T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY II
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Verifying Ohm's law and measuring specific resistances

PREPARED BY

NAME AND SURNAME :

STUDENT NUMBER :

DEPARTMENT :

GROUP NO :

TEACHING ASSISTANT :

DATE OF THE EXPERIMENT : ….. / ….. / ……….

DATE : ….. / ….. / ……….

Signature:

Experimental Procedure:

The experimental setup is illustrated in Figure 3.1. Take a series of voltage and current measurements in the circuit and use these to determine the relationship between potential difference ΔV and current I. To limit the current flowing through the wire, connect the rheostat in series with the circuit. Ensure that the voltmeter is connected in parallel across and the ammeter is connected in series with the conducting wires. Smoothly adjust the rheostat from minimum resistance to maximum resistance and at regular intervals, note the multimeter reading and obtain a set of values from the two multimeters.

1. Insert the probes (banana jacks) into the sockets on the resistance board to build the circuit that is shown as in the Figure 3.3.
2. Connect the voltmeter in parallel to the *constantan* wire 1 mm diameter and connect the voltage source, and the ammeter in series to this arrangement. Adjust voltage drops ΔV between 0.2 V and 1.0 V in steps of 0.2 V, each time reading the current I and taking ΔV and I down.
3. Connect the *constantan* wire 0.7 mm diameter and record the series of measurements in steps of 0.2 V.
4. Record further series of measurements on the *constantan* wire 0.5 mm diameter in steps of 0.2 V up to 1.0 V and on the *constantan* wire 0.35 mm diameter in steps of 0.2 V up to 1.0 V.
5. For the series connection of the two *constantan* wires 0.7 mm diameter (total length L = 2 m), connect the two sockets on one side via a short cable. Then, connect the voltmeter, the ammeter and the voltage source to the sockets on the opposite side. Record another series of measurements in steps of 0.2 V.
6. Record a series of measurements on *messing* 0.5 mm diameter in steps of 0.1 V, and compare it with the series of measurements on *constantan* 0.5 mm diameter.
7. For each voltage output, read and record the readings of the voltage ΔV and current I by voltmeter and ammeter, respectively, and note down the values in the related tables below.

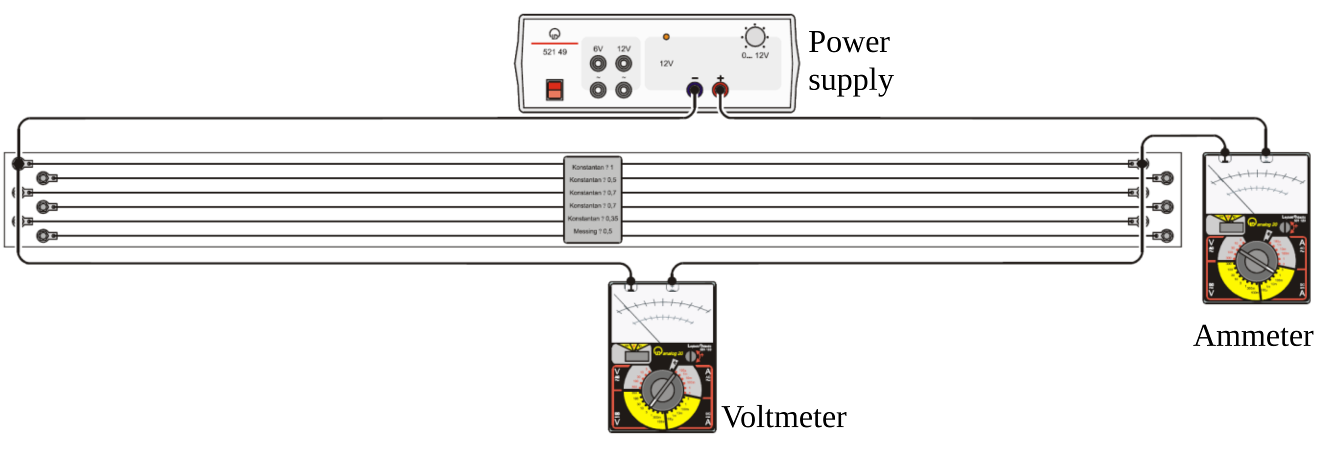

Figure 3.3: Experimental setup for verifying Ohm's law.

