Chapter 3

EMT1150
Introduction to Circuit Analysis

Department of Computer Engineering Technology

Fall 2018

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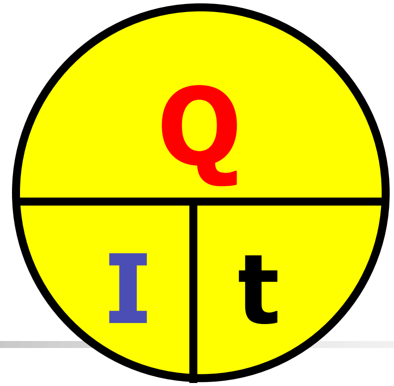
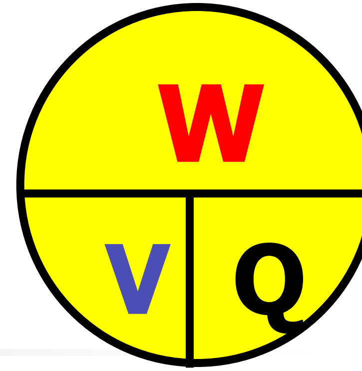


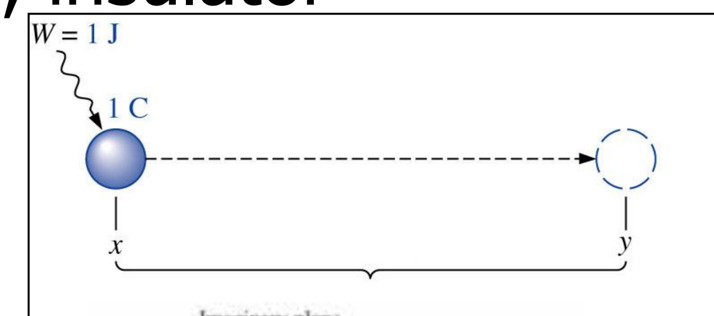


Review

- Current, Voltage
- Voltage source, battery Amp-hour rating, lifetime
- Current and voltage measurements
- Conductor, semiconductor, insulator

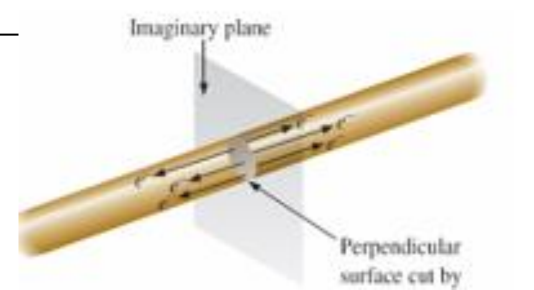
$$V = \frac{W}{Q}$$

V = voltage (V)
Q = coulombs (C)
W = potential energy (J)



$$I = \frac{Q}{t}$$

I = amperes (A)
Q = coulombs (C)
t = seconds (s)

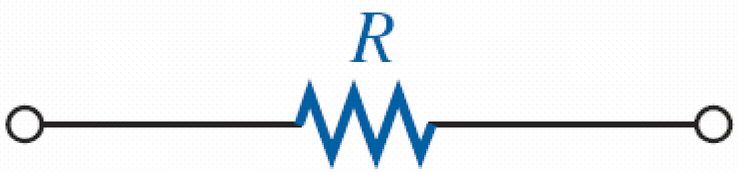


Chapter 3. Resistance

- Introduction to Resistance
- Different Unit system
- Color Coding
- Types of Resistors
- Temperature effect
- Conductance
- Ohmmeter

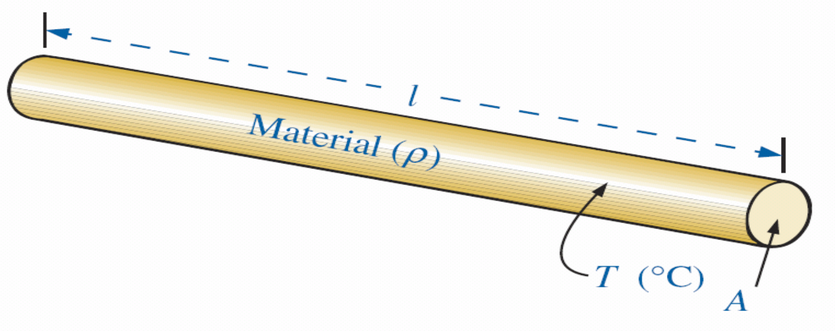
Resistance

- This opposition to the flow of charge through an electrical circuit is called resistance.
- This opposition, due primarily to collisions and friction between the free electrons and other electrons, ions, and atoms in the path of motion, converts electrical energy into another form of energy such as heat



Resistance

- The resistance of any material is due primarily to four factors:
  - Material
  - Length
  - Cross-sectional area
  - Temperature of the material

