Physics Lab

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Review and Analysis of Factors Affecting Electrical Resistance

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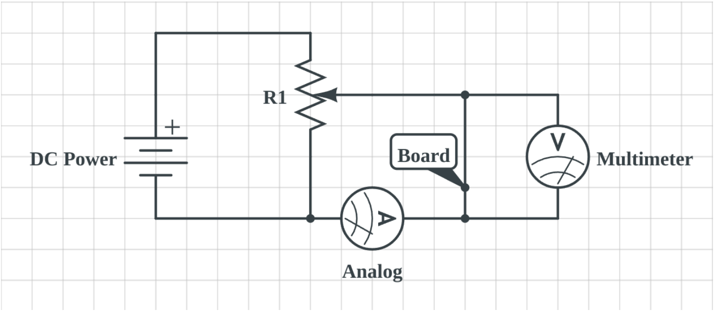
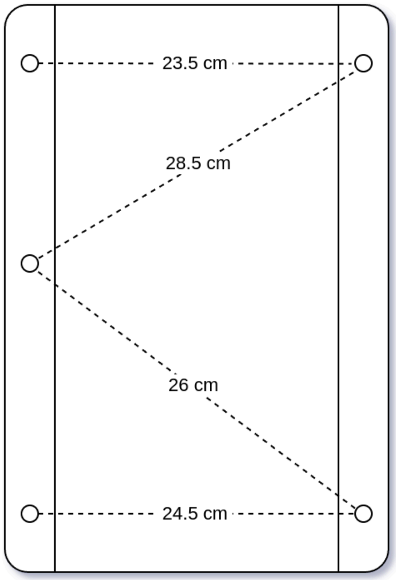
Overview

Here is book of Physics Lab experiment 3, Affecting Factors on Electrical Resistance overview

Experiment Info

- **Purpose >** Studying the Factors that Determine the Resistance of a Metal Conductor
- **Necessary Equipment >** DC Power, Resistance Board, Digital Voltmeter, Analog Ammeter Wires, Rheostat





Resistance : $R = \frac{\rho \times L}{A}$ where $A = \frac{\pi \times D^2}{4}$

Board Resistivity : $\rho = 160 \times 10^{-8}\,\Omega \cdot m$

Wires Diameter : $D = 0.05cm$

Affecting Factor on Resistance - Wire's Length

Steps

1. First we need to select a board, the selected board diagram is as in the previous page.
2. for experiment ⅓, We used the shortest wire ($23.5cm$).
3. then we set source DC power to $4V$ because more voltage may cause the wires to burn out and make the board useless.
4. Then we configure rheostat to see $0.02A$ accurately on Ammeter. Teacher said that we must not touch the rheostat slider after this for our other experiments today.
5. We connected multimeter to shortest path ($23.5cm$) and it showed us $35.1\ mV$.
6. Then we calculated resistance of wire using formula $R = \frac{V}{I}$ and it was 1.755Ω.
7. for experiment ⅔, We used first two wires ($23.5cm$ and $28.5cm$ equal to $52cm$). then we did all above steps and multimeter showed us $77.9mV$ and after using resistance formula we got 3.895Ω for wire resistance.
8. for the last experiment, We used first three wires ($23.5cm$, $28.5cm$ and $26cm$ equal to $78cm$). then we did all above steps and multimeter showed us $115.1mV$ and after using resistance formula we got 5.755Ω for wire resistance.
9. Finally as **Conclusion** we thought about all 3 results and concluded that **the resistance of a wire is directly proportional to its length**.

Next pages are experiments calculations

Affecting Factor on Resistance - Wire’s Length Table

L	V	I	$R = \frac{V}{I}$	$Result$
shortest $0.235m$	$35.1mV$	$0.02A$	1.755Ω	the resistance of a wire is directly proportional to its length
first two $0.520m$	$77.9mV$	$0.02A$	3.895Ω	
first three $0.780m$	$115.1mV$	$0.02A$	5.755Ω	

Affecting Factor on Resistance - Wire’s Diameter and Resistivity

1. We have conducted 3 experiments for same length of wire ($0.235m$)
2. for experiment ⅓, On the last assembled circuit we write down voltage and current again.
3. Then we calculated resistance via formula of $R = \frac{V}{I}$ and it was 1.94Ω.
4. for experiment ⅔, We change rheostat slider carefully till be able to see $0.3A$ on Ammeter. then connect multimeter to it and we saw $58.3mV$ on it.
5. Then we calculated resistance with formula of $R = \frac{V}{I}$ and it was 1.94Ω.
6. for the last experiment we do above steps.
7. Teacher said that in these experiments valid error is up to 0.1Ω.