Table 3.1: Constantan wires with equal length (L = 1m) and different thickness.

	d = 1.00 (mm)	d = 0.70 (mm)	d = 0.50 (mm)	d = 0.35 (mm)
ΔV (V)	I ( )	I ( )	I ( )	I ( )
0.2				
0.4				
0.6				
0.8				
1.0				

Table 3.2: Constantan wires with equal thickness (d = 0.7 mm) and different length. Use data from Table 3.1 above for L = 1 m constantan wire.

	L = 1 (m)	L = 2 (m)
ΔV (V)	I ( )	I ( )
0.2		
0.4		
0.6		
0.8		
1.0		

Table 3.3: Messing and Constantan wires with equal thickness (d = 0.50 mm) and length (L =1 m).

	Messing	Constantan
ΔV (V)	I ( )	I ( )
0.1		
0.2		
0.3		
0.4		
0.5		

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Calculations and Analysis:

As a result of calculations and analysis, the proportionality between the current *I* and the voltage *ΔV* will be verified for metal wires with various thicknesses and lengths and made of different materials. In each case, the resistance is determined as the proportionality constant. The dependence of the proportionality constant on the length and the cross-sectional area is examined, and the specific resistance of the material will be determined according to Equation 3.13.

I. Verifying Ohm's Law:

To verify the ohm's law, plot $\Delta V - I$ graph for each constantan wire, on reserved millimetric space, using *ΔV* and *I* columns of Table 3.1 as *x*– and *y*–axis, respectively. According to Ohm's law, which states that the current flowing in a conducting material is directly proportional to the voltage, we expect a line in the form of $y = mx$ to pass through those points and the origin, where *m* is the slope of the line. The slope of the line should be calculated by means of the statistical linear fitting method called the "*least squares method*" its formulae are given below.

Calculate the slopes of the lines that fit the data points on your $\Delta V - I$ graphs, which are plotted in the following step. In the following formulae, the x_i's represent the ΔV, while the y_i's represent the *I* values. *k* is the number of data used in calculations.

i) *d* = 0.35 *mm*

$$\sum_{i=1}^{k} \Delta V_i \, I_i =$$

$$m_{0.50} = \frac{1}{R_{0.50}} = \frac{\sum_{i=1}^{k} \Delta V_i \, I_i}{\sum_{i=1}^{k} \Delta V_i^2} =$$

$$\sum_{i=1}^{k} \Delta V_i^2 =$$

$$R_{0.35} = \frac{1}{m_{0.35}} =$$

ii) *d* = 0.50 *mm*

$$\sum_{i=1}^{k} \Delta V_i \, I_i =$$

$$m_{0.50} = \frac{1}{R_{0.50}} = \frac{\sum_{i=1}^{k} \Delta V_i \, I_i}{\sum_{i=1}^{k} \Delta V_i^2} =$$

$$\sum_{i=1}^{k} \Delta V_i^2 =$$

$$R_{0.50} = \frac{1}{m_{0.50}} =$$

iii) *d* = 0.70 *mm*

$$\sum_{i=1}^{k} \Delta V_i \, I_i =$$

$$m_{0.70} = \frac{1}{R_{0.70}} = \frac{\sum_{i=1}^{k} \Delta V_i \, I_i}{\sum_{i=1}^{k} \Delta V_i^2} =$$

