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On the Specific Resistivity of Graphite Pieces of Different Types

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High resistance or extremely low resistance resistors are often difficult to procure due to most of the supply being used by industries which may lead to spacing problems in homemade or laboratory circuits. We investigate the practicality of the usage of pencil lead in terms of the resistivity of the type of lead(HB, 2B, etc.) We demonstrate the usage of graphite from pencil lead as a viable resistor under certain circumstances and investigate the data.

DEFINITIONS

While a piece of graphite is still inside the wooden casing, we will call it a *pencil lead*. Once the casing is removed for easier access to the graphite it is called a *graphite piece* [or words to the same effect]

INTRODUCTION

Graphite can be used for making resistors for flat circuits and may play a role in the development of new flexible circuits, finding usage in the form of resistors. Our investigation deals with the usage of non-flexible pencil leads but can be easily applied(Footnote 1) to thin layers of graphite through the usage of the formula (1)

$$R = \rho \frac{L}{A} \tag{1}$$

where,
R is the resistance,
ρ is the specific resistivity of the particular type of graphite
L is the length of the graphite line
A is the cross-sectional area of the deposited graphite.

METHOD OF EXTRACTING THE GRAPHITE AND PREPARING IT.

Graphite was procured from pencils of the “Bianyo” company(Footnote 2) and two methods were used depending on the thickness of the pencil lead to procure the graphite. In the first method for the thicker leads a handheld knife was used to strip the paint covering the wood and the wood was then burnt away. We will see later why this does not affect the graphite. For the thinner pencil leads a knife was used to peel away the wood to easily let the graphite be cut into suitable sizes.

1. These figures will not be accurate for molecular or sub molecular scales.
2. Suspended on the plastic cards.

MAKING THE APPARATUS TO MEASURE THE RESISTIVITY

Resistivity was measured through the usage of a multimeter. A good contact could not be formed between the graphite and the steel contact of the multimeter’s wires and so mercury was used to form a proper contact point between the graphite and the steel. Two slits were made in a piece of thermocol foam and two plastic cards were inserted in the slits. The cards had a hole in the middle to which a box was attached. The graphite was suspended between the cards and the ends of the graphite were placed in the holes. The boxes had mercury inside them. The mercury was used to form a proper contact between the steel of the multimeter wires and the graphite.

The mercury/steel did not affect the resistance measured due to the specific resistivity of the steel and mercury being almost three orders of magnitude lower than that of graphite.

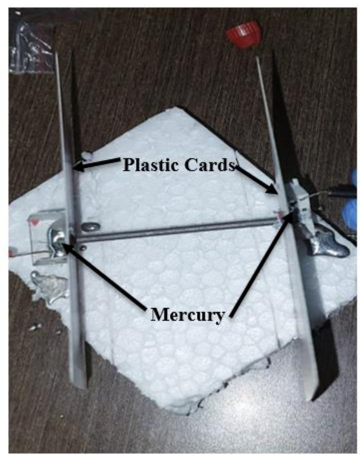


Figure 1: An image of the apparatus (top view) used to measure the resistance of the graphite piece.

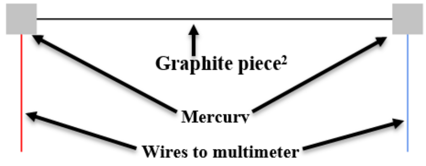


Figure 2: A diagram representing the apparatus used to measure the resistance.

DATA COLLECTION

Six types of pencil were used to extract the graphite shown in the list below

Type of lead	Trial 1 (Ω)	Trial 2 (Ω)	Trial 3 (Ω)	Average (Ω)	Error (Ω)
2H	16.50	17.60	17.20	17.10	0.60
H	10.55	10.85	9.80	10.40	0.60
HB	8.00	8.90;	8.20	8.37	0.63
2B	4.00	4.40	4.30	4.23	0.23
4B	3.30	3.00	NA	3.15	0.15
5B	2.60	3.00	NA	2.80	0.20

Pencil graphite usually tends to break during the process of extraction which is why some of the data is missing from the table above (represented by NA). Since different types of graphite have different thicknesses while in the pencil, the graphite was sanded down to ensure that all the pieces were of uniform thickness. Each piece of graphite was sanded to 2±0.1 mm in diameter and 55±1 mm in length. Trial results were averaged to reduce any errors that may be present.

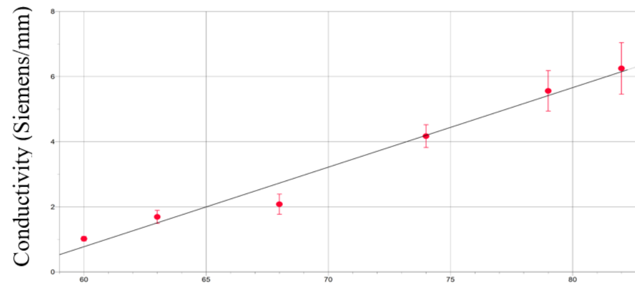
The known formula (1) is then used with the data to calculate the specific resistivity of each graphite piece. This data is shown below. This was then used to calculate the specific conductivity of each graphite type.

Data from [1] was used to get the percentages of graphite and clay in standard pencils. This data is shown below along with the resistivity and conductivity.

Type of graphite piece	Percentage of graphite in piece (mass)	Resistivity (Ω·mm)	Conductivity (Siemens/mm)
2H	60	0.98	1.02
H	63	0.59	1.69
HB	68	0.48	2.08
2B	74	0.24	4.17
4B	79	0.18	5.56
5B	82	0.16	6.25

GRAPH OF DATA

A graph of the data was made and linear regression was performed. A high R^2 value of 0.977 was obtained showing that the results are consistent with what is expected(An increase in conductivity as graphite percentage increases)



Percentage of graphite in the graphite piece (by mass)

CONCLUSION

We conclude that different types of graphite have different conductivity and that as graphite percentage increases so does the conductivity. Thin layers of graphite may be used as resistors in flexible electronics and knowing the conductivity of different types of graphite will be helpful in more efficiently designing resistors.

REFERENCES

[1]. Sousa, Mario Costa, and John W. Buchanan. "Observational Models of Graphite Pencil Materials." *Computer Graphics Forum*, vol. 19, no. 1, Mar. 2000, pp. 27–49., https://doi.org/10.1111/1467-8659.00386. Table 2 from above, accessed through https://blog.penvibe.com/the-graphite-pencil-scale-ultimate-guide/ on 12th March 2023.