PHYSICS LAB 1 - RESISTIVITY

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AIM: THE AIM OF THIS EXPERIMENT IS TO DETERMINE THE RESISTIVITY (ρ) OF A WIRE USING A MICROMETER, AMMETER AND VOLTMETER.

BACKGROUND: THE RESISTIVITY IS AN ELECTRICAL RESISTANCE OF A CONDUCTOR OF A GIVEN SIZE (AREA AND LENGTH). THE RESISTIVITY OF A METAL IS A MATERIAL PROPERTY AND IS USUALLY LABELLED ρ (rho).

$$R = \frac{\rho \times L}{A}$$

(DIRECTLY PROPORTIONAL; DIRECTLY PROPORTIONAL) → DOUBLE LENGTH, DOUBLE RESISTANCE

R = RESISTANCE OF THE COMPONENT (Ω)
ρ = RESISTIVITY OF THE MATERIAL (Ω m)
L = LENGTH IN CURRENT DIRECTION (m)
A = CROSS-SECTIONAL AREA THE CURRENT PASSES THROUGH (m^2)

$R \propto L$ (PROPORTIONAL)

$R \propto 1/A$ (INVERSELY PROPORTIONAL)

- IN ORDER TO FIND THE RESISTIVITY OF THE WIRE, IT IS FIRST NEEDED TO CALCULATE THE RESISTANCE USING OHM'S LAW;

OHM'S LAW STATES THAT THE POTENTIAL DIFFERENCE (p.d) ACROSS A RESISTOR IS DIRECTLY PROPORTIONAL TO THE CURRENT THROUGH IT, PROVIDED THE EXTERNAL CONDITIONS REMAIN CONSTANT (E.G. THE TEMPERATURE).

$V = I \cdot R$

$R = V/I$

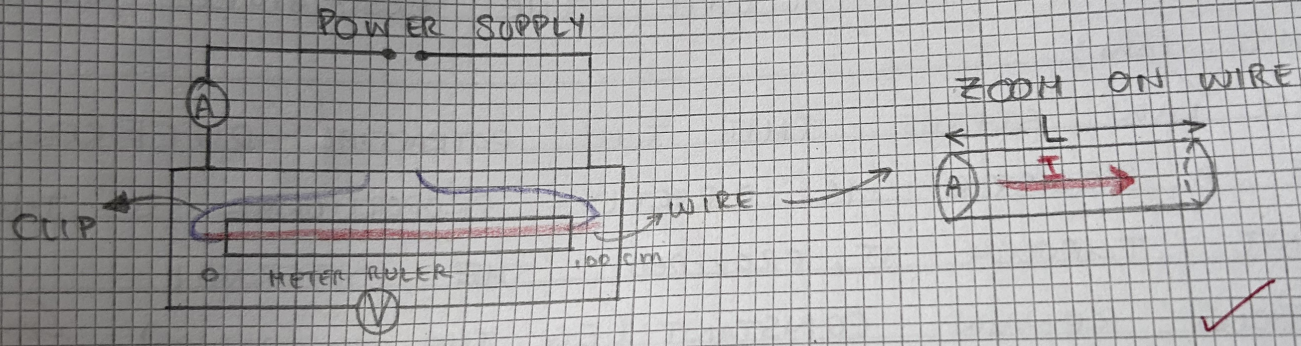
V → VOLTAGE (V)
I → CURRENT (A)
R → RESISTANCE (Ω)

- WRITING DOWN THE RESISTANCE'S EQUATION, IT IS NOTICEABLE HOW THIS IS SIMILAR TO THE EQUATION OF A STRAIGHT LINE;

$$R = \frac{\rho}{A} \times L \longrightarrow y = mx + c \longrightarrow y = R;\ m = \frac{\rho}{A}$$

- A GRAPH IS DRAWN IN ORDER TO FIND THE GRADIENT (m), AND IT IS EXPECTED THAT THE GRAPH SHOWS A STRAIGHT LINE (IN THE MIDDLE OF THE POINTS). AS THE Y-INTERCEPT IS NOT PRESENT IN THE EQUATION (THEREFORE C=0), IT IS EXPECTED THAT THE LINE OF BEST FIT PASSES THROUGH THE ORIGIN.