$$\sum_{i=1}^{k} \Delta V_i^2 =$$

$$R_{0.70} = \frac{1}{m_{0.70}} =$$

iv) *d* = 1.00 *mm*

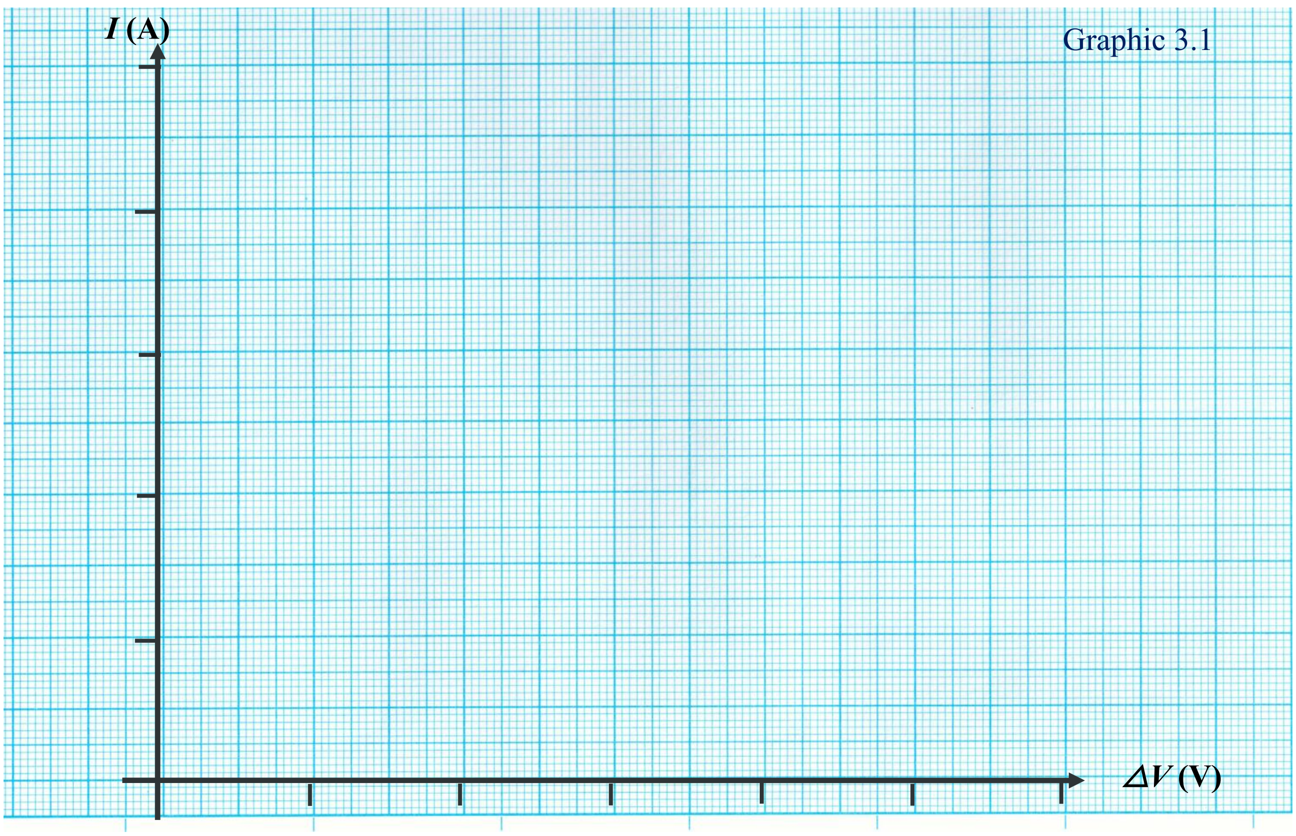
$$\sum_{i=1}^{k} \Delta V_i \, I_i =$$

$$m_{1.00} = \frac{1}{R_{1.00}} = \frac{\sum_{i=1}^{k} \Delta V_i \, I_i}{\sum_{i=1}^{k} \Delta V_i^2} =$$

$$\sum_{i=1}^{k} \Delta V_i^2 =$$

$$R_{1.00} = \frac{1}{m_{1.00}} =$$

In the following graph, plot four data sets from Table 3.1. Represent the *ΔV* values on the *x*–axis, while the *I* values on the *y*–axis of your graphs. Represent the data as points on your graph and draw the lines $y = mx$ for *constantan* wires where the slopes *m's* are calculated in the previous steps. Use those *m* values to plot the straight lines passing from the origin on your graph and observe how they fit with your experimental data points.



Do the graphs you plotted above confirm the ohm's law? Please explain your answer, supporting it with theory. Can we say *ohmic* for the wires that we used in the experiment?

