Electrical Circuit-I

1st Lecture

Circuit Elements & Temperature Effect

By:

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Ref: Robert L. Boylestad, *INTRODUCTORY CIRCUIT ANALYSIS*, Pearson Prentice Hall, Eleventh Edition, 2007

Basic Concepts

System of Units

The basic SI units		
Quantity	**Basic Unit**	**Symbol**
Length	Meter	M
Mass	Kilogram	Kg
Time	Second	S
Electric Current	Ampere	A
Thermodynamic Temperature	Kelvin	K

Basic Concepts

System of Units

The SI Prefixes		
Multiplier	Prefixes	Symbol
10^{18}	Exa	E
10^{15}	Peta	P
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}	Mege	M
10^{3}	Kilo	K
10	Deca	da
10^{-2}	Centi	C
10^{-3}	Milli	m
10^{-6}	Micro	μ
10^{-9}	Nano	n
10^{-12}	Pico	p
10^{-15}	Femto	f

Basic Concepts

System of Units

Multiplication Factors	SI Prefix	SI Symbol
$1\ 000\ 000\ 000\ 000\ 000\ 000 = 10^{18}$	exa	E
$1\ 000\ 000\ 000\ 000\ 000 = 10^{15}$	peta	P
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera	T
$1\ 000\ 000\ 000 = 10^{9}$	giga	G
$1\ 000\ 000 = 10^{6}$	mega	M
$1\ 000 = 10^{3}$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	μ
$0.000\ 000\ 001 = 10^{-9}$	nano	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	p
$0.000\ 000\ 000\ 000\ 001 = 10^{-15}$	femto	f
$0.000\ 000\ 000\ 000\ 000\ 001 = 10^{-18}$	atto	a

Circuit Elements

Passive elements	Active elements
Resistor	Voltage source
Inductor	Current source
Capacitor	Generators
	Operational amplifier

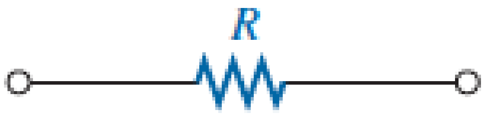
There are two types of elements found in electric circuits: passive & active

An active elements is capable of generating energy while a passive element is not.

Resistance of the material

The flow of charge through any material encounters an opposing force due to the collisions between electrons and other atoms in the material, which converts electrical energy into another form of energy such as heat, is called the resistance of the material.

The unit of measured of resistance is the ohm, for which the symbol is (Ω). The circuit symbol for the resistance appears in figure below



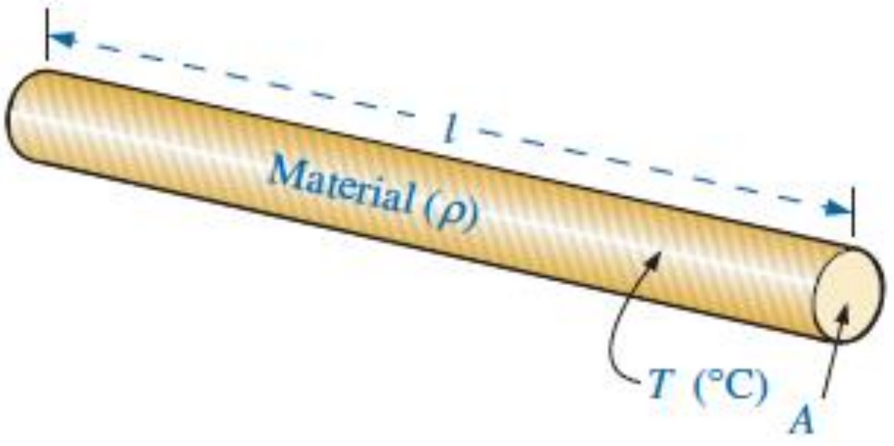
The resistance of any material with a uniform cross-sectional area is determined by the following four factors:

1- Material resistivity

2- Length

3- Cross-sectional area

4- Temperature



Resistance of the material

Conductors will have low resistance level, while insulators will have high resistance characteristic. At a fixed temperature of $20^{o}\,C$ *(room temperature), the resistance is related to the other three factors by:*

