Physics Lab

Teacher : Ms. Farzaneh Noor Mohammadi
Student : Mr. Ramtin Kosari

Ohm’s Law Analysis

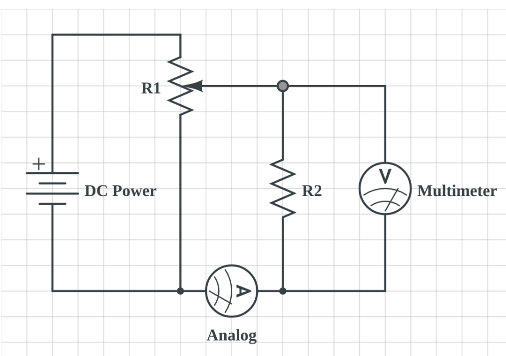
October 20, 2024

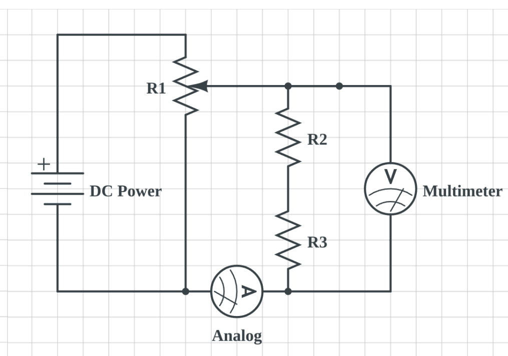
Overview

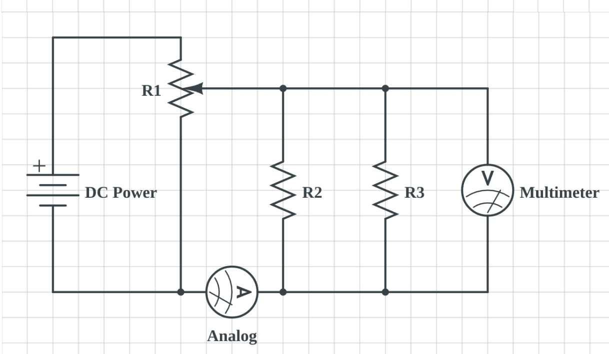
Here is book of Physics Lab experiment 2, Ohm’s Law overview

Experiment Info

- **Purpose >** Experimental Investigation of Ohm's law
- **Necessary Equipment >** Selective Resistance, DC Power, Digital Voltmeter, Analog Ammeter Wires, Rheostat







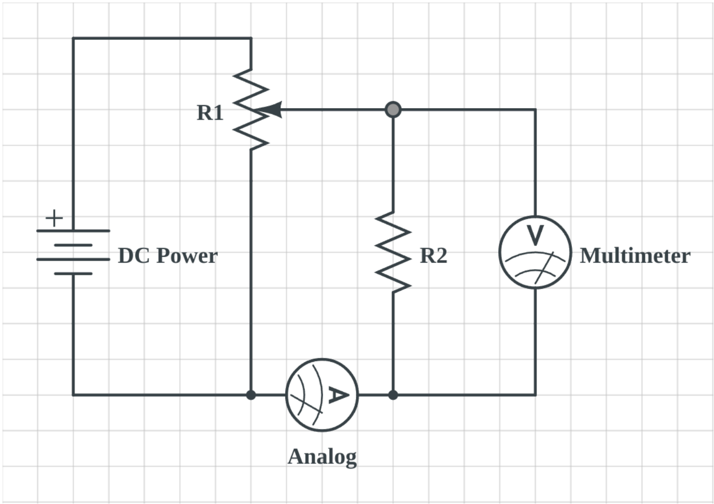
Ohm’s Law : $V = I.R$

Ohm's Law on Single Resistor

First we need to do this experiment on single resistor, R is a selective resistor. I conducted 2 experiments to validate Ohm's Law on a single resistor.