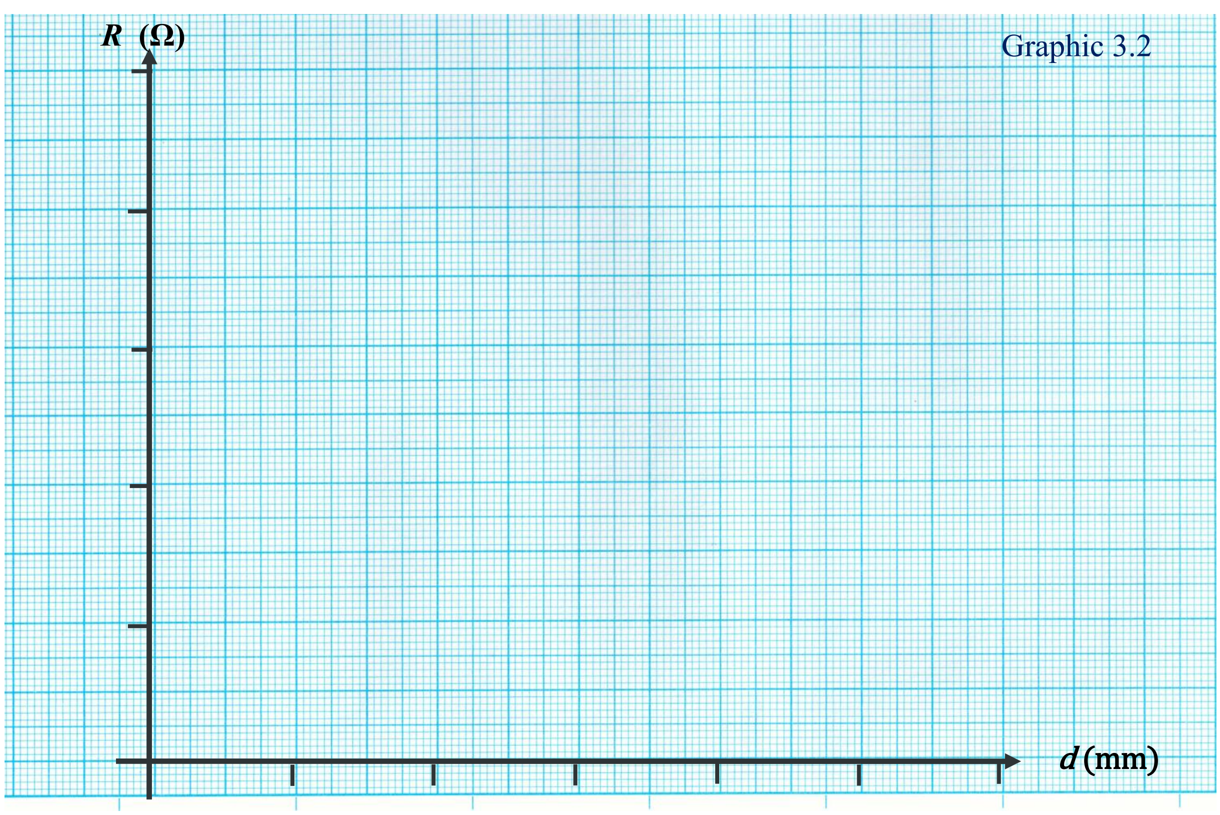
II. Dependence on the diameter *d* (same material and equal length $L = 1$ *m*):

In order to find the diameter (d) dependence of resistance (R), you need to plot $\log R - \log d$ graph. Fill the second column of Table 3.4 with the calculated resistance (R) from the previous step and create the following Table 3.4 after calculating logarithms of diameter (d) and resistance (R).

Table 3.4: Radius dependence of resistance of Constantan wires.

d (mm)	R (Ω)	$\log d$	$\log R$
0.35			
0.50			
0.70			
1.00			

You are asked to plot the resistance vs. diameter ($R - d$) graph using Table 3.4. Choose the x–axis as d and the y–axis as R. Represent the data in Table 3.4 as points on your plot. Draw the curve on your graph that fits best to your data points by *crude eye estimation*. What type of a curve is expected to pass through those points?



As it can be seen from your resistance vs. diameter graph, the relation between those quantities is not linear. However, it can still be investigated using the linear fitting methods by manipulating the diameter-resistance relationship. We begin by assuming a relationship between resistance and diameter in the following form:

$$R \propto d^{\alpha} \;\Rightarrow R = \beta d^{\alpha} \qquad 3.14$$

If we take the logarithm of Equation 3.14, we get Equation 3.15

$$\log R = \log \beta + \alpha \log d \qquad 3.15$$

Note that this is a linear relation of the form $y = n + mx$. So if we take $\log R$ and $\log d$ as our variables from Table 3.4, we can determine the values of α and $\log \beta$ by linear fitting techniques.