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

Where ρ *(Greek letter rho) is a characteristic of the material called the resistivity,* l *is the length of the sample, and* A *is the cross-sectional area of the sample.*

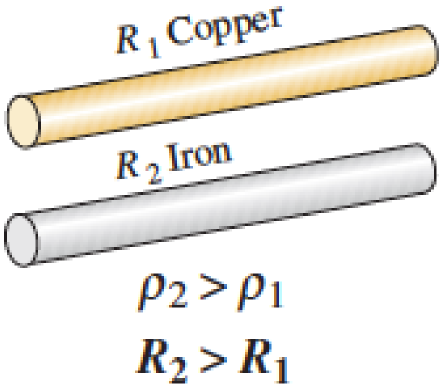
Resistance of the material

Resistivity (ρ) of various materials.

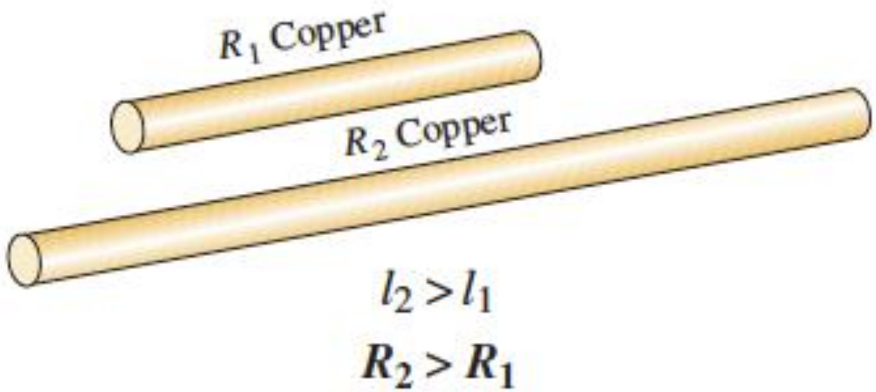
Material	ρ (CM · Ω/ft)@20°C
Silver	9.9
Copper	**10.37**
Gold	14.7
Aluminum	17.0
Tungsten	33.0
Nickel	47.0
Iron	74.0
Constantan	295.0
Nichrome	600.0
Calorite	720.0
Carbon	21,000.0

Resistance of the material

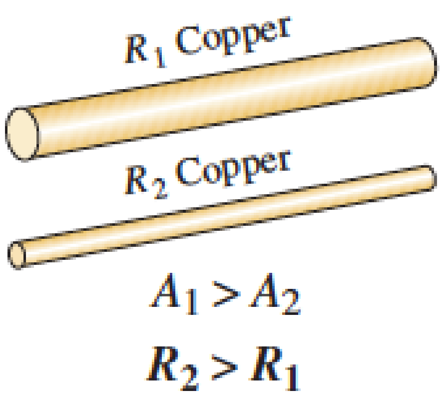
the higher the resistivity, the greater the resistance of a conductor



the longer the conductor, the greater the resistance



the greater the area of a conductor, the less the resistance



Example (1)

What is the resistance of a (100 ft) length of copper wire with area of 400 CM. at 20°C?

Solution:

$$\rho = 10.37 \frac{\text{CM-}\Omega}{\text{ft}}$$

$$R = \rho\frac{l}{A} = \frac{(10.37\ \text{CM-}\Omega/\text{ft})(100\ \text{ft})}{400\ \text{CM}}$$