Steps

1. for experiment ½, I set selective resistor on 8 so output will be $(10 - 8) * 100 = 200\Omega$ (because of using two black inputs, I used this conversion) but after connecting to multimeter I got 199.9Ω (Not $k\Omega$ because it was around 200Ω I used the first multimeter so I wrote Ω instead of $k\Omega$).
2. I set ammeter on $0.02A$ accurately.
3. Turn on DC power and enable output.
4. I set source DC power to $3.94V$ because i must configure rheostat to check $0.02A$ accurately on Ammeter.
5. Connected multimeter to R and written down its voltage, then calculated Resistor via formula and compared it to real resistor value (199.9Ω)
6. for last experiment, I only set ammeter to $0.04A$ and did the previous steps again.
7. then i changed Resistor to 9 so output will be $(10 - 9) * 100 = 100\Omega$ and multimeter showed 110.2Ω then did all the steps again.



Next pages are experiments calculations

Ohm’s Law on Single Resistor - Experiments Table 1

R_{real}	V_S	I	$Ammeter_{accuracy}$	$R_{measured} = \frac{V_S}{I}$
199.9Ω	$3.94V$	$0.02A$	$0.01A$	$197.000\Omega : \alpha$
199.9Ω	$7.87V$	$0.04A$	$0.01A$	$196.750\Omega : \beta$

Calculations of α and β :

$$\alpha : R = \frac{V_S}{I} = \frac{3.94}{0.02} = 197.000\Omega \qquad \beta : R = \frac{V_S}{I} = \frac{7.87}{0.04} = 196.750\Omega$$

Ohm’s Law on Single Resistor - 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 α : $\varepsilon_{abs} = |199.9\Omega - 197.0\Omega| = 2.9\Omega$

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

We get this absolute error for α : $\varepsilon_{rel} = \frac{2.9\Omega}{199.9\Omega} \approx 0.015$

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 :

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

for R :

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

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

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

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

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

$$Final: \qquad \frac{\Delta R}{R} = \frac{10^{-2}V}{3.94V} + \frac{10^{-2}\times 0.5A}{0.02A} = 0.2525$$

$$\Rightarrow \varepsilon_{sys} = 0.2525$$

Ohm's Law on Single Resistor - Experiments Table 2

R_{real}	V_S	I	$Ammeter_{accuracy}$	$R_{measured} = \frac{V_S}{I}$
110.2Ω	$4.52V$	$0.04A$	$0.01A$	$113.000\Omega : \alpha$
110.2Ω	$2.10V$	$0.02A$	$0.01A$	$105.000\Omega : \beta$

Calculations of α and β :

$$\alpha : R = \frac{V_S}{I} = \frac{4.52}{0.04} = 113.000\Omega \qquad \beta : R = \frac{V_S}{I} = \frac{2.10}{0.02} = 105.000\Omega$$

Ohm's Law on Single Resistor - 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 α :

$$\varepsilon_{abs} = |110.2\Omega - 113.0\Omega| = 2.8\Omega$$

from relative formula :

$$Relative\ Error = \frac{|real\ value - measured\ value|}{real\ value}$$

We get this absolute error for α :

$$\varepsilon_{rel} = \frac{2.8\Omega}{110.2\Omega} \approx 0.025$$

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 :

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

for R :

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

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

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

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

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

$$Final: \qquad \frac{\Delta R}{R} = \frac{10^{-2}V}{4.52V} + \frac{10^{-2}\times 0.5A}{0.04A} = 0.1272$$