Calculate the slope α and the intercept $\log \beta$ of the line using the linear fitting formula that fits the data points on your $\log R - \log d$ graph. In the following sums, the x_i's represent the $\log d$ values on the x–axis, while the y_i's represent the $\log R$ values on the y–axis of your graphs. k is the number of data used in calculations.

$$\sum_{\text{i}=1}^{k} x_i =$$

$$\sum_{\text{i}=1}^{k} y_i =$$

$$\sum_{\text{i}=1}^{k} x_i^2 =$$

$$\sum_{\text{i}=1}^{k} x_i\, y_i =$$

$$\alpha = \frac{4\sum_{\text{i}=1}^{k} x_i\, y_i - \sum_{\text{i}=1}^{k} x_i \sum_{\text{i}=1}^{k} y_i}{4\sum_{\text{i}=1}^{k} x_i^2 - \left(\sum_{\text{i}=1}^{k} x_i\right)^2} =$$

$$\log \beta = \frac{\sum_{\text{i}=1}^{4} x_i^2 \sum_{\text{i}=1}^{4} y_i - \sum_{\text{i}=1}^{4} x_i\, y_i \sum_{\text{i}=1}^{4} x_i}{4\sum_{\text{i}=1}^{4} x_i^2 - (\sum_{\text{i}=1}^{4} x_i)^2} =$$

Compare your calculated α to its expected value. Discuss the reasons for possible causes of differences.

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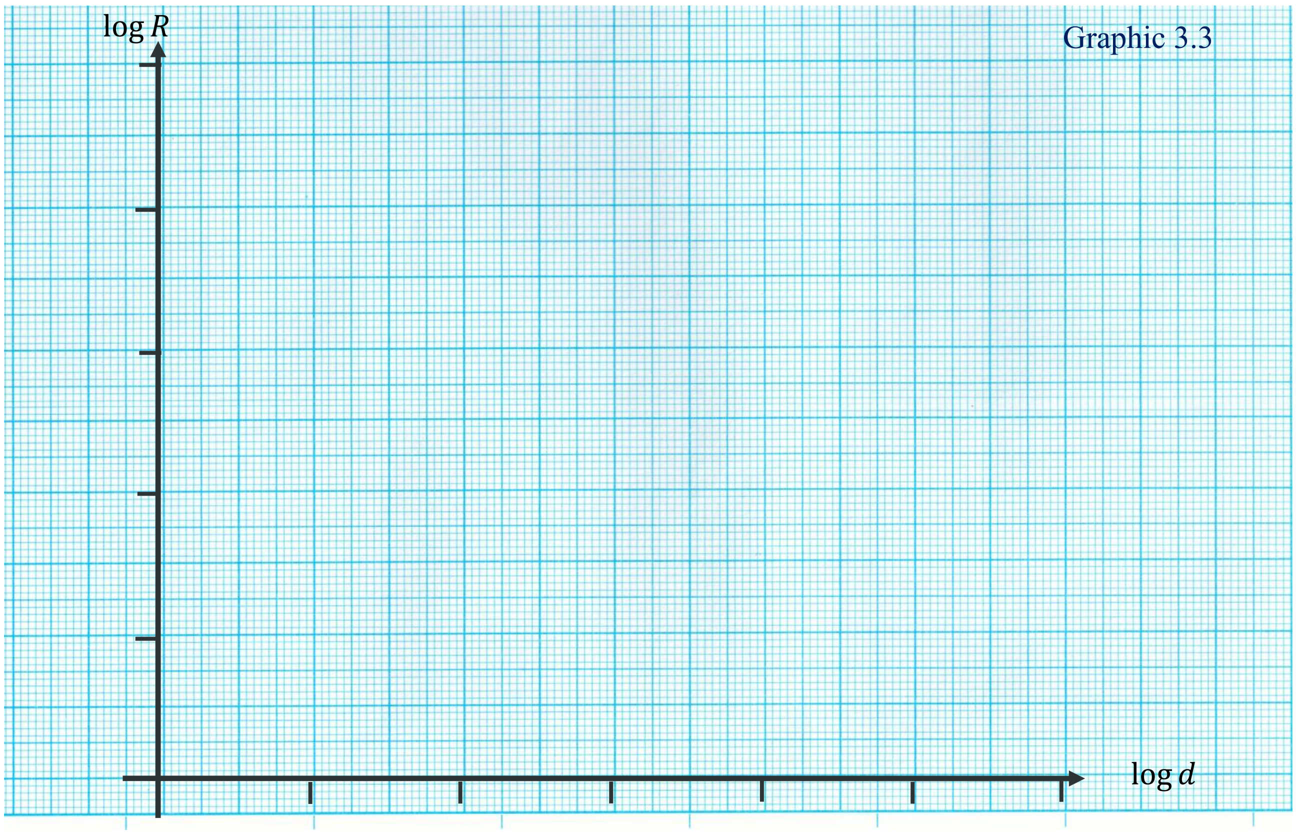
In the following graph, plot $\log d - \log R$ using $\log d$ and $\log R$ columns of Table 3.4 as x– and y–axis, respectively. Represent the data as points on your graph and draw the straight line $\log R = \log \beta + \alpha \log d$ for *constantan* wires.