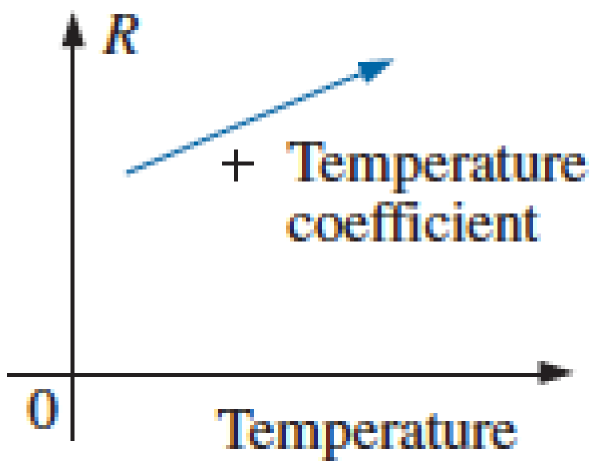
$$R = 2.59\ \Omega$$

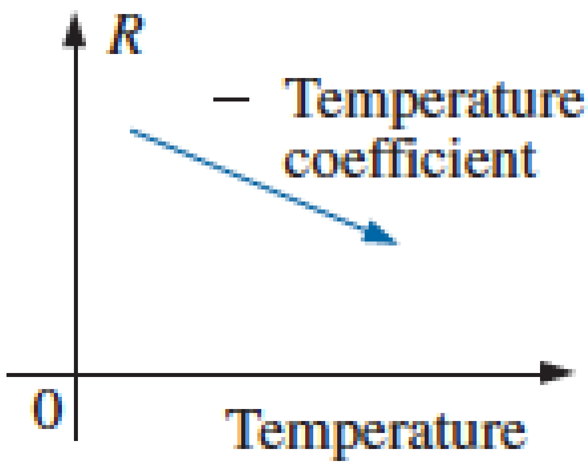
Temperature Effects

Temperature has a significant effect on the resistance of conductors, semiconductors, and insulators.

Conductors have a generous number of free electrons, and any introduction of thermal energy will have little impact on the total number of free carriers. In fact, the thermal energy only increases the intensity of the random motion of the particles within the material and makes it increasingly difficult for a general drift of electrons in any one direction to be established. The result is that:

for good conductors, an increase in temperature results in an increase in the resistance level. Consequently, conductors have a positive temperature coefficient.





Temperature Effects

It is important that we have some method of determining the resistance at any temperature within operating limits.

At two different temperatures, T1 and T2, the resistance of copper is R1 and R2.

We may develop a mathematical relationship between these values of resistances at different temperatures

$$\frac{234.5 + T_1}{R_1} = \frac{234.5 + T_2}{R_2}$$

For Copper

$$\frac{|T_1| + T_1}{R_1} = \frac{|T_1| + T_2}{R_2}$$

For other Materials

Temperature Effects

where |T1| indicates that the inferred absolute temperature of the material involved is inserted as a positive value in the equation. In general, therefore, associate the sign only with T1 and T2.

Material	°C
Silver	−243
Copper	−234.5
Gold	−274
Aluminum	−236
Tungsten	−204
Nickel	−147
Iron	−162
Nichrome	−2,250
Constantan	−125,000

Example (2)

If the resistance of a copper wire is 50 Ω at 20°C, what is its resistance at 100°C (boiling point of water)?

Solution:

$$\frac{234.5°C + 20°C}{50\ \Omega} = \frac{234.5°C + 100°C}{R_2}$$

$$R_2 = \frac{(50\ \Omega)(334.5°C)}{254.5°C} = 65.72\ \Omega$$

Example (3)

If the resistance of a copper wire at freezing (0°C) is 30 Ω, what is its resistance at - 40°C?

Solution:

$$\frac{234.5°C + 0}{30\ \Omega} = \frac{234.5°C - 40°C}{R_2}$$

$$R_2 = \frac{(30\ \Omega)(194.5°C)}{234.5°C} = 24.88\ \Omega$$

Example (4)

If the resistance of an aluminum wire at room temperature (20°C) is 100 m Ω (measured by a milliohm meter), at what temperature will its resistance increase to 120 m Ω?

Solution:

$$\frac{236°\text{C} + 20°\text{C}}{100\ \text{m}\Omega} = \frac{236°\text{C} + T_2}{120\ \text{m}\Omega}$$

and

$$T_2 = 120\ \text{m}\Omega\left(\frac{256°\text{C}}{100\ \text{m}\Omega}\right) - 236°\text{C}$$

$$T_2 = \mathbf{71.2°C}$$