- DIAGRAM :



- AS WE KNOW THAT THE MATERIAL INVESTIGATED IS CONSTANTAN, THE FINAL VALUE OF ρ SHOULD BE AROUND $4.9 \times 10^{-7}\ \Omega m$.
- THE FINAL AIM IS TO FIND THE RESISTIVITY, IN ORDER TO DO SO, IT IS POSSIBLE TO REARRANGE:

$$m = \frac{\rho}{A} \rightarrow \rho = m \cdot A$$

- AS IT IS NOT POSSIBLE TO MEASURE AREA, THE diameter RADIUS OF THE WIRE WILL BE MEASURED ACROSS SEVERAL POINTS FIRST. THE AVERAGE OF THE RADIUS WOULD THEN BE DIVIDED BY 2. THEREFORE, IT WILL BE POSSIBLE TO USE THE FORMULA:

$$A = \pi \cdot r^2 \qquad (r)\ \text{radius} = d/2$$

METHOD & EQUIPMENT:

EQUIPMENT:

- METER RULER
- MICROMETER (0.01 mm)
- DC SUPPLY AND MULTIMETER
- APPROX. 1 m OF CONSTANTAN WIRE
- CONNECTING LEADS
- CROCODILE CLIPS
- COLOURED TAPE
- SCISSORS

METHOD:

- THE DIAMETER OF THE WIRE WAS MEASURED USING THE MICROMETER ACROSS 3 DIFFERENT POINTS. ONCE THE AVERAGE DIAMETER WAS FOUND, IT WAS DIVIDED BY ~~to~~ 2 TO FIND THE RADIUS (THAT WAS CONVERTED IN METRES).
- APPROX. 1 m OF WIRE WAS CUT USING SCISSORS.
- THE WIRE WAS THEN STRETCHED OUT AND FIXED WITH TAPE ONTO THE METER RULER IN 3 DIFFERENT POINTS. DOING THAT, IT WAS POSSIBLE TO VARY THE LENGTH ~~BETWEEN~~ BETWEEN THE READINGS.
- THE CROCODILE CLIPS WERE CONNECTED TO THE CONNECTING LEADS (THAT WERE CONNECTED TO THE POWER SUPPLY).
- ONE OF THE CROCODILE CLIPS WAS ATTACHED AT ONE OF THE END OF THE WIRE, AND ~~ATTACHED~~ WITH THE OTHER IT WAS POSSIBLE TO VARY THE LENGTH BETWEEN THE READINGS (DONT GO BELOW THAN 30 cm, AS THIS WILL CAUSE OVERHEATING AND MAY BURN THE EQUIPMENT).
- IN ADDITION TO THE LENGTH, IT WAS POSSIBLE TO ~~VARY~~ SET THE VOLTAGE (V) ON THE POWER SUPPLY (IN THE RANGE 1-5 V OTHERWISE IT CAN BURN THE WIRE).

L (m)	I (A)	V (V)	R (Ω)
0.9	0.40	4.00	10
0.9	0.30	3.00	10
0.9	0.20	2.00	10
0.8	0.39	3.50	8.97
0.8	0.28	2.50	8.93
0.8	0.16	1.50	9.375
0.7	0.47	3.75	7.98
0.7	0.35	2.75	7.86
0.7	0.22	1.75	7.95
0.5	0.35	2.00	5.71
0.5	0.17	1.00	5.88
0.5	0.08	0.50	6.25
0.40	0.16	0.76	4.75
0.31	0.38	1.38	3.63
0.76	0.13	1.18	9.08
0.82	0.28	2.58	9.21
0.64	0.62	4.46	7.19
0.60	0.30	2.00	6.60
0.80	0.22	2.00	9.09
1.00	0.18	2.00	11.01

Results should be entered here in pen during the lab.

RESULTS & CALCULATIONS:

-MEASUREMENT ERROR ESTIMATE ± 0.01 A, BECAUSE THE 3rd DECIMAL PLACE WAS OBSERVED TO BE CHANGING AND HENCE UNRELIABLE.

	diameter d(mm)
1°	0.23
2°	0.23
3°	0.23
4°	0.23
5°	0.23
AV.	0.23

Error in L should not be neglected.

THE AVERAGE OF THE d OF WIRE IS 0.23mm, THEREFORE THE d WILL BE 0.23mm.

