

The Measurement of Resistance: Ammeter-Voltmeter Methods and Wheatstone Bridge Method

Lab #1

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Objective

The objective of the lab is to measure the resistance of unknown resistors by means of both the Wheatstone bridge of balancing the resistance of both sides of the bridge, and by a combined ammeter and voltmeter.

Introduction

The measuring of resistance can be done by several methods, the first of which depends on Ohm's Law, stating $R = \frac{V}{I}$. On the other hand, since the voltmeter, placed in parallel such that the voltage is equal, takes away a portion of the current, or because the ammeter, placed in series such that the current is equal, takes away a portion of the voltage, the measurement is not exact. If the resistance of the voltmeter greatly exceeds that of the resistor, it will not interfere, while if the resistance of the ammeter is vastly less, it will not interfere. Otherwise, for the voltmeter impacting the current, $R = \frac{V}{I_R} = \frac{V}{I - I_v} = \frac{V}{I - \frac{V}{R_V}}$, where I_R is the current through the resistor, I_v is the current through the voltmeter, and R_V is the resistance of the voltmeter. For the ammeter impacting the voltage, $R = \frac{V_R}{I} = \frac{V - V_A}{I} = \frac{V - R_A I}{I} = \frac{V}{I} - R_A$.

As a result, it can be seen that as the voltmeter resistance approaches infinity, the resistance approaches $\frac{V}{I}$ for the former case, such that it plays no effect, and likewise, as the ammeter resistance approaches zero, the resistance approaches the same, such that there is no effect. This is due to the fact that as voltmeter resistance is infinite, the resistance through the other path is so far below, that all the current moves through there, while the current through the voltmeter is negligible. As the ammeter resistance approaches 0, no voltage is lost passing through it as a result, since it acts like a normal wire, thus having no effect.

The other method of calculating resistance is the Wheatstone Bridge method, which can be done either by the slide-wire method or the four-resistor method. The four resistor method places two known resistors in series on one side of the bridge, and a variable resistor and the unknown on the other side, with a galvanometer/ammeter connected from the center of both sides. The variable resistor can then be modified such that the first resistor on each side has an equal voltage to the other ($I_1 R_1 = I_2 R_V$) and the second on each has an equal voltage ($I_2 R_1 = I_2 R_X$), where R_V is the variable resistance and R_X is the unknown resistor. Thus, at that point $R_X = \frac{R_2 R_V}{R_1}$.

The slide-wire method uses a slide wire resistor instead of the two known resistors and a known resistor instead of the variable one. As a result, since the resistance of each part of the slide wire resistor is proportional to the length, it can similarly be found that $R_X = \frac{L_2 R_K}{L_1}$, where R_K is the known resistor, L_1 is the length of the wire parallel to the known resistor, and L_2 is the length parallel to the unknown resistor.

Procedures and Results

First, the Ammeter-Voltmeter methods are used with a small resistor, first creating a circuit such that the ammeter reading is slightly higher than actual, second so that the voltmeter reading is slightly higher than actual, with an additional variable resistor, a rheostat in this case using only one of the resistors, separate from the resistor being measured, in series. The resistance of the ammeter and the voltmeter can be separately measured by an ohmmeter, so that they can be taken into account. The voltage and current across the resistor can thus be found as well. It is then taken for three different rheostat resistances, such that the voltage and current through the unknown resistor varies. It is then redone by the same means for a large resistor.

The slide-wire form of the Wheatstone Bridge is then made in a variation, with a rheostat used as the two unknown resistors, due to acting as two varying resistors in series, with a divider between, similar to a slide-wire. It is measured for some small and large unknown resistor, taken for three different known resistors with each part of the rheostat resistance measured by an ohmmeter when there is no current passing through the bridge, measured by an ammeter.

Small Resistor:

$$R_V(\text{Voltmeter Resistance}) = 1\Omega$$

$$R_X(\text{Expected Resistance}) = 50.2\Omega$$

Rheostat Setting	1	2	3
Current, I (A)	0.048	0.039	0.031
Voltage, V (V)	2.6	2.1	1.6

$$R_A(\text{Ammeter Resistance}) = 0.48\Omega$$

$$R_X(\text{Expected Resistance}) = 50.2\Omega$$

Rheostat Setting	1	2	3
Current, I (A)	0.048	0.039	0.032
Voltage, V (V)	2.6	2.1	1.6

Large Resistor:

$$R_V(\text{Voltmeter Resistance}) = 1\Omega$$

$$R_X(\text{Expected Resistance}) = 74.7\Omega$$

Rheostat Setting	1	2	3
Current, I (A)	0.033	0.029	0.024
Voltage, V (V)	2.6	2.3	1.9

$$R_A(\text{Ammeter Resistance}) = 0.48\Omega$$

$$R_X(\text{Expected Resistance}) = 74.7\Omega$$

Rheostat Setting	1	2	3
Current, I (A)	0.032	0.029	0.021
Voltage, V (V)	2.6	2.3	1.7