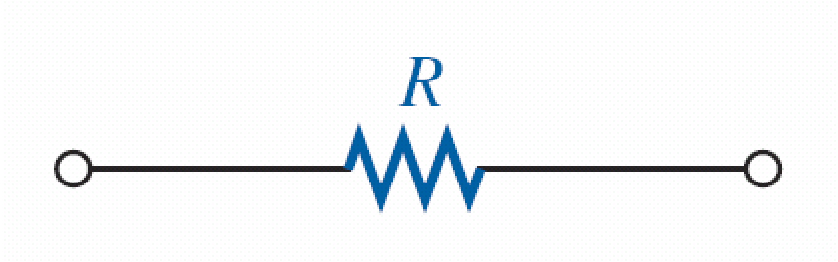


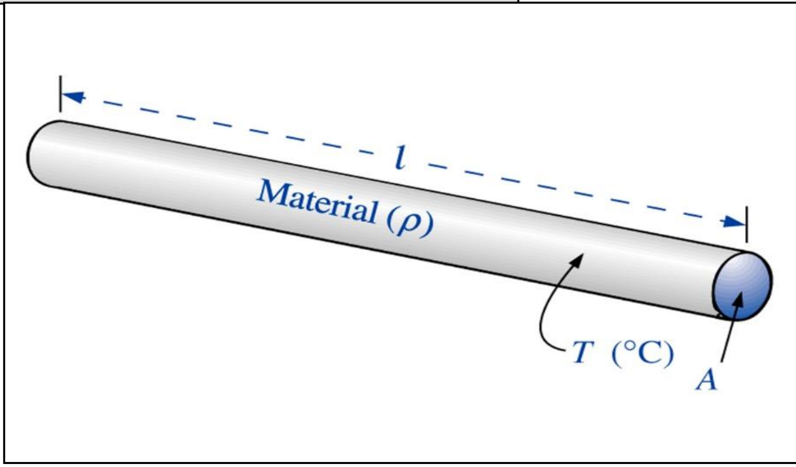
At a fixed temperature of 20°C (room temperature), the resistance is related to the other three factor by

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

(ohms, Ω)

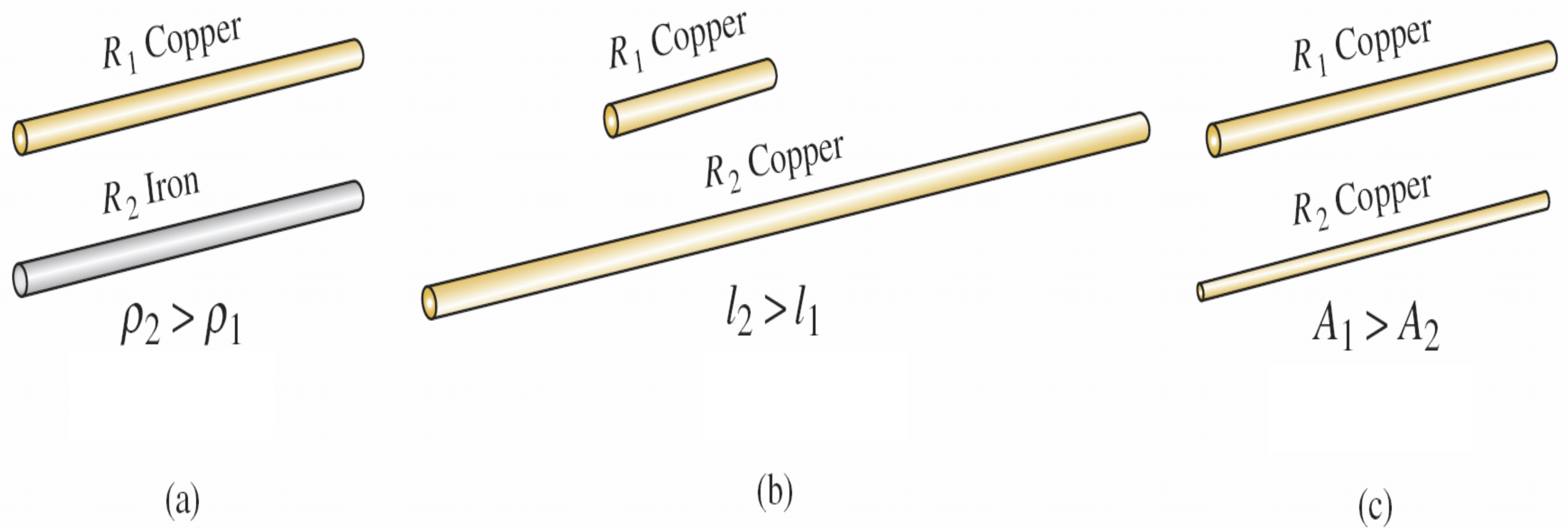
ρ : resistivity of the sample (Ω-centimeter at T=20° C)
l : the length of the sample (centimeter)
A : cross-sectional area of the sample (cm^2)





Material	Ω-cm
Silver	1.645×10^{-6}
Copper	$\mathbf{1.723 \times 10^{-6}}$
Gold	2.443×10^{-6}
Aluminum	2.825×10^{-6}
Tungsten	5.485×10^{-6}
Nickel	7.811×10^{-6}
Iron	12.299×10^{-6}
Tantalum	15.54×10^{-6}
Nichrome	99.72×10^{-6}
Tin oxide	250×10^{-6}
Carbon	3500×10^{-6}

TABLE 3.6 *Resistivity (r) of various materials.*



R1 Copper
R2 Iron
$\rho_2 > \rho_1$
(a)
R1 Copper
R2 Copper
$l_2 > l_1$
(b)
R1 Copper
R2 Copper
$A_1 > A_2$
(c)

Example1: Calculate the resistance of a 10 meter copper wire with a cross sectional area of 0.8 mm^2.