- A TABLE WAS DRAWN (WITH HEADINGS L(m), I(A), V(V), R(Ω))
- IN EACH AND EVERY READING, THE VOLTMETER READING (V) AND LENGTH (L) WAS RECORDED AND THE CURRENT (I) WAS MEASURED.
- AFTER EVERY READING, THE POWER SUPPLY WAS DISCONNECTED TO AVOID OVERHEATING.
- AFTER MEASURING DIRECTLY AND RECORDING THE LENGTH (L), CURRENT (I), VOLTAGE (V) VALUES ON THE TABLE, THE RESISTANCE (R) WAS CALCULATED USING OHM'S LAW.
- A GRAPH OF R-L WAS PLOTTED TO FIND THE GRADIENT, (m) THEREFORE TO DETERMINE THE RESISTIVITY.
- CROSS-SECTIONAL AREA (A) WAS CALCULATED BY USING THE RADIUS THAT WAS FOUND BEFORE ($A = \pi \cdot r^2$)
- ONCE THE GRADIENT (m) AND THE AREA (A) WAS FOUND, IT WAS POSSIBLE TO DETERMINE THE RESISTIVITY (ℓ). → $\ell = m \cdot A$

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RESULTS & CALCULATIONS:

1st MEASUREMENT OF DIAMETER (d) WITH MICROMETER A:

$d_{WIRE} = 0{,}20 \text{ mm} \pm 0.01 = 0{,}20 \cdot 10^{-3} \text{ m}$

$r_{WIRE} = 0{,}20/2 = 0.10 \cdot 10^{-3} \text{ m}$

- DURING THE LAB OTHER MICROMETERS WERE GIVING DIFFERENT VALUES OF DIAMETER OF THE SAME WIRE. ONCE VERIFIED, IT WAS FOUND OUT THAT ONE OF THE MICROMETER (MICROMETER A) WAS FAULTY AND HENCE NOT RELIABLE. THEREFORE, IF NO ONE HAD NOTICED, THE RESISTIVITY WOULD HAVE NOT BEEN WHAT WAS EXPECTED. Good

2nd MEASUREMENT OF DIAMETER (d) WITH MICROMETER B:

$d_{WIRE} = 0{,}23 \cdot 10^{-3} \text{ m} \rightarrow r_{WIRE} = 0{,}23/2 = 0.115 \cdot 10^{-3} \text{ m}$

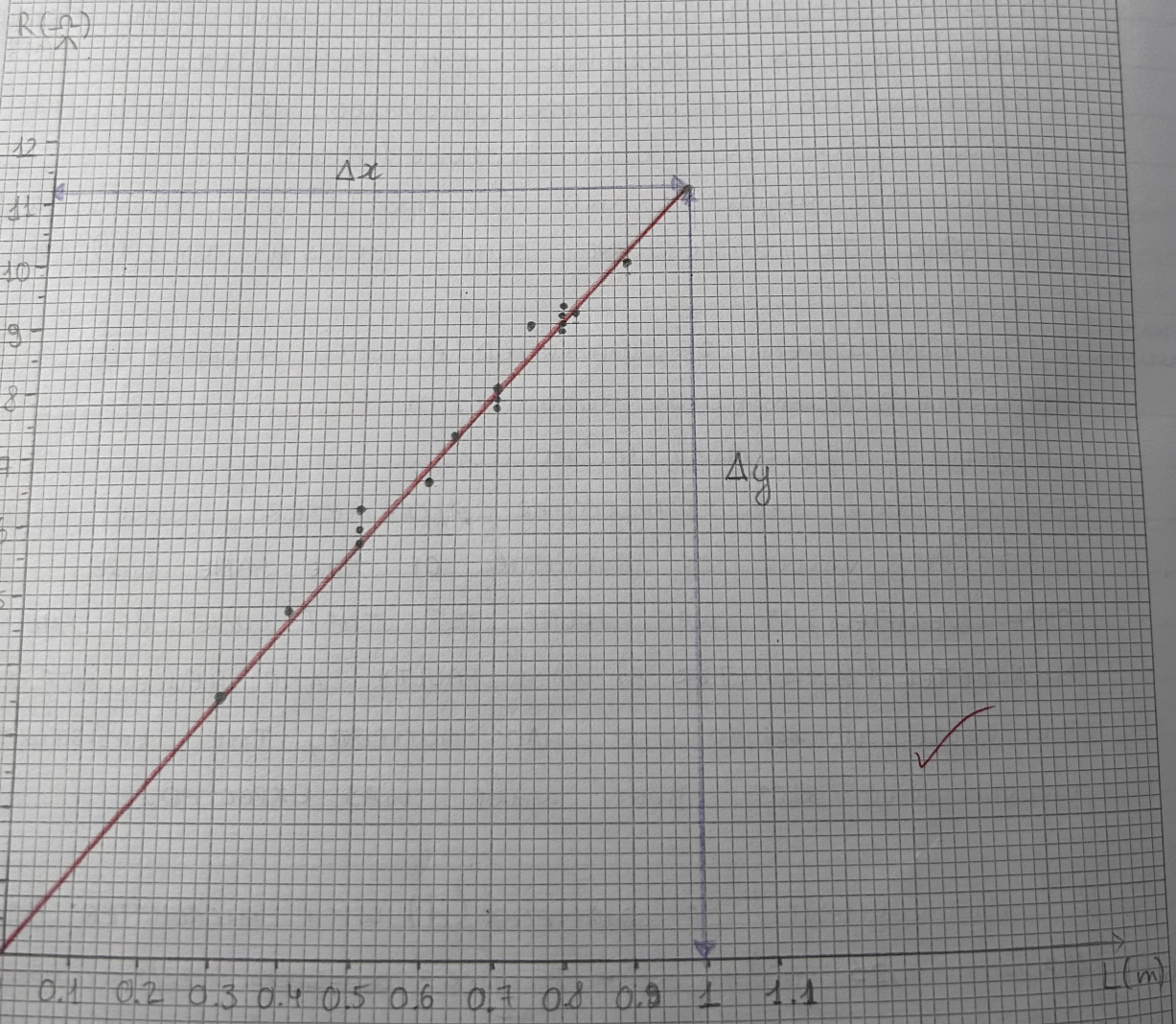
- $A = \pi \cdot r^2 \rightarrow A = \pi \cdot (0{,}115 \cdot 10^{-3})^2 = 4.155 \cdot 10^{-8} \text{ m}^2$
- $R = V/I \rightarrow$ 1st READING: $R = 4/0.40 = 10\ \Omega$ → THE REST OF RESISTANCES (R) WERE FOUND USING THE SAME FORMULA