Considering the graphs you plotted above, what can you say about the relationship between resistance and diameter, and the effect of the diameter of the wire on resistance.

III. Dependence on the length *L* (same material and equal diameter *d* = 0.70 *mm*) :

In Table 3.2, there are two constantan wires with the same diameter but different length. To investigate the dependence of resistance on length, plot $\Delta V - I$ graphs using ΔV and I columns of Table 3.2 as *x*– and *y*–axis, respectively. According to Ohm's law, we expect a line in the form of $y = mx$ passing through the data points and the origin, where *m* is the slope of the line. The slope of the line should be calculated by means of the statistical fitting method called the "*least squares method*" its formulae are given below.

i) for *L* = 1 m;

$$\sum_{i=1}^{k} \Delta V_i \, I_i =$$

$$\sum_{i=1}^{k} \Delta V_i^2 =$$

$$m_1 = \frac{1}{R_1} = \frac{\sum_{i=1}^{k} \Delta V_i \, I_i}{\sum_{i=1}^{k} \Delta V_i^2} =$$

$$R_1 = \frac{1}{m_1} =$$

ii) for *L* = 2 m;

$$\sum_{i=1}^{k} \Delta V_i \, I_i =$$

$$\sum_{i=1}^{k} \Delta V_i^2 =$$

$$m_2 = \frac{1}{R_2} = \frac{\sum_{i=1}^{k} \Delta V_i \, I_i}{\sum_{i=1}^{k} \Delta V_i^2} =$$