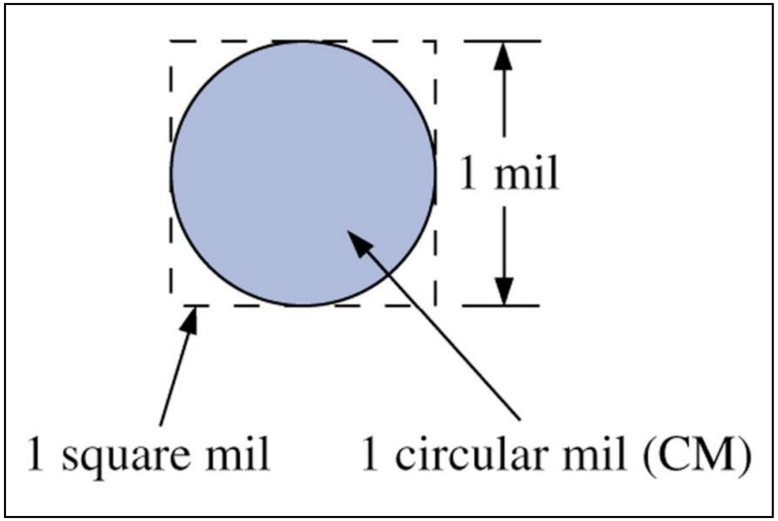
$$R = \rho \frac{l}{A} = 1.72 \times 10^{-6} \Omega \cdot cm \frac{10 \times 100 cm}{0.8 \times 10^{-2} cm^2} = 0.22(\Omega)$$

Circular Mils(CM)

- In industry, the area of the conductor is measured in circular mils (CM) and not in square meters, inches, as determined by the equation

$$Area(circle) = \pi \cdot r^2 = \frac{\pi \cdot d^2}{4}$$

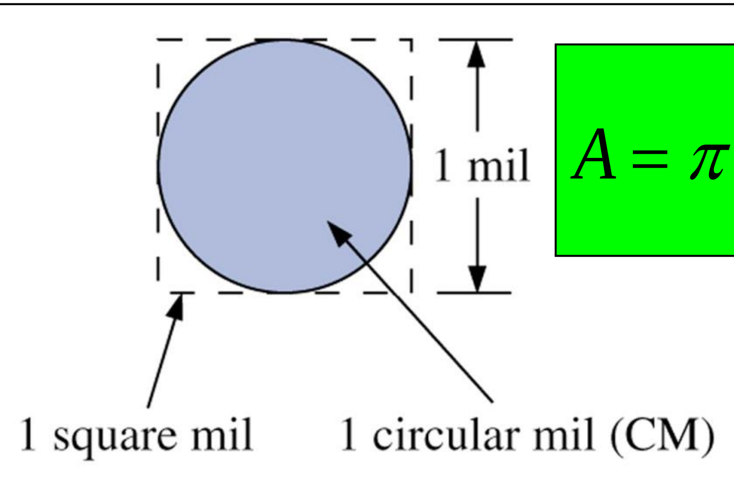
r = radius
d = diameter



$$1 mil = \frac{1}{1000} in.$$

$$1000 mils = 1 in.$$

A wire with a diameter of 1 mil has an area of 1 circular mil (CM),



$$A = \pi \cdot r^2 = \frac{\pi \cdot d^2}{4} = \frac{\pi}{4}(1mil)^2 = \frac{\pi}{4} sq \cdot mil \equiv 1CM$$

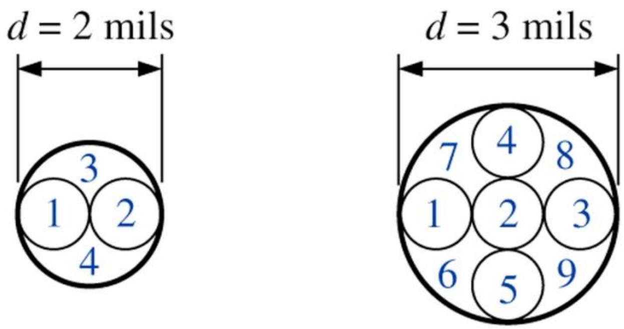
$$1CM = \frac{\pi}{4} sq \cdot mils$$

$$1sq \cdot mil = \frac{4}{\pi} CM = 1.273CM$$

$$A = \frac{\pi \cdot d^2}{4} = \frac{\pi \cdot N^2}{4}(sq \cdot mils) = \left(\frac{\pi \cdot N^2}{4}\right)\left(\frac{4}{\pi} CM\right) = N^2 CM$$

