Resistance Lab

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1. Purpose

For part 1, the goal was to examine how material, cross-sectional area, and length impact resistance. For each coil of wire, resistance was determined in three ways: based on measurements of voltage and current; based on the resistance readings from the multimeter; and based on the dimensions of the wires and the resistivity of the materials. In addition, the results of the three methods of determining resistance were compared.

2. Results

Table 1 contains the properties of the resistance coils used in part 1. ρ is the resistivity of the material. L is the length of the coil of wire. D is the diameter of the wire. Note that the values for ρ, L, and D were assumed to be exact, without uncertainty.

Table 1. Resistance Coils

Coil	Material	ρ (Ω m)	L (cm)	D (cm)
1	Nickel-Silver	44×10^{-8}	40	0.0254
2	Nickel-Silver	44×10^{-8}	80	0.0254
3	Nickel-Silver	44×10^{-8}	120	0.0254
4	Nickel-Silver	44×10^{-8}	160	0.0254
5	Nickel-Silver	44×10^{-8}	200	0.0254
6	Nickel-Silver	44×10^{-8}	200	0.0320
7	Copper	1.72×10^{-8}	2000	0.0254

Table 2 contains the measurements made during part 1. ΔV is the voltage across the resistance coil. I is the current through the resistance coil. $(R_{\mathrm{m}}+r)$ is the resistance, measured using the multimeter, of the resistance coil and the wires connecting it to the multimeter. r is the resistance, measured using the multimeter, of just the wires used for connecting the multimeter to the resistance coil.

Table 2. Part 1 Measurements
Note: r, the resistance of the two wires connected to the multimeter, was measured to be (0.1 ± 0.1) Ω.

Coil	ΔV (V)	I (mA)	$R_{\mathrm{m}} + r$ (Ω)
1	0.214 ± 0.001	55.07 ± 0.05	4.0 ± 0.1
2	0.400 ± 0.001	49.72 ± 0.01	8.3 ± 0.1
3	0.536 ± 0.001	44.53 ± 0.02	12.0 ± 0.1
4	0.662 ± 0.001	41.70 ± 0.01	15.9 ± 0.1
5	0.772 ± 0.001	38.19 ± 0.01	20.3 ± 0.1
6	0.538 ± 0.001	45.44 ± 0.01	11.7 ± 0.1
7	0.357 ± 0.001	51.31 ± 0.01	7.3 ± 0.1

Table 3 contains the two experimental values for resistance in the coil ($R_{V/I}$ and R_{m}) and the theoretical value (R_{th}). $R_{V/I}$ is the experimental resistance determined using measured values for ΔV and I. R_{m} is the experimental resistance determined using the readings from the multimeter. R_{th} is the theoretical resistance determined using the dimensions of the wires (L and D) and the resistivity of the material (ρ).

Table 3. Part 1 Experimental and Theoretical Resistances

Coil	$R_{V/I}$ (Ω)	R_{m} (Ω)	R_{th} (Ω)
1	3.89 ± 0.02	3.9 ± 0.1	3.47
2	8.05 ± 0.02	8.2 ± 0.1	6.95
3	12.04 ± 0.02	11.9 ± 0.1	10.42
4	15.88 ± 0.02	15.8 ± 0.1	13.89
5	20.21 ± 0.03	20.2 ± 0.1	17.37
6	11.84 ± 0.02	11.6 ± 0.1	10.94
7	6.96 ± 0.02	7.2 ± 0.1	6.79

Figure 1 plots resistance ($R_{V/I}$, R_{m}, and R_{th}) versus length (L) for the first five resistance coils used in part 1. Those coils were chosen for the graph as they all had the same material and diameter. Since the graphs seemed linear (and that's what theory predicts) a linear fit was applied.

