PHYSICS INVESTIGATION
IB PHYSICS SL

Determination of the specific resistance of the metal taking aluminum as an example.

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June 2016

Word Count: 1638

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Introduction:

When I was in high school, I had a wonderful teacher of physics, which could well explain and motivate students. Physics I began to study with grade 7, and since the subject is causing me a lot of interest. My teacher always showing interesting experiments, which caused me and my classmates delight. I also really love history, especially I got interested in the topic of the arms race between the superpowers and the development of nuclear weapons during the Cold War. I believe that the history and physics have some common topics that I would like to study.

I have a lot of time to conduct my own experiments at home, but it were simple enough. I once had a bad experience when I have burned out light of the fact that the resistance was not compatible with the mains voltage. From that moment, I wanted to learn more about the electrical resistance, to continue not to make mistakes.
The aim of this investigation is to determine the specific resistance of the metal taking aluminum as an example.

Machinery and equipment: 50 cm ruler, battery, micrometer, 2 multimeter, scissors, connecting wires, foils.

Background Theory:

The basic concepts used in electricity - a "current" and "voltage". In order to make it easier to understand, I use the analogy and compare the movement of electric charge through a conductor with the flow of fluid in a horizontal tube.

The basic value, which describes the flow of fluid, is deemed volume V, which flows through the pipe cross-section in unit time. To the liquid flowed through the pipe, to its ends need to apply some pressure difference P. Flow depending on the pressure difference is determined by the properties of the pipe. The thinner and longer the pipe, the greater the pressure difference would require in order passing water there through.

All the same can be said about the electric current flowing through the wire. Its main characteristic is the amount of charge flowing through the wire cross-section per unit time. This value is called the current I, measured in amperes[1]. To flow through the wire to the electric current, to its ends should apply the voltage U, which is created by the source, in my work - battery. Voltage is measured in volts[2]. The strength of an electric current also depends on the properties and geometric dimensions of the wire, for example, of its length. Characterized by the ability of conductor to prevent the passage of electric current is called resistance.

Obviously, in order to through a pipe per unit of time has passed more water I need to increase the pressure of the water at its ends. Such a law called Ohm's law, valid for the electric current.

Ohm's Law (for conductor): The strength of the current I in the conductor is directly proportional to the voltage U at the ends of the conductor and inversely proportional to its the resistance of the R: $I = \frac{U}{R}$. From the Ohm's law to be the ratio of voltage U and current I depend on the length of x as follows: $\frac{U}{I} = \rho\frac{x}{S}$. The ratio of U to I can be designated as r: $r = \rho\frac{x}{S}$ [3].
Resistivity - a physical quantity that characterizes the ability of a substance prevent the passage of an electric current.

The electrical resistance of a rectangular conductor with resistivity ρ, a length l and the cross-sectional area S can be calculated by the formula: $R = \rho\frac{l}{S}$ [4].

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[1] K. A. Tsokos «Physics for the IB Diploma», Chapter 5.4: Electric current and electric resistance, p.310
[2] K. A. Tsokos «Physics for the IB Diploma», Chapter 5.4: Electric current and electric resistance, p.314
[3] K. A. Tsokos «Physics for the IB Diploma», Chapter 5.4: Electric current and electric resistance, p.314
[4] K. A. Tsokos «Physics for the IB Diploma», Chapter 5.4: Electric current and electric resistance, p,312

Description of the experiment:

I divided my IA into 3 parts.

In the first part of investigation, I will measure the foil thickness with a micrometer. I will measure the dependence of thickness of the stack of several layers of foil L on the number of layers of N. Then I'm going to build a graph of the dependence of thickness of the stack L on the number of layers of N. Using the graph, I can find the thickness of one foil layer.

In the second part of investigation I will make a long strip from the foil. Using a multimeter, I will define the dependence of the resistance area of the foil strip R on its length L. For this purpose, one of the multimeter probes connected to one of ends of the foil strip. The second probe is connected to different points of the foil strip[5]. I will build a graph of dependence of the resistance area of strip R on its length L. Using this chart and the results of the first part of the study, I will define the resistivity of the metal of the foil.

