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Resistance Lab Worksheet

Introduction

In this worksheet, we will examine the physical properties of different types of material to understand and determine their resistances. The American Wire Gauge (AWG) system is also introduced, and we will use the table of gauges to determine the diameter of different gauge wires and to calculate the wire resistances.

Discussion Overview

Resistance

Resistance is the inherent property of materials to “resist” the flow of electric current (electrons). Similar to a water pipe where the friction between water molecules and the pipe wall causes resistance, electrons experience resistance in a wire as they jump from atom to atom. Moreover, just as friction converts kinetic energy to heat, resistance converts electric energy to heat that is radiated and wasted.

In general, materials are grouped into three different categories: conductors, non-conductors and semi-conductors. Most metals fall in the conductive category where electrons can freely move through the material. Different metals, however, do exhibit different levels of conductivity, with copper’s being one of the best (and cheapest) conductive metals used in wires.

Most other material fall in the non-conductive category; the materials in this category do not allow free movement of electrons. Wood, glass and plastic are examples of non-conductive materials. Some of these materials, plastic for example, are used as wire insulators.

Semi-conductor category contains materials such as silicon and Germanium. Semiconductors are the primary materials used in integrated circuits.

Resistors

Resistors are man-made electronic components from materials such as carbon with a specific amount of resistance. Using resistors, electrical engineers can design circuits that would control the flow of electrons (current) in the circuit in a predictable manner.

The symbol used to indicate a resistor is  . The letter designator for a resistor is “R”, and the unit of resistance is Ohms, named after German physicist Georg Simon Ohm, and is designated with the Greek letter capital omega: Ω.

Resistance of a wire

As mentioned above, even good conductors such as copper exhibit a certain level of resistance to the movement of electrons (current flow) similar to the way a water pipe would show

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resistance to the flow of water due to friction. Extending this water analogy, one can intuitively identify the physical aspects of a wire that would contribute to resistance:

- Just as the inner surface of a long pipe would introduce more friction, and therefore, resistance to the water flow, one can guess that a long wire would have more resistance compared to a short wire. Therefore, resistance of a wire is directly proportional to the length of the wire: $R \propto l$.
- Cross sectional area is the other physical property of a pipe affecting the flow of water. The larger the cross sectional area, the smaller the resistance. In a similar manner, the cross sectional area of a wire is inversely proportional to the resistance of a wire: $R \propto \frac{1}{A}$
- Lastly, the type of the material used in constructing the water pipe can affect how much it resists water flow. A pipe with a rougher interior wall would exert more force due to friction than a pipe made with smoother material. Similarly, the resistivity of the material used in making a wire is directly proportional to the total resistance of a wire: $R \propto \rho$. The resistivity constant, ρ, is used to denote how "resistive" a material is. The unit of ρ is Ω/m.
- Therefore, the formula for determining the resistance of simple cylindrical objects is given by

  $R = \rho \frac{l}{A}$, where

  l = length in m
  A = cross sectional area in m^2, and
  ρ = resistivity in Ω/m

American Wire Gauge (AWG) System

American Wire Gauge system has been used predominantly in North America since 1857 to indicate the diameters of round and solid electrically conducting wires. Smaller AWG values designate larger diameters, and therefore, thicker wires. The table below gives the diameters in inches and mm, and the cross sectional area of wires with AWG 0000 to 40.

Table 1 - American Wire Gauge System Index and Sizing

American Wire Gauge (AWG)	Diameter (in)	Diameter (mm)	Cross Sectional Area (mm^2)
0000	0.4600	11.6840	107.21930
000	0.4096	10.4049	85.02877
00	0.3648	9.2658	67.43088
0	0.3249	8.2515	53.47512

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American Wire Gauge (AWG)	Diameter (in)	Diameter (mm)	Cross Sectional Area (mm^2)
1	0.2893	7.3481	42.40770
2	0.2576	6.5437	33.63083
3	0.2294	5.8273	26.67046
4	0.2043	5.1894	21.15064
5	0.1819	4.6213	16.77322
6	0.1620	4.1154	13.30177
7	0.1443	3.6649	10.54878
8	0.1285	3.2636	8.36556
9	0.1144	2.9064	6.63419
10	0.1019	2.5882	5.26115
11	0.0907	2.3048	4.17229
12	0.0808	2.0525	3.30877
13	0.0720	1.8278	2.62398
14	0.0641	1.6277	2.08091
15	0.0571	1.4495	1.65023
16	0.0508	1.2908	1.30870
17	0.0453	1.1495	1.03784
18	0.0403	1.0237	0.82305
19	0.0359	0.9116	0.65271
20	0.0320	0.8118	0.51762
21	0.0285	0.7229	0.41049
22	0.0253	0.6438	0.32553
23	0.0226	0.5733	0.25816
24	0.0201	0.5106	0.20473
25	0.0179	0.4547	0.16236
26	0.0159	0.4049	0.12876
27	0.0142	0.3606	0.10211
28	0.0126	0.3211	0.08098

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American Wire Gauge (AWG)	Diameter (in)	Diameter (mm)	Cross Sectional Area (mm^2)
29	0.0113	0.2859	0.06422
30	0.0100	0.2546	0.05093
31	0.0089	0.2268	0.04039
32	0.0080	0.2019	0.03203
33	0.0071	0.1798	0.02540
34	0.0063	0.1601	0.02014
35	0.0056	0.1426	0.01597
36	0.0050	0.1270	0.01267
37	0.0045	0.1131	0.01005
38	0.0040	0.1007	0.00797
39	0.0035	0.0897	0.00632
40	0.0031	0.0799	0.00501

Procedure

1. For each of the items given to you for this lab project, measure the length and diameter of each item, calculate each item's resistance and record the values in the table below.
   a. For wire spools,
      i. Refer to Table 1 for the wires' diameter, and
      ii. The following table for the wire lengths

Spool	Length (ft)	AWG
Copper	40	22
Green	75-21	26
Red	200-21	30

   b. Use the table below for the resistivity value of the material in your collection.

Material	Resistivity (Ω/m)	Material	Resistivity (Ω/m)
Silver	1.6×10^{-8}	Carbon	35 to 5000×10^{-8}

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Material	Resistivity (Ω/m)	Material	Resistivity (Ω/m)
Copper	1.7×10^{-8}	Graphite	800×10^{-8}
Aluminum	3.2×10^{-8}	Silicon	2.3×10^{-3}
Lead	21.0×10^{-8}	Germanium	6.5×10^{-1}
Manganin alloy	44.0×10^{-8}	Pyrex glass	10^{12}
Eureka alloy	49.0×10^{-8}	PTFE	10^{12} to 10^{16}
Steel	10 to 100×10^{-8}	Quartz	5×10^{16}

2. Using an Ohm-meter, measure each item's resistance and compare it to the calculated value in the table below.

Item	Length (m)	Diameter (m)	Area (m^2)	ρ (Ω/m)	Calculated (Ω)	Measured (Ω)
Pencil Lead				800×10^{-8}		
Copper Wire Spool				1.7×10^{-8}		
Green Wire Spool				1.7×10^{-8}		
Red Wire Spool				1.7×10^{-8}		