Resistance and Resistivity

Various factors affect the resistance of a material:

1. <u>Temperature</u>. The resistance of all substances changes to some degree with temperature. In the case of pure metals, the resistance increases rapidly with a rise in temperature. The extreme case of this is superconductivity. When materials reach a sufficiently low temperature, their resistance can completely vanish; electrical currents can run through them without any resistance.
2. <u>Length</u>. Resistance of a uniform conductor is directly proportional to its length. When length increases, resistance increases.
3. <u>Cross-Sectional Area</u>. The resistance of a uniform conductor is inversely proportional to its cross-sectional area. When cross-sectional area increases, resistance decreases.
4. <u>Material Properties</u>. The resistance of a given conductor depends on the material from which it is made. A numerical value called the *resistivity* is assigned to materials based on how well they conduct electricity.

To remember trends in electrical resistance, it is helpful to think of water flowing in a pipe. If the length of the pipe increases, the resistance increases. Think of drinking through a very long straw -- It would take a lot of effort! On the other hand, increasing the diameter (and so the cross-sectional area) decreases the resistance. A straw with a bigger diameter is easier to use, especially when drinking those thick fast-food store milkshakes. Bringing all of these trends together results in this formula: $R = \frac{\rho l}{A}$

R is the resistance, ρ is the resistivity of the material, l is length, and A is cross-sectional area. Below are the resistivities of some common conductors at 20°C, in units of ohm-meters.

Resistivities at 20°C

Material	Resistivity (Ω•m)
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Gold	2.44×10^{-8}
Nichrome	$150. \times 10^{-8}$
Silver	1.59×10^{-8}
Tungsten	5.60×10^{-8}

Material	Resistivity (ρ) Ωm
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Silver	1.59×10^{-8}
Carbon	3.5×10^{-5}
Teflon	1×10^{16}
Rubber (hard)	$10^{13} - 10^{16}$
Maple wood	30×10^{10}
Silicon	20 - 2300

Problems

1. Compute the resistance of a hardened copper rod 2 meters long and 8 mm in diameter if the resistivity of the material is 1.756×10^{-8} ohm-meters.

2. A 0.500-meter length of wire with a cross-sectional area of 3.14×10^{-6} meters squared is found to have a resistance of 2.53×10^{-3} ohms. According to the resistivity chart, from what material is the wire made?

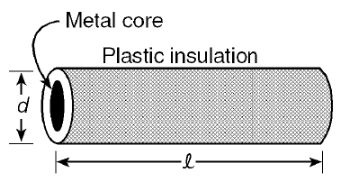
3. The resistance of a uniform copper wire 50.0 meters long and 1.15 mm in diameter is 0.830 ohms at 20° C. What is the resistivity of the copper at this temperature?

4. At 20° C, 33 meters of copper wire has a resistance of 0.639 ohms. What is the resistance of 165 meters?

5. A 200 m long aluminum wire has the same resistance and cross-sectional area as a carbon wire. What is the length of the carbon wire?

6. A wire of radius R and length L has a resistance of 14 Ω. What is the resistance of a wire made from the same material that has twice the radius and five times the length?

Multiple Choice Questions



7. Plastic insulation surrounds a wire having diameter *d* and length l as shown below. A decrease in the resistance of the wire would be produced by an increase in the

A) length l of the wire

B) diameter *d* of the wire

C) temperature of the wire

D) thickness of the plastic insulation

8. A manufacturer recommends that the longer the extension cord used with an electric drill, the thicker (heavier gauge) the extension cord should be. This recommendation is made because the resistance of a wire varies

A) directly with length and inversely with cross-sectional area

B) inversely with length and directly with cross-sectional area

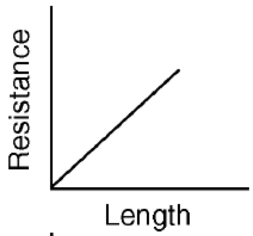
C) inversely with both length and cross-sectional area

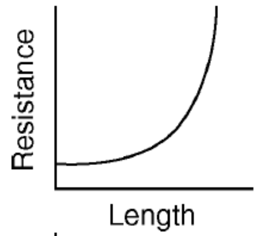
D) directly with both length and cross-sectional area

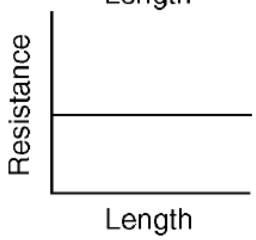
9. A complete circuit is left on for several minutes, causing the connecting copper wire to become hot. As the temperature of the wire increases, the electrical resistance of the wire

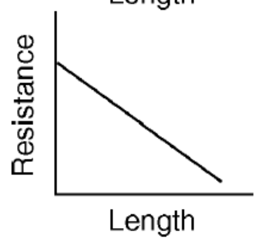
A) decreases B) remains the same C) increases

10. Which graph best represents the relationship between resistance and length of a copper wire of uniform cross-sectional area at constant temperature?

A) 

C) 

B) 

D) 

11. The table below lists various characteristics of two metallic wires, A and B.

Wire	Material	Temperature (°C)	Length (m)	Cross-Sectional Area (m^2)	Resistance (Ω)
A	silver	20.	0.10	0.010	*R*
B	silver	20.	0.20	0.020	???

If wire A has a resistance of R, then wire B has a resistance of

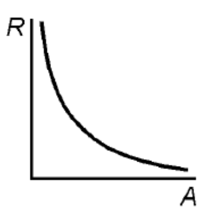
A) R

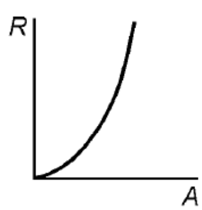
B) $4R$

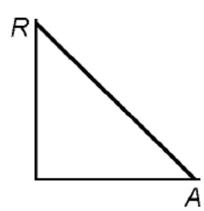
C) $\frac{R}{2}$

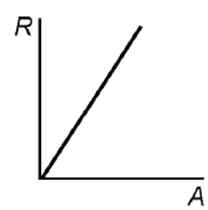
D) $2R$

12. Several pieces of copper wire, all having the same length but different diameters, are kept at room temperature. Which graph best represents the resistance, R, of the wires as a function of their cross-sectional areas, A?

A) 

B) 

C) 

D) 

13. The four wires shown below are made from the same resistive material. Rank the resistance in the wires from high to low. Explain your answer.