In the third part of investigation to the ends of the foil strips are connected in series and connected to the battery meter, working in the ammeter mode. To one end of the strip connected to one of the probes of another multimeter, operating in voltmeter mode. His second probe can be connected to different points on the strip (the length of the strip that connects the probes of the voltmeter is equal to x). In this part, I will calculate the dependence of voltage on the voltmeter U and current I expected to flow through the ammeter, the length of x. Also, I will build a graph of dependence of r values of the length x. Using a plot of $r(x)$ and the measured value in the first part of the thickness of the foil, I look to determine the resistivity of the metal.

[5] K. A. Tsokos «Physics for the IB Diploma», Chapter 5.5: Electric circuits, p. 325.

Main Body:

For a stack of N number of layers is performed formula:

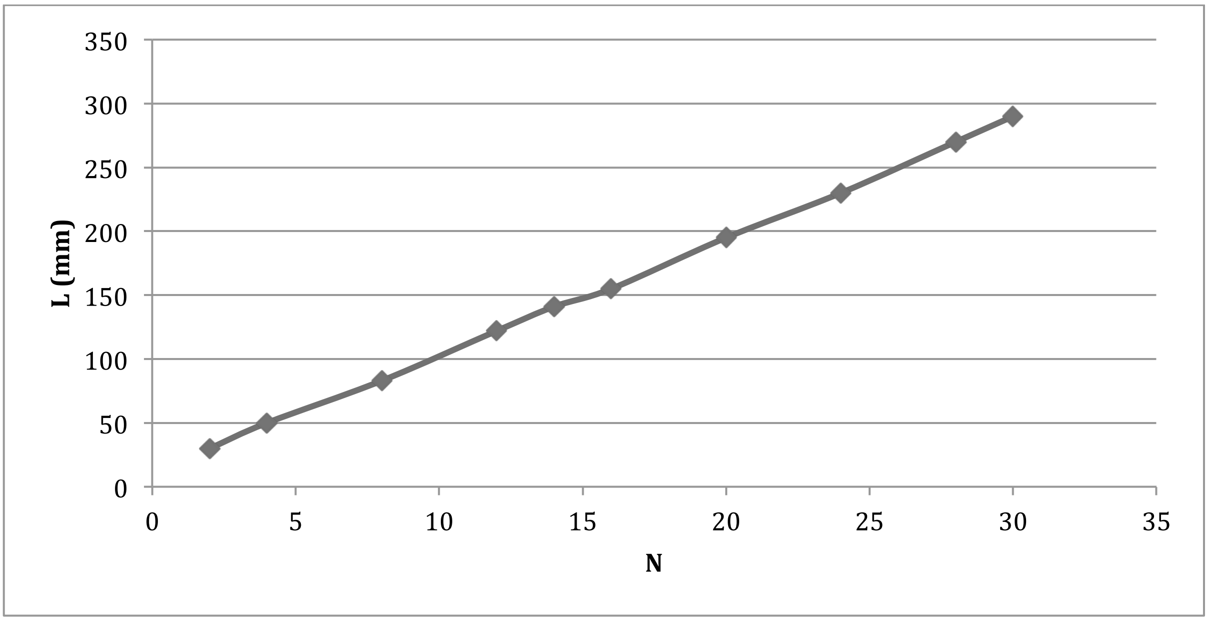
$$L = d \cdot N \quad (1)$$

Where L - thick stack, d- the thickness of 1 foil layer, N- number of layers.
A graph of dependence of $L(N)$ should reflect the linear relationship, the slope of this dependence is equal to d.
Taking measurements (Table 1.):

N	L, mm
2	30
4	50
8	83
12	122
14	141
16	155
20	195
24	230
28	270
30	290

Table 1.

Construct a graph (Graph 1.):



Graph 1.

From the graph I got $d = 9.2\ micrometers$.