Wheatstone Bridge:

$$R_X(\text{Expected Resistance}) = 25.6\Omega$$

Known Resistor, $R_K(\Omega)$	50.2	74.6	25.6
Varying Resistor 1, $R_1(\Omega)$	24.2	26.1	17.5
Varying Resistor 2, $R_2(\Omega)$	12.8	9.4	17.5

$$R_X(\text{Expected Resistance}) = 74.7\Omega$$

Known Resistor, $R_K(\Omega)$	25.6	50.2	74.6
Varying Resistor 1, $R_1(\Omega)$	8.7	13.9	17
Varying Resistor 2, $R_2(\Omega)$	26.1	21.2	17.9

Discussion

Sample calculations for the non-measured data are as shown using the formulas found above:

$$t_{avg} = \frac{t_1 + t_2 + t_3}{3} = \frac{1.47 + 1.21 + 1.31}{3} = 1.33$$

$$a = \frac{2y}{t^2} = \frac{2 * 0.8984}{1.33^2} = 1.015$$

$$m_t = m_1 + m_2 + m_{pulley} = 0.06636 + 0.055 + 0.0316 = 0.1529$$

$$F_{net} = (m_2 - m_1 - m_f)g = (0.06636 - 0.055 - 0.00136)(9.8) = 0.098$$

$$a_t = \frac{F_{net}}{m_t} = \frac{0.098}{0.1529} = 0.64$$

$$\text{Percent Acceleration Error} = \frac{|a_t - a_m|}{a_t} * 100\% = \frac{|0.64 - 1.015|}{0.64} * 100\% = \frac{0.375}{0.64} * 100\% = 58.59\%$$

Trial	1	2	3	4
Average Time, t_{avg} (s)	1.33	2.183	2.486	3.41
Measured Acceleration, a_m (kgm/s^2)	1.015	0.359	0.196	0.105
Total Mass, m_t (kg)	0.1529	0.3466	0.547	0.7489
Net Force, F_{net} (N)	0.098	0.163	0.149	0.098
Theoretical Acceleration, a_t ($kg * m/s^2$)	0.64	0.47	0.27	0.131
Percent Acceleration Error (%)	58.59	23.62	27.4	19.7
Trial	5	6	7	8
Average Time, t_{avg} (s)	7.88	4.13	2.98	2.076
Measured Acceleration, a_m (m/s^2)	0.0196	0.0715	0.137	0.283
Total Mass, m_t (kg)	0.5589	0.5589	0.5589	0.5589
Net Force, F_{net} (N)	0.0098	0.049	0.0882	0.1862
Theoretical Acceleration, a_t (m/s^2)	0.0175	0.0877	0.158	0.333
Percent Acceleration Error (%)	12	18.5	13.3	15.01

Our percent error was fairly high for the first set of data, especially as the mass was lower, most likely indicating an issue with the time measurement, as it was faster at the start, at which points the percent of error was far higher.

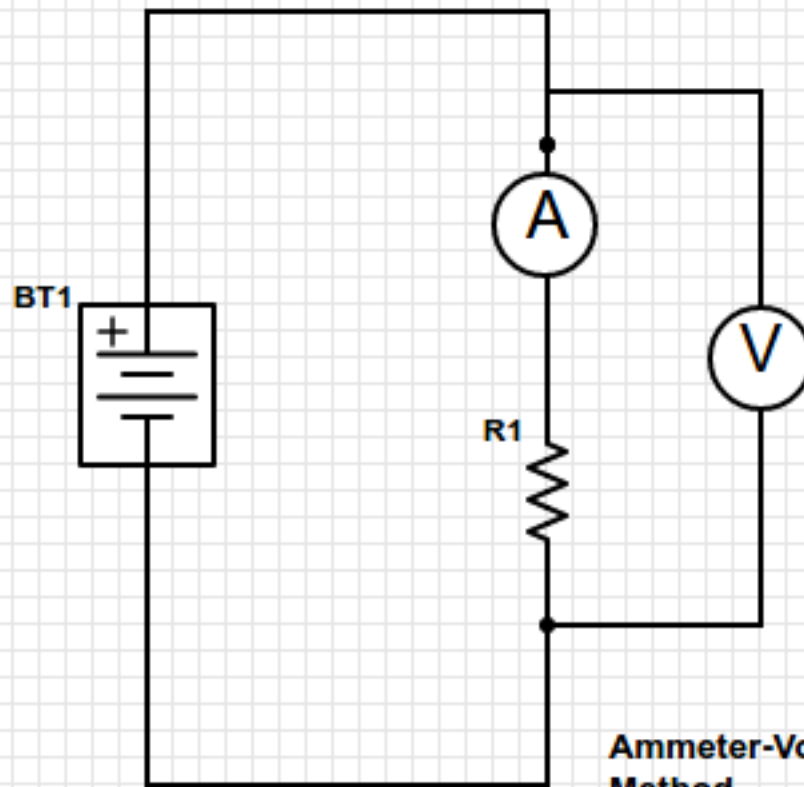
Other sources of error that could have occurred was within the pulley mechanism itself, estimating the frictional mass manually, which created room for error, and it assumes that the pulley itself worked as intended, although there was the chance of it slipping or catching at any point. In addition, there is the possibility of drag force slowing the measured acceleration, which is consistent with the data, except in the 1st and 5th trial.