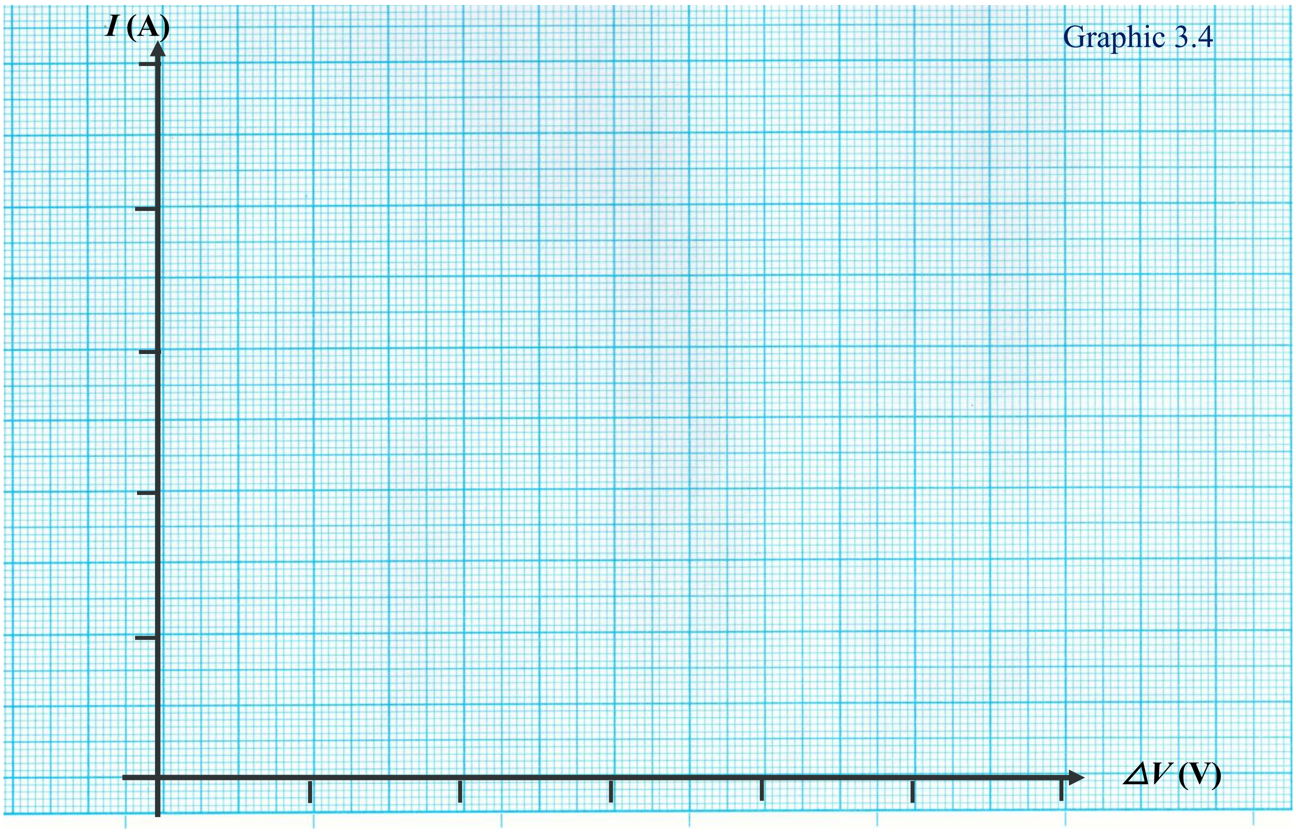
$$R_2 = \frac{1}{m_2} =$$

What is your expected ratio for the resistance of the 1 and 2 *m* length constantan wires? Calculate the following two ratios and interpret the relationship between resistance and length of a conductor.

$$\frac{L_1}{L_2} =$$

$$\frac{R_1}{R_2} =$$

Use data from Table 3.2, represent the ΔV values on the x–axis and the I values on the y–axis of your graphs below. Mark the data as points on your graph and draw the straight lines $y = mx$ passing from the origin for *constantan* wires where the m slopes are calculated in the previous steps for different lengths.



IV. Dependence on the material (equal length L=1 m and diametereter d=0.50 mm):

Resistivity ρ is the property of material, while resistance is a property of an object, and resistance depends on resistivity.

Plot $\Delta V - I$ graphs, by using ΔV and I columns of Table 3.3 as x– and y–axis, respectively, show that current is directly proportional to voltage and investigate the dependence of resistance on materials. According to Ohm's law, we expect a line in the form of $y = mx$ to pass through those points and the origin, where m is the slope of the line. The slope of the line should be calculated by means of the statistical fitting method called "*least squares method*" its formulae are given below.

i) Constantan wire

$$\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i \, I_i =$$

$$\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i^2 =$$

$$m_C = \frac{1}{R_{\text{Constantan}}} = \frac{\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i \, I_i}{\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i^2} = \qquad R_{\text{Constantan}} = \frac{1}{m_C} =$$

$$R = \rho \frac{L}{\pi r^2} \Rightarrow \rho_{\text{Constantan}} = \frac{R\pi r^2}{L} =$$