In order to make a long strip of a sheet of foil, I need to cut the sheet in accordance with a Figure 1:

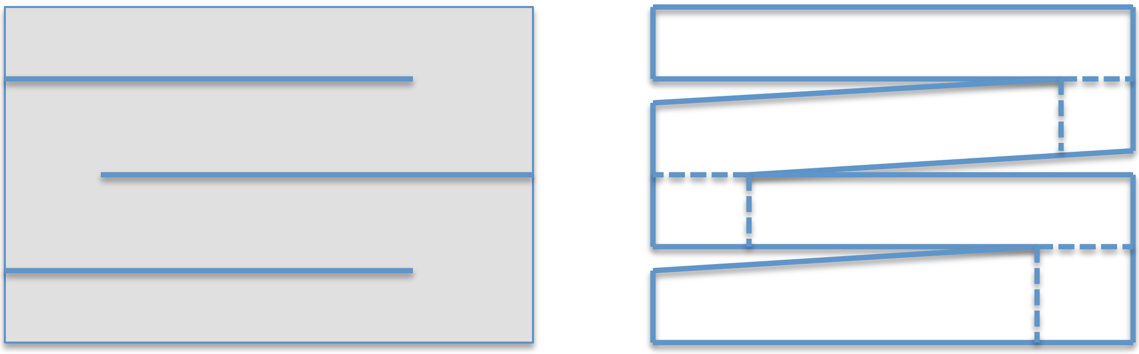


Figure 1.

Junction folded in half along the lines marked by a dotted line. To foil strip runs the formula:

$$R = \frac{\rho}{S} l = al \qquad (2)$$

where R- resistance, ρ- resistivity, S- sectional area of the foil strip, l- length of the strip. The formula shows that the R is a linear function of l, the ratio $\frac{\rho}{S}$ plays the role of slope a, which can be found from the graph. In my case, the width $b = 10 \pm 1\ mm$.
One of the multimeter probes operating in the resistance measurement mode, connected to one end of the strip. The second probe is connected alternately at different points strip (Figure 2):