Finally, the equations themselves assumed a point mass, while in actuality, as the masses got higher, they became less and less point-like in shape, interfering in the data.

Conclusion

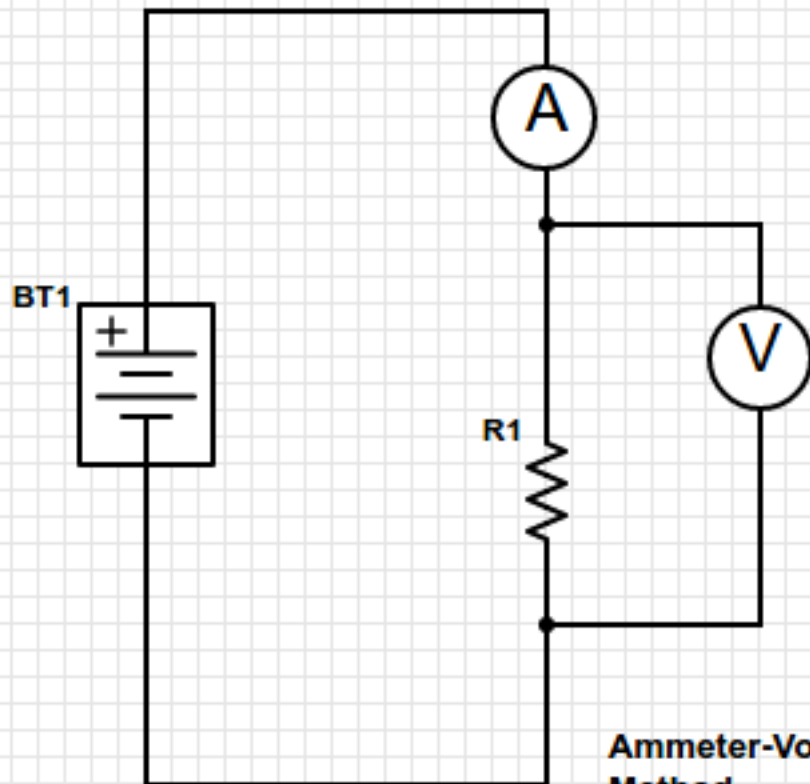
The acceleration as the mass on each side before frictional mass was added increased from 0.05 to 0.15 to 0.25 to 0.35, went from 1.015 m/s^2 with 58.59% error, to 0.359 m/s^2 with 23.62 % error, to 0.196 m/s^2 with 27.4 % error, to 0.105 m/s^2 with 19.7% error.

The acceleration as the mass difference increased from 2 g to 6 g to 10 g to 20 g, went from 0.0196 m/s^2 with 12 % error, to 0.0715 m/s^2 with 18.5 % error, to 0.137 m/s^2 with 13.3 % error, to 0.283 m/s^2 with 15.01 % error.



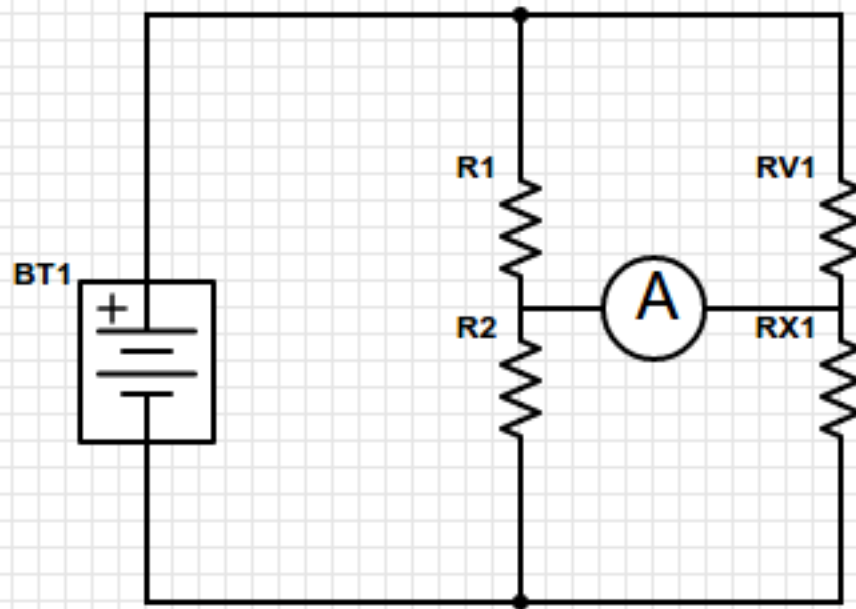
**Ammeter-Voltmeter
Method**

Ammeter impacting Voltmeter
measurement



**Ammeter-Voltmeter
Method**

Voltmeter impacting Ammeter
measurement



**Wheatstone Bridge
Method**

4-Resistor Method