AS STATED BEFORE:

$\ell = m \cdot A \longrightarrow m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{11.1 - 0}{1 - 0} = 11.1 \frac{\Omega}{m}$ (GRADIENT)

$\ell = 11.1 \cdot (4.155 \cdot 10^{-8}) = \boxed{4.612 \cdot 10^{-7}\ \Omega m} \simeq 4.9 \cdot 10^{-7}\ \Omega m$

$y = mx + c \rightarrow \boxed{R = 11.1x}$ (c → 0)



CONCLUSION

- IT IS POSSIBLE TO DOUBLE CHECK WITH THE EQUATION OF THE RESISTIVITY: 1st READING → R = 10 Ω ; L = 0.9 m

$$R = \frac{\rho \cdot L}{A} \longrightarrow \rho = \frac{R \cdot A}{L} = \frac{10\,(4.155 \cdot 10^{-8})}{0.9} = 4.616 \cdot 10^{-7}\ \Omega m$$

$$\simeq 4.612 \cdot 10^{-7}\ \Omega m$$ ✓

CONCLUSION: AS IT WAS STATED INITIALLY, THE RESISTANCE AND THE LENGTH ARE DIRECTLY PROPORTIONAL ($R \propto L$). THIS CAN BE SEEN ON THE TABLE; WHENEVER THE LENGTH INCREASES, THE RESISTANCE INCREASES AND VICEVERSA (BOTH DECREASE). ✓

HOWEVER, IN ORDER TO INCREASE THE RELIABILITY AND PRECISION OF THE RESULTS, USE THE EQUIPMENT PROPERLY ENSURING THAT ITS CALIBRATED AND FUNCTIONING. THIS DID NOT HAPPEN DURING THE FIRST MEASUREMENT OF THE DIAMETER AS THE MICROMETER WAS FAULTY AND HENCE NOT RELIABLE. ✓

THE EQUIPMENT MUST BE DOUBLE-CHECKED BEFORE OTHERWISE IT COULD LEAD TO UNEXPECTED RESULTS.

BESIDES THAT, TO INCREASE THE PRECISION, YOU COULD SIMPLY PUT THE WIRE MORE PRECISELY ON THE METER RULER.

IN ADDITION TO THAT, TO GET MORE RELIABLE VALUES YOU COULD PLOT A BIGGER GRAPH TO CALCULATE THE GRADIENT. ✓

THE PRECISION OF THE GRAPH (THE BEST FIT LINE) IS RELIABLE, AND THE RESISTIVITY CALCULATED ($4.612 \cdot 10^{-7}\ \Omega m$) IS AROUND THE ACCEPTED VALUE ($4.9 \cdot 10^{-7}\ \Omega m$), THEREFORE THE AIM OF THIS EXPERIMENT WAS ACHIEVED AS THE RESISTIVITY WAS DETERMINED AND EVERY CALCULATION, PREDICTION WAS RIGHT.

% error?

6 1/75