

How does length affect resistance and resistivity?

Instructor Preparation and Discussion

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Age: Appropriate for middle school to high school students.

Background: The "lead" in pencils is made of a mixture of graphite and clay. Adding more graphite makes the pencil lead softer and produces a darker stroke. Adding more clay makes the pencil lead harder and produces a lighter stroke. The grading system of pencils goes from H for hardness (more clay) to B for blackness (more graphite). The standard U.S. #2 pencil corresponds closest to the HB pencil.

Electrical Resistivity

The measured electrical resistance (R) of a material is equal to the electrical resistivity of the material times the length (L) over which the resistance is measured, divided by the cross-sectional area of the material (A).

$$R = \rho L/A$$

R : measured electrical resistance (ohms, Ω)

ρ : electrical resistivity of material (Ω -cm)

L : distance between the measuring terminals on the line (cm)

A : cross-sectional area of the material

Supplies

- Multimeter set to measure resistance (ohms) – available at Radio Shack
- Pencils with a grading of B (e.g. HB, 2B, 4B, 6B, etc.) - available at any craft store or art supply store

Instructions

Draw a straight line in the box below. Repeatedly draw on the line until it appears completely dark and try to keep the width of the line as uniform as possible. Use the multimeter to measure the resistance at varying distances along the drawn line. When measuring the resistance, touch the blunt edge (NOT the sharp point) of the multimeter probes to each end of the line. The sharp tip can damage the line.



Length between electrodes (L) - cm			
Measured Resistance (R) - ohm			
*Calculate the electrical resistivity of the material (ρ) -ohm-cm			

* Assume the cross-sectional area of your line is 3 mm wide and approximately 10 μm thick, such that $A = 3 \times 10^{-4}$ cm.

Consider this:

1. Does the measured resistance vary with the length of the line?
2. Does the calculated resistivity vary with the length of the line?
3. (optional) Draw another line twice as wide – does the measured resistance and calculated resistivity vary with the width of the line?
4. Repeat the activity with a different pencil. How does the measured resistance and calculated resistivity compare with this pencil? Which has a higher electrical resistivity, one with more clay or one with more graphite?

Discussion:

The measured resistance will vary directly with the distance. The electrical resistivity is an intrinsic property and should therefore be independent of length and cross-sectional area, but in this activity, inconsistencies while drawing the line will result in varied width and thickness of the line thus affecting the results of the calculated resistivity. You can examine the impact by comparing the resistance after adding more and more lines on top of each other (changing the line thickness) or next to each other (changing the line width).

Reference

This activity is a modified version of an activity that is part of the Institute for Chemical Education Kit – Line of Resistance, by Dr. Lawrence D. Woolf.

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