Affecting Factor on Electric Resistance - Wire’s Diameter and Resistivity Table

L	ρ	D	V	I	$Ammeter_{accuracy}$	$R_m = \frac{V}{I}$	$R_{real} = \frac{\rho \times L}{A}$
$0.235m$	$160 \times 10^{-8}\Omega m$	$5 \times 10^{-4}m$	$38.8mV$	$0.02A$	$0.01A$	$\beta: 1.9400\Omega$	$\alpha:$ 1.914952Ω
$0.235m$	$160 \times 10^{-8}\Omega m$	$5 \times 10^{-4}m$	$58.3mV$	$0.03A$	$0.01A$	$\gamma: 1.9430\Omega$	
$0.235m$	$160 \times 10^{-8}\Omega m$	$5 \times 10^{-4}m$	$79.1mV$	$0.04A$	$0.01A$	$\delta: 1.9775\Omega$	

Calculations of α :

$$A = \frac{\pi \times D^2}{4} = 1.963495 \times 10^{-7}m \qquad R = \frac{\rho \times L}{A} = \frac{160 \times 10^{-8} \times 0.235}{A} = 1.914952\Omega$$

Affecting Factor on Electric Resistance - Error Calculations

Error calculations are divided into 3 categories, absolute, relative and systematic errors and my personal task is to calculate errors of **first experiment** :

from absolute formula : $Absolute\ Error = |real\ value - measured\ value|$

We get this absolute error for β : $\varepsilon_{abs_\beta} = |1.914952\Omega - 1.94\Omega| = 0.025048\Omega$

We get this absolute error for γ : $\varepsilon_{abs_\gamma} = |1.914952\Omega - 1.943\Omega| = 0.028048\Omega$

We get this absolute error for δ : $\varepsilon_{abs_\delta} = |1.914952\Omega - 1.9775\Omega| = 0.062548\Omega$

from relative formula : $Relative\ Error = \frac{|real\ value - measured\ value|}{real\ value}$

We get this absolute error for β : $\varepsilon_{rel_\beta} = \frac{0.025048\Omega}{1.914952\Omega} \approx 0.013080$

We get this absolute error for γ : $\varepsilon_{rel_\gamma} = \frac{0.028048\Omega}{1.914952\Omega} \approx 0.014646$

We get this absolute error for δ : $\varepsilon_{rel_\delta} = \frac{0.062548\Omega}{1.914952\Omega} \approx 0.032662$

for systematic formula, We must do several mathematics operations :

1. Consider we have formula $V = I.R \Rightarrow R = \frac{V}{I}$.
2. Take the ln from both sides.
3. Take the differential from both sides.
4. Convert differentials to delta (Δ).
5. Convert every $-$ to $+$.
6. accuracy of **Analog Device** is equal to the lowest shown range on the device.
7. Error of **Analog Device** is equal to the lowest shown range on device multiplied by 0.5.
8. accuracy of **Digital Device** is equal to 10^{-x} where x is float level on the screen.
9. Error of **Digital Device** is equal to 10^{-x} where x is float level on the screen.

Now we can calculate systematic error using main formula :

$$Step\ 1: \quad R = \frac{V_s}{I_{am}}$$

for R_β :

$$Step\ 2: \quad ln(R) = ln(V_s) - ln(I_{am})$$

$$Step\ 3: \quad \frac{dR}{R} = \frac{dV_s}{V_s} - \frac{dI_{am}}{I_{am}}$$

$$Step\ 4: \quad \frac{\Delta R}{R} = \frac{\Delta V_s}{V_s} - \frac{\Delta I_{am}}{I_{am}}$$

$$Step\ 5: \quad \frac{\Delta R}{R} = \frac{\Delta V_s}{V_s} + \frac{\Delta I_{am}}{I_{am}}$$

$$Step\ 6\sim: \quad \Delta V_S = 10^{-1} \qquad \Delta I_{am} = 10^{-2} \times 0.5$$

$$Final: \quad \frac{\Delta R}{R} = \frac{10^{-1}V}{38.8V} + \frac{10^{-2}\times 0.5A}{0.02A} = 0.2526$$

$$\Rightarrow \varepsilon_{sys} = 0.2526$$

for R_β :

$$Step\ 2: \quad ln(R) = ln(V_s) - ln(I_{am})$$

$$Step\ 3: \quad \frac{dR}{R} = \frac{dV_s}{V_s} - \frac{dI_{am}}{I_{am}}$$

$$Step\ 4: \quad \frac{\Delta R}{R} = \frac{\Delta V_s}{V_s} - \frac{\Delta I_{am}}{I_{am}}$$

$$Step\ 5: \quad \frac{\Delta R}{R} = \frac{\Delta V_s}{V_s} + \frac{\Delta I_{am}}{I_{am}}$$

$$Step\ 6\sim: \quad \Delta V_S = 10^{-1} \qquad \Delta I_{am} = 10^{-2} \times 0.5$$

$$Final: \quad \frac{\Delta R}{R} = \frac{10^{-1}V}{58.3V} + \frac{10^{-2}\times 0.5A}{0.03A} = 0.1684$$

$$\Rightarrow \varepsilon_{sys} = 0.1684$$

for R_β :

$$Step\ 2: \quad ln(R) = ln(V_s) - ln(I_{am})$$

$$Step\ 3: \quad \frac{dR}{R} = \frac{dV_s}{V_s} - \frac{dI_{am}}{I_{am}}$$

$$Step\ 4: \quad \frac{\Delta R}{R} = \frac{\Delta V_s}{V_s} - \frac{\Delta I_{am}}{I_{am}}$$

$$Step\ 5: \quad \frac{\Delta R}{R} = \frac{\Delta V_s}{V_s} + \frac{\Delta I_{am}}{I_{am}}$$

$$Step\ 6\sim: \quad \Delta V_S = 10^{-1} \qquad \Delta I_{am} = 10^{-2} \times 0.5$$

$$Final: \quad \frac{\Delta R}{R} = \frac{10^{-1}V}{79.1V} + \frac{10^{-2}\times 0.5A}{0.04A} = 0.1263$$

$$\Rightarrow \varepsilon_{sys} = 0.1263$$