s Current Law.**

|  |  |  |  |
| --- | --- | --- | --- |
| Kirchoff's Current Law Comparison | | | |
| Resistor | Expected Current (A) | Actual Current (A) | Percent Error |
| Series (33 Ω) | 0.037593985 | 0.0365 | 2.910% |
| Series (100 Ω) | 0.037593985 | 0.038636364 | 2.773% |
| Parallel (33 Ω) | 0.090909091 | 0.091515152 | 0.667% |
| Parallel (100 Ω) | 0.03 | 0.0302 | 0.667% |

**Table 3-9.** Expected and actual (calculated) current across each resistor for each configuration.

**Conclusions**

In this experiment, we have attempted to validate Ohm’s Law and, by extension, Kirchoff’s Voltage and Current Laws. To start off, we attempted to use Ohm’s law to predict the total resistance of two resistors configured in all possible permutations. Overall, the derived resistances calculated using regression utilities match significantly the respective calculated resistances, fully in support of Ohm’s Law. For the single outlier who’s expected/actual discrepancy arose to ~25% error, this can be attributed to the inconsistency of the LabPro ammeter. The current reading provided by the power supply was much more accurate, even if less precise. The LabPro measurements were valued in this case per instructions, resulting in the given mismatch. The voltage measurements taken against Kirchoff’s Voltage Law were very close to the calculated voltages for each resistor in each configuration, providing it great foundation. The same can be said for the current measurements taken against Kirchoff’s Current Law, for which each measurement exemplified the exact same margin of error as its voltage counterpart. This is due to the current being a derived quantity. Overall, these experiments provide great support for Ohm’s Law and Kirchoff’s Voltage and Current Laws and provide little-to-no evidence of the contrary.