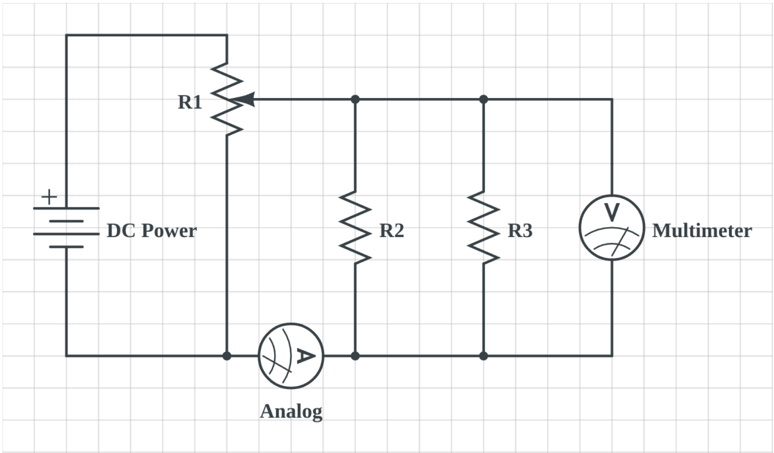
$$\Rightarrow \varepsilon_{sys} = 0.1272$$

Ohm’s Law on Parallel Resistors

Now we need to do this experiment on parallel resistors, R_2 is a selective and R_3 is a box resistor. I conducted 2 experiments to validate Ohm’s Law on parallel resistors.

Steps

1. for experiment ½, I set selective resistor on 8 so output will be $(10 - 8) * 100 = 200\Omega$ (because of using two black inputs, I used this conversion) but after connecting to multimeter I got 199.9Ω (Not $k\Omega$ because it was around 200Ω I used the first multimeter so I wrote Ω instead of $k\Omega$). also i set box resistor on 100Ω.
2. I set ammeter on $0.04A$ accurately.
3. Turn on DC power and enable output.
4. I set source DC power to $1.57V$ because i must configure rheostat to check $0.04A$ accurately on Ammeter.
5. Connected multimeter to R_3 and written down its voltage, then calculated Parallel Resistor via formula and compared it to real parallel resistor value.
6. for last experiment, I only set ammeter to $0.04A$ and did the previous steps again.



Ohm's Law on parallel Resistor - Experiments Table

R_2	R_3	$R_{real} = \frac{R_2 \times R_3}{R_2 + R_3}$	V_S	I	$Ammeter_{accuracy}$	$R_{measured} = \frac{V_S}{I}$
199.9Ω	110.2Ω	71.038Ω	$1.57V$	$0.02A$	$0.01A$	$78.500\Omega : \alpha$
199.9Ω	110.2Ω	71.038Ω	$2.78V$	$0.04A$	$0.01A$	$69.500\Omega : \beta$

Calculations of R, α and β :

$$R_{real} = \frac{199.9 \times 110.2}{199.9 + 110.2} = 71.038\Omega$$

$$\alpha : R = \frac{V_S}{I} = \frac{1.57}{0.02} = 78.500 \qquad \beta : R = \frac{V_S}{I} = \frac{2.78}{0.04} = 69.500$$

Ohm's Law on Parallel Resistors - 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 α : $\varepsilon_{abs} = |71.038\Omega - 69.500\Omega| = 1.538\Omega$

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

We get this absolute error for α : $\varepsilon_{rel} = \frac{1.538\Omega}{71.038\Omega} \approx 0.022$

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 :

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

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

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

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

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

$$Final: \quad \frac{\Delta R}{R} = \frac{10^{-2}V}{2.78V} + \frac{10^{-2}\times 0.5A}{0.04A} = 0.1286$$