ii) Messing wire

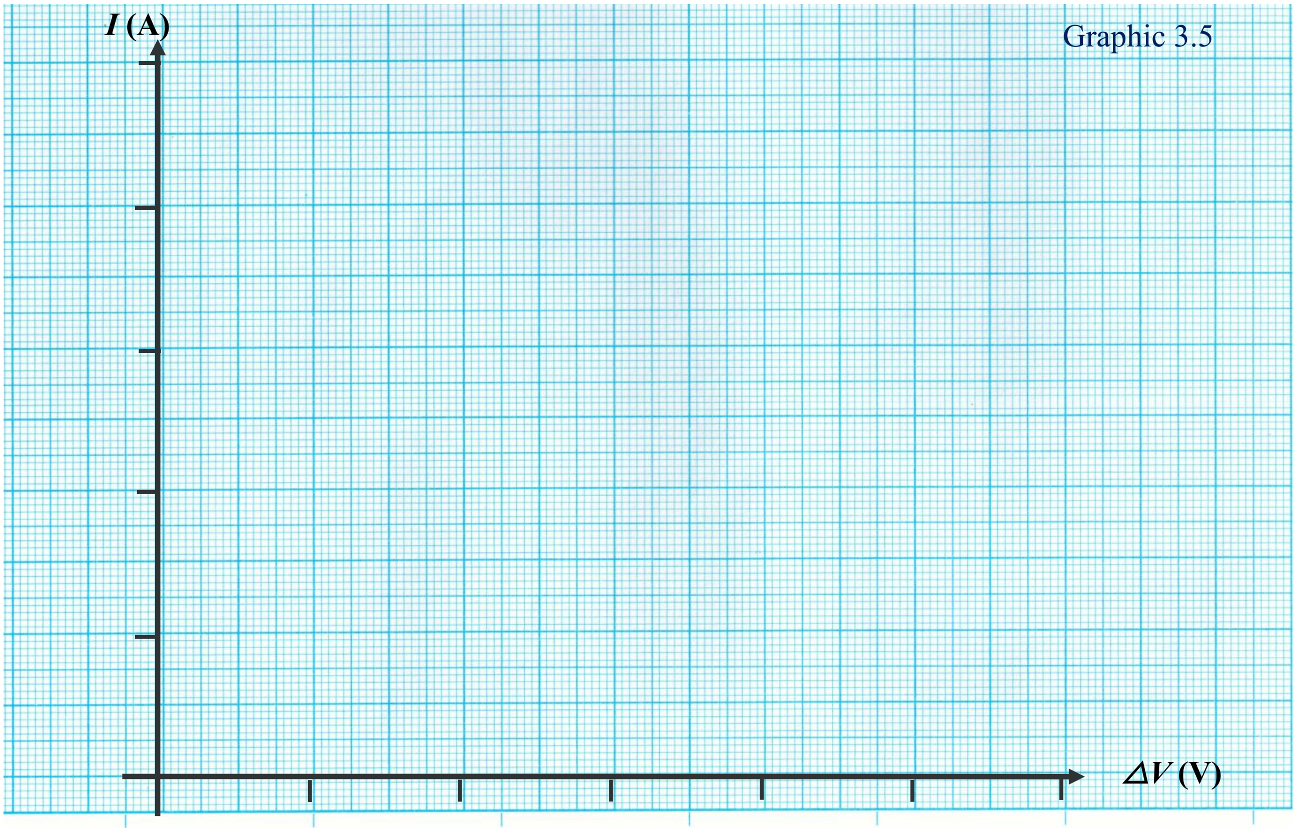
$$\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i \, I_i =$$

$$\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i^2 =$$

$$m_M = \frac{1}{R_{\text{Messing}}} = \frac{\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i \, I_i}{\sum_{\mathrm{i}=1}^{k} \Delta \mathrm{V}_i^2} = \qquad R_{\text{Messing}} = \frac{1}{m_M} =$$

$$R = \rho \frac{L}{\pi \mathrm{r}^2} \Rightarrow \rho_{\text{messing}} = \frac{R\pi r^2}{L} =$$

Represent the ΔV values on the x–axis and the I values on the y–axis of your graphs below. Mark the data as points on your graph and draw the straight lines $y = mx$ passing from the origin for *constantan* and *messing* wires where the m slopes are calculated in the previous steps for different materials.



What is the relationship between resistance and conductivity? What can you say about the resistivity and conductivity of messing and constantan wires?

Conclusion, Comment and Discussion:

(Tips: Explain your general observations and experimental findings objectively and scientifically with your original sentences. Please give detailed explanations about what you have learned from the experiment and also explain the possible errors and their reasons.)

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Questions:

1. Explain briefly *ohmic* and *non-ohmic* statements. Give two examples for each material type.

2. Which physical properties of the *ohmic* materials determine the magnitude of their resistance?

3. For *ohmic* materials, what is the relationship between resistance and temperature?