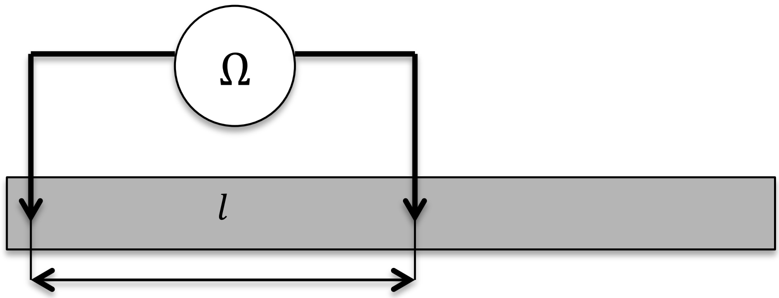


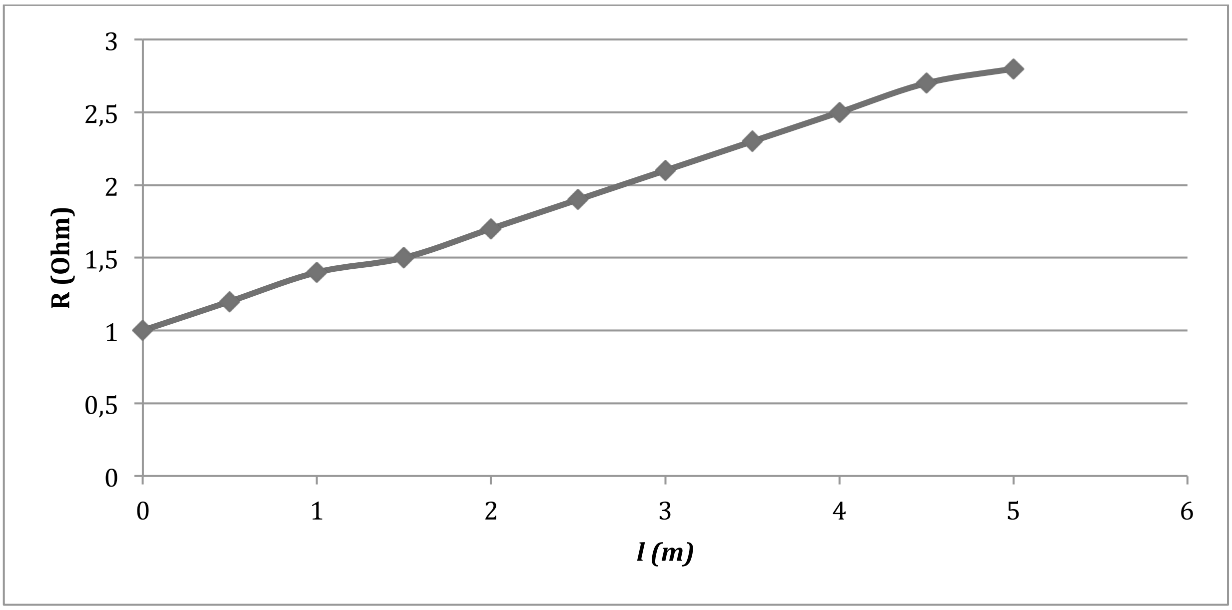
Figure 2. The foil strip

I get the following measurements (Table 2.):

$1, m$	R, Ohm
0	1
0,5	1,2
1	1,4
1,5	1,5
2	1,7
2,5	1,9
3	2,1
3,5	2,3
4	2,5
4,5	2,7
5	2,8

Table 2.

Construct a graph of dependence of $R(l)$ (Graph 2.):



Graph 2.

From the graph I got $a = 0{,}37\ \frac{Ohm}{m}$.
Carry out calculations. From the formula (2):

$$\rho = a \cdot S = a \cdot d \cdot b \tag{3}$$

$$\rho = 0{,}37\frac{Ohm}{m} \cdot 0{,}092\ mm \cdot 10\ mm = 0{,}034\ \frac{Ohm \cdot mm^2}{m}.$$

To the ends of the foil strips are connected in series and connected to the battery meter, working in the ammeter mode. To one end of the strip connected to one of the probes of another multimeter, operating in voltmeter mode. His second probe can be connected to different points on the strip[6] (Figure 3.):

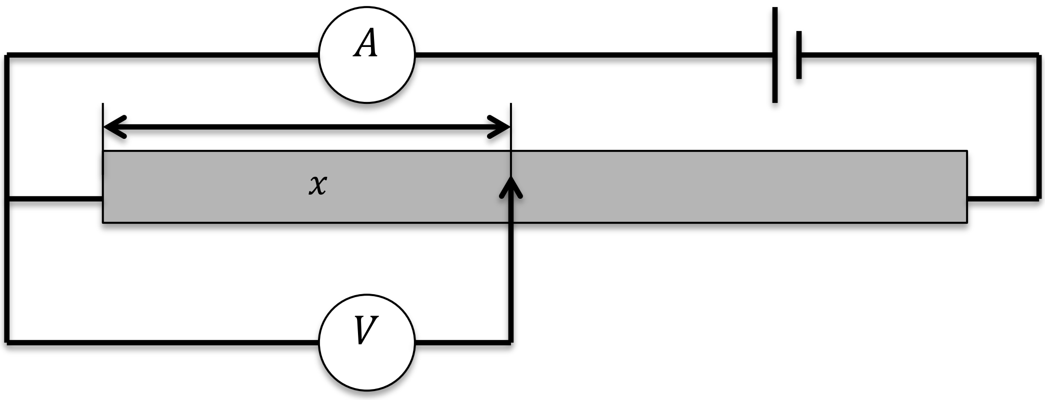


Figure 3.

For the circuit shown in Figure 1, I use following formula:

