PRACTICES TO IMAGINE THE SHAPE DEPENDENCE OF ELECTRICAL RESISTANCE

Michiya Shintsuruta[a], Hirokazu Okubo[b], and Tsutomu Iwayama[c]

Presenting Author: Michiya Shintsuruta (shintsuru@isenshu-u.ac.jp)
[a]Department of Human Education, Ishinomaki Senshu University, Ishinomaki Miyagi 986-8580, Japan
[b]Graduate School of Education, Aichi University of Education, Kariya Aichi 448-8542, Japan
[c]Department of Physics, Aichi University of Education, Kariya Aichi 448-8542, Japan

KEYWORDS: Paper resistor, Shape dependence of electrical resistance, Creative thinking, Degree of consent, Extended learning

CARBON-NANOTUBE PAPER RESISTORS

We used Carbon-nanotube paper (CNP) electrical resistors (shown in Figure 1) as a teaching material in secondary school science (physics) lessons. The CNP is conductive paper with excellent electrical conductivity. Using CNP resistors, it is possible to elucidate the dependence of the resistance values on the length and width (Shintsuruta et al., 2021). Introducing the shape dependence of electrical resistance is effective for students to solve an advanced problem of combined resistance with parallel connections. As students can adjust the paper shape as they like, it becomes possible for students to visually and actively learn about electrical resistance by using them.

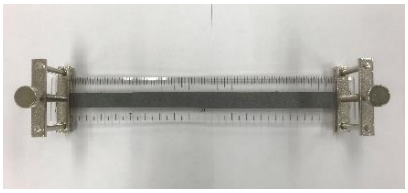

Figure 1. The resistor consists of CNP, two stainless steel pinchcocks, and a plastic ruler.

THE PRACTICES OF NEW SCIENCE (PHYSICS) LESSONS

We designed new lesson plans to engage students through hands-on experiments and activities using CNP resistors. Students elucidate the two-dimensional shape dependence of electrical resistance by experiments using resistors adjusted by themselves with creative thinking, as you can see the Figure 2.

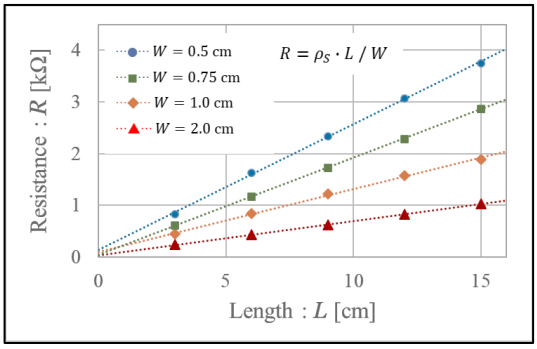

Figure 2. Resistance values as a function of length for the CNPs.

The resistance value $\boldsymbol{R}$ is given by $\boldsymbol{R = \rho_S L/W}$, and it is characterized by two parameters: length $\boldsymbol{L}$ and width $\boldsymbol{W}$. Here, $\boldsymbol{\rho_S}$ is the surface resistivity with thickness $\boldsymbol{D}$; $\boldsymbol{\rho_S = \rho/D}$.
The combined resistance value of two CNP resistors ($\boldsymbol{R_1}$ and $\boldsymbol{R_2}$) is expressed as, $\boldsymbol{R_S = (L_1 + L_2)\,\rho_S/W}$ for a series connection and $\boldsymbol{1/R_P = (W_1 + W_2)/\rho_S L}$ for a parallel connection, respectively.

RESULTS AND DISCUSSION

As the results of this practical, the students learned the concept of electrical resistance and increased their understanding of combining resistances in parallel circuits. Moreover, we increased the sample size, number of students by running the practical in another school. In this case, the effect sizes were smaller than the previous results, but we confirmed the effect of a similar tendency. We confirmed that the students' creative thinking deepens and they extend their learning. “Deep learning” is one of the policies of the new course of study by the ministry in Japan. It is an innovation in physics education for these students to understand electrical resistance as well as dependence on its two-dimensional shape.

REFERENCE

Shintsuruta, M., Okubo, H., & Iwayama, T. (2021). Electrical resistor and capacitor using carbon-based papers for creative thinking to deepen and extend learning. *Physics Education,* 56(3), 035006. https://doi.org/10.1088/1361-6552/abdd8f

Proceedings of the IUPAP International Conference on Physics Education, ICPE 2022 5-9 December 2022, page 153, ISBN: 978-1-74210-532-1.