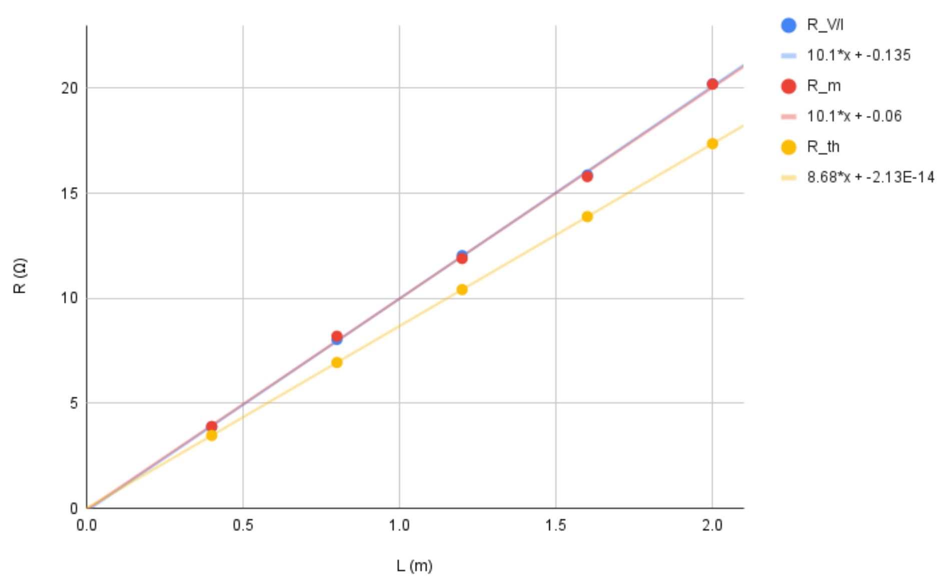

Figure 1. Resistance vs Length (Constant ρ and A)

3. Uncertainty

All the voltage, current, and resistance measurements in the experiment were made using a multimeter. If there were fluctuations in a particular reading with the multimeter (voltage, current, or resistance), then the uncertainty was taken to be the magnitude of the fluctuations, as that gives an upper bound for how much the value could have varied. If the reading with the multimeter (voltage, current, or resistance) was stable and did not fluctuate, then the uncertainty was taken to be the smallest increment of measure, since that was the limiting precision of the equipment.

In part 1, $R_{V/I}$ was calculated using equation 1.

$$R_{V/I} = \frac{\Delta V}{I} \tag{1}$$

The uncertainty of $R_{V/I}$ is given by equation 2.

$$\begin{aligned} \Delta R_{V/I} &= \left[\left(\frac{\partial R_{V/I}}{\partial \Delta V} \Delta\Delta V \right)^2 + \left(\frac{\partial R_{V/I}}{\partial I} \Delta I \right)^2 \right]^{\frac{1}{2}} \\ &= \frac{\Delta V}{I} \left[\left(\frac{\Delta\Delta V}{\Delta V} \right)^2 + \left(\frac{\Delta I}{I} \right)^2 \right]^{\frac{1}{2}} \end{aligned} \tag{2}$$

In part 1, R_{m} was calculated using equation 3. Note that the combined value $(R_{\mathrm{m}} + r)$ was measured, as was the value for r. But R_{m} was not measured, hence why it is being calculated as a difference of two values.

$$R_{\mathrm{m}} = (R_{\mathrm{m}} + r) - r \tag{3}$$

The uncertainty of R_{m} is given by equation 4.

$$\begin{aligned} \Delta R_{\mathrm{m}} &= \left[\left(\frac{\partial R_{\mathrm{m}}}{\partial (R_{\mathrm{m}} + r)} \Delta (R_{\mathrm{m}} + r) \right)^2 + \left(\frac{\partial R_{\mathrm{m}}}{\partial r} \Delta r \right)^2 \right]^{\frac{1}{2}} \\ &= \left[(\Delta(R_{\mathrm{m}} + r))^2 + (\Delta r)^2 \right]^{\frac{1}{2}} \end{aligned} \tag{4}$$

In part 1, R_{th} was calculated using equation 5.

$$\begin{aligned} R_{\mathrm{th}} &= \frac{\rho L}{A} \\ &= \frac{\rho L}{\pi (D/2)^2} \\ &= \frac{4 \rho L}{\pi D^2} \end{aligned} \tag{5}$$

Note that the values for ρ, L, and D were assumed to be exact, without uncertainty. Thus, R_{th} would have no uncertainty as well.

4. Conclusion

5. Citations

[1] Karen Schnurbusch, *Physics 4B Lab Book*, Mt. San Antonio College, 2023, pp. 65-70.
[2] Karen Schnurbusch, *Physics 4B Equations*, Mt. San Antonio College, 2023, pp. 4, 10.