$$r = \frac{\rho}{S}x = \beta x \qquad (4)$$

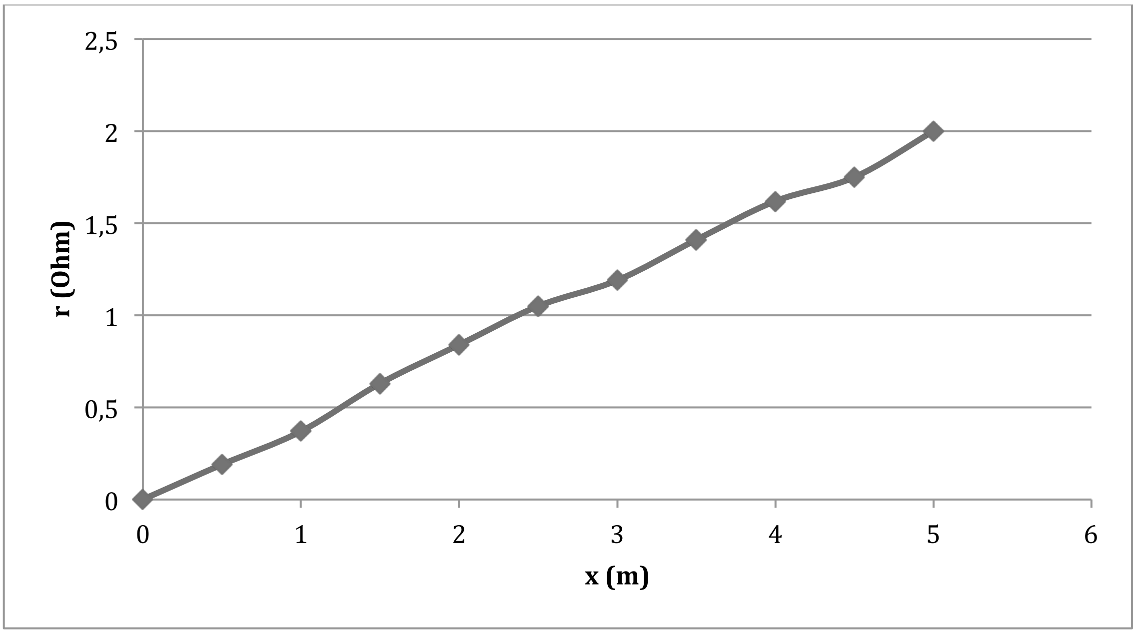
where x- coordinate of the probe position on the strip (measured from the point of connection of another probe). The formula (4) shows that r linearly depends on x, the ratio of $\frac{\rho}{S}$ plays the role of slope β, which can be found from the graph.
I received the following measurements:

x, m	U, mV	I, A	R, Ohm
0	0	0,38	0,00
0,5	71	0,38	0,19
1	138	0,37	0,37
1,5	238	0,38	0,63
2	310	0,37	0,84
2,5	390	0,37	1,05
3	439	0,37	1,19
3,5	520	0,37	1,41
4	600	0,37	1,62
4,5	647	0,37	1,75
5	720	0,36	2,00

Table 3.

[6] K. A. Tsokos «Physics for the IB Diploma», Chapter 5.5: Electric circuits, p.326

Construct a graph of dependence of $r(x)$ (Graph 3.):



Graph 3.

From the graph I got $\beta = 0{,}40\ \frac{Ohm}{m}$.

Carry out computations:

$$\rho = \beta \cdot d \cdot b \tag{5}$$

$$\rho = 0{,}40\frac{Ohm}{m} \cdot 0{,}0092\ mm \cdot 10\ mm = 0{,}037\frac{Ohm \cdot mm^2}{m}.$$

Conclusion:

Used this method for finding the resistivity showed the results that equal to 0.034 and 0.037. Tabulated values for the metal is 0.027 taken from «Metals Reference Book»[7]. Thus, our experience can be considered acceptable to a finding of a sufficiently accurate value.
I believe that the finding of resistance is an important part of many physical research. Therefore, this experience can find its application in real life.
However, it is worth noting that if you connect probes of the multimeter, I could not precisely determine the length of the foil, where the current flows because of form of used probes. If I would have probes with thinner ends, the calculation would be more accurate.

[7] Colin J. Smiithells «Metals Reference Book», Chapter 19: Electrical properties, resistivity, p. 1035.

Bibliography:

Colin J. Smiithells «Metals Reference Book», Fifth edition, printed and bound by R. J. Aeford Ltd., Industrial Estate, Chichester.

K. A. Tsokos «Physics for the IB Diploma», fifth edition(full colour version) 2010, printed in the United Kingdom by Latimer Trend, Cambridge University Press.