$$\Rightarrow \varepsilon_{sys} = 0.1286$$

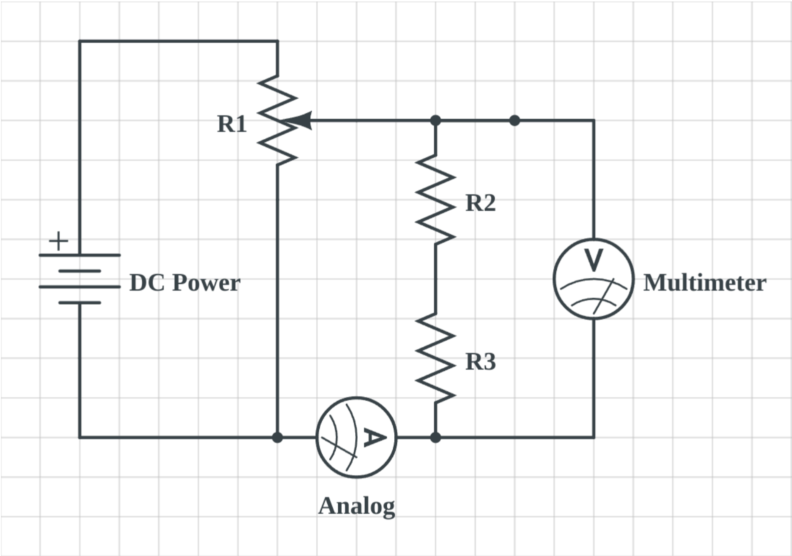
Ohm’s Law on Series Resistors

Now we need to do this experiment on series resistors, R_2 is a selective and R_3 is a box resistor.

I conducted 2 experiments to validate Ohm’s Law on parallel resistors.

Steps

1. for experiment ½, I set selective resistor on 8 so output will be $(10 - 8) * 100 = 200\Omega$ (because of using two black inputs, I used this conversion) but after connecting to multimeter I got 199.9Ω (Not $k\Omega$ because it was around 200Ω I used the first multimeter so I wrote Ω instead of $k\Omega$). also i set box resistor on 100Ω.
2. I set ammeter on $0.02A$ accurately.
3. Turn on DC power and enable output.
4. I set source DC power to $6.03V$ because i must configure rheostat to check $0.02A$ accurately on Ammeter.
5. Connected multimeter to R_3 and R_2 and wrote down its voltage, then calculated Series Resistor via formula and compared it to real parallel resistor value.
6. for last experiment, I only set ammeter to $0.04A$ and did the previous steps again.



Ohm’s Law on parallel Resistor - Experiments Table

R_2	R_3	$R_{real} = R_2 + R_3$	V_S	I	$Ammeter_{accuracy}$	$R_{measured} = \frac{V_S}{I}$
199.9Ω	110.2Ω	310.100Ω	$6.03V$	$0.02A$	$0.01A$	$301.500\Omega : \alpha$
199.9Ω	110.2Ω	310.100Ω	$12.24V$	$0.04A$	$0.01A$	$306.000\Omega : \beta$

Calculations of R, α and β :

$$R_{real} = 199.9 + 110.2 = 301.500\Omega$$

$$\alpha : R = \frac{V_S}{I} = \frac{6.03}{0.02} = 301.500\Omega \qquad \beta : R = \frac{V_S}{I} = \frac{12.24}{0.04} = 306.000\Omega$$

Ohm’s Law on Parallel Resistors - 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 α : $\varepsilon_{abs} = |310.100\Omega - 306.000\Omega| = 4.100\Omega$

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

We get this absolute error for α : $\varepsilon_{rel} = \frac{4.100\Omega}{310.100\Omega} \approx 0.013$

for systematic formula, We must do several mathematics operations :

10. Consider we have formula $V = I.R \Rightarrow R = \frac{V}{I}$.
11. Take the ln from both sides.

12. Take the differential from both sides.
13. Convert differentials to delta (Δ).
14. Convert every $-$ to $+$.
15. accuracy of **Analog Device** is equal to the lowest shown range on the device.
16. Error of **Analog Device** is equal to the lowest shown range on device multiplied by 0.5.
17. accuracy of **Digital Device** is equal to 10^{-x} where x is float level on the screen.
18. 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 :

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

for R :

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

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

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

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

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

$$Final: \qquad \frac{\Delta R}{R} = \frac{10^{-2}V}{12.24V} + \frac{10^{-2}\times 0.5A}{0.04A} = 0.1258$$

$$\Rightarrow \varepsilon_{sys} = 0.1258$$

Result

1. We proved Ohm's Law for single, parallel and series resistors.