# On non-ideal voltage and current measurement tools

Latipov Vladimir && Onishenko Sergiy

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# Contents

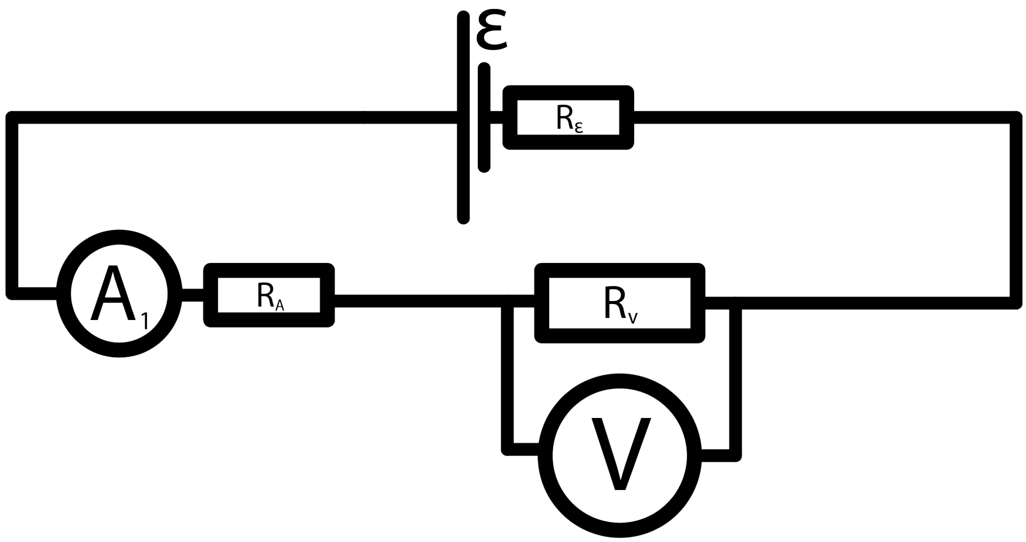
# 1 Abstract

The contents of this section should be too abstract for me to be able to write it.

# 2 Experiments

There were 3 experiments and 4 measurements arranged:

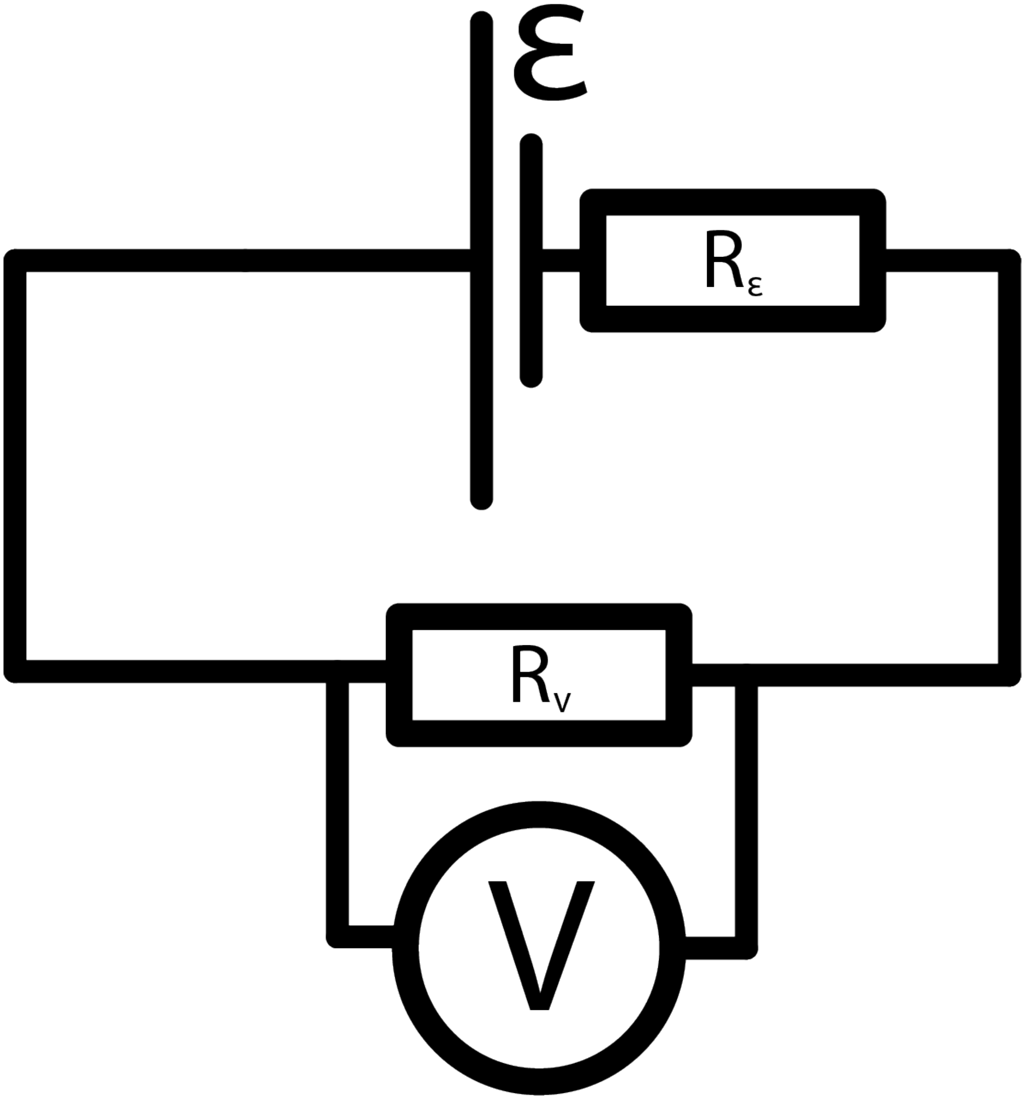
## 2.1 Experiment №1: Sequential plugging in




$$A_1 = \frac{\varepsilon}{R_{all}}$$

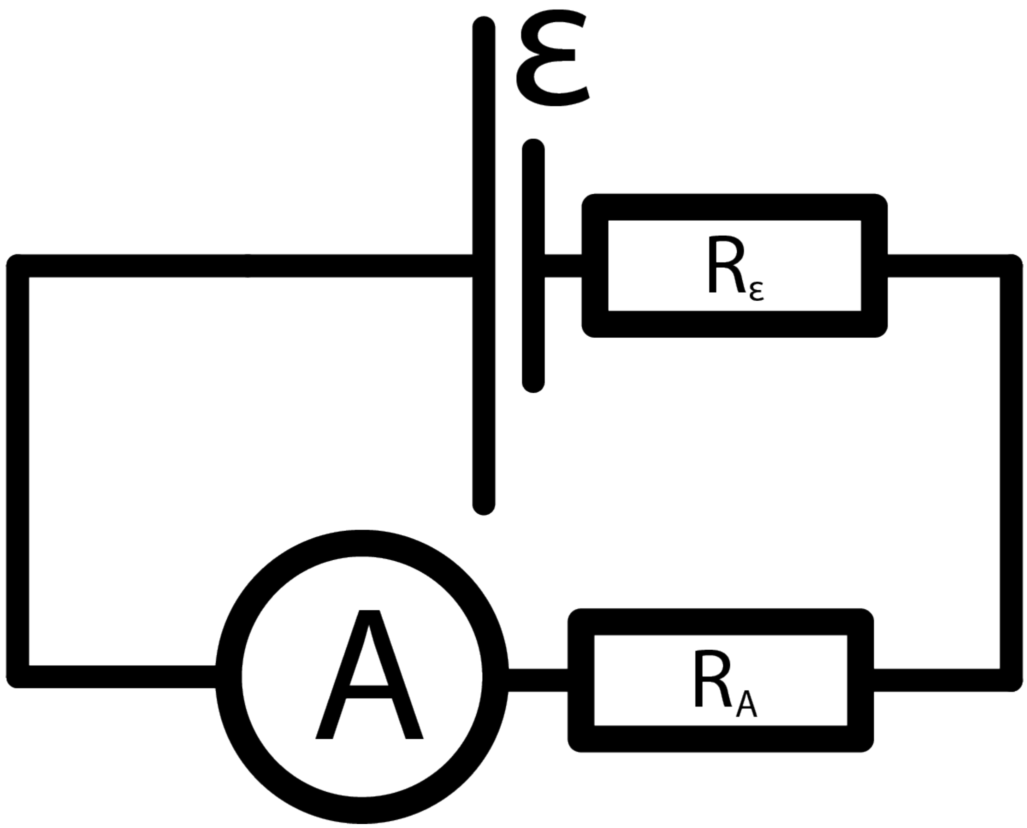
$$V_1 = \varepsilon \cdot \frac{R_v}{R_{all}}$$
$$R_{all} = R_\varepsilon + R_A + R_v$$

## 2.2 Experiment №2: Only Voltmeter




$$V_2 = \varepsilon \cdot \frac{R_v}{R_v + R_\varepsilon}$$

### 2.3 Experiment №3: Only Ampermeter




$$A_3 = \varepsilon \cdot \frac{1}{R_A + R_\varepsilon}$$

# 3 Solving equation system

***<u>Some bold, italic and underlined text here</u>***

$$A_1 = \frac{\varepsilon}{R_{all}} \tag{1}$$

$$V_1 = \varepsilon \cdot \frac{R_v}{R_{all}} \tag{2}$$

$$R_v = \frac{V_1}{A_1}$$

$$V_2 = \varepsilon \cdot \frac{R_v}{R_v + R_\varepsilon} \tag{3}$$

$$\varepsilon = V_2 + V_2 \cdot \frac{R_\varepsilon}{R_v}$$

$$A_3 = \varepsilon \cdot \frac{1}{R_A + R_\varepsilon} = \left(V_2 + V_2 \cdot \frac{R_\varepsilon}{R_v}\right) \cdot \frac{1}{R_A + R_\varepsilon} \tag{4}$$

$$A_3 \cdot R_A + A_3 \cdot R_\varepsilon = V_2 + R_\varepsilon \cdot \frac{V_2}{R_v}$$

$$R_\varepsilon \cdot \left(A_3 - \frac{V_2}{R_v}\right) = V_2 + A_3 \cdot R_A$$

$$R_\varepsilon = \frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}$$

$$(1) \rightarrow A_1 = \frac{\varepsilon}{R_{all}} = \frac{\varepsilon}{R_v + R_A + R_\varepsilon} = \frac{\varepsilon}{R_v + R_A + \frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}}$$

$$A_1 = \frac{\varepsilon}{R_v + \frac{V_2}{A_3 - \frac{V_2}{R_v}} + R_A \cdot \left(1 + \frac{A_3}{A_3 - \frac{V_2}{R_v}}\right)}$$

$$\varepsilon = V_2 + V_2 \cdot \frac{\frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}}{R_v} = V_2 + V_2 \cdot \frac{\frac{V_2}{A_3 - \frac{V_2}{R_v}} + \frac{A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}}{R_v} = V_2 + \frac{V_2^2}{R_v \cdot A_3 - V_2} + R_A \cdot \frac{A_3 \cdot V_2}{A_3 \cdot R_v - V_2}$$

$$V_2+\frac{V_2^2}{R_v\cdot A_3-V_2}+R_A\cdot\frac{A_3\cdot V_2}{A_3\cdot R_v-V_2}=A_1\cdot R_v+\frac{V_2\cdot A_1}{A_3-\frac{V_2}{R_v}}+R_A\cdot A_1\cdot\left(1+\frac{A_3}{A_3-\frac{V_2}{R_v}}\right)$$

$$R_A\cdot\frac{A_3\cdot V_2}{A_3\cdot R_v-V_2}-R_A\cdot A_1\cdot\left(1+\frac{A_3}{A_3-\frac{V_2}{R_v}}\right)=A_1\cdot R_v+\frac{V_2\cdot A_1}{A_3-\frac{V_2}{R_v}}-V_2-\frac{V_2^2}{R_v\cdot A_3-V_2}$$

$$R_A\cdot\left(\frac{A_3\cdot V_2}{A_3\cdot R_v-V_2}-A_1\cdot\left(1+\frac{A_3}{A_3-\frac{V_2}{R_v}}\right)\right)=A_1\cdot R_v+\frac{V_2\cdot A_1}{A_3-\frac{V_2}{R_v}}-V_2-\frac{V_2^2}{R_v\cdot A_3-V_2}$$

$$R_A=\frac{A_1\cdot R_v+\frac{V_2\cdot A_1}{A_3-\frac{V_2}{R_v}}-V_2-\frac{V_2^2}{R_v\cdot A_3-V_2}}{\frac{A_3\cdot V_2}{A_3\cdot R_v-V_2}-A_1\cdot\left(1+\frac{A_3}{A_3-\frac{V_2}{R_v}}\right)}$$

$$R_\varepsilon=\frac{V_2+A_3\cdot R_A}{A_3-\frac{V_2}{R_v}}$$

$$\varepsilon=V_2+V_2\cdot\frac{R_\varepsilon}{R_v}$$

# 4 Measurement Results

We‘re neglecting the inaccuracy of the pre-determined upper device measurement limit which is written on those devices. It‘s inaccuracy is pretty low!

$$A_1=((0.6\pm0.07)\,Ampere)\times\frac{15.8}{2000}=(4.7\pm0.6)\,milliAmpere$$

$$V_1=((3.25\pm0.1)\,Volt)\times\frac{6.1}{6}=(3.30\pm0.1)\,Volt$$

$$V_2=((3.7\pm0.1)\,Volt)\times\frac{6.1}{6}=(3.76\pm0.1)\,Volt$$

$$A_3=((1.8\pm0.07)\,Ampere)\times\frac{15.8}{2000}=(14.22\pm0.6)\,milliAmpere$$

# 5 Computing the Result

For this purpose I‘ve written a python script, which is situated here:
https://github.com/donRumata03/Experiments/blob/master/BadVoltageSensors/new_formula_counter.py
To compute the dispersion automatically I used Andrew Sitnikov‘s library from https://github.com/sitandr/dispersion_counter
However, it contained some bugs, for example, with computing relative dispersion of negative numbers, so, I‘ve made some commits to that repository.

# 6 The Answer

So, the impedance and voltage values are the following:

$$R_v = (697 \pm 18)\ Ohm$$

$$R_e = (75 \pm 13) \times 10^1\ Ohm$$

$$R_A = (20 \pm 5) \times 10^1\ Ohm$$

$$\varepsilon = (7.8 \pm 1.4)\ Volts$$

# 7 Conclusion

Unfortunately, there are many computations required to find the answer, which decrease the accuracy of it.
However, the answer itself seems to me reasonable.
As expected, the quality of the devices leaves much to be desired...
However, it’s quite suspicious that there is a bit too high resistance of the battery.
There can be no errors with equation solving because their solutions are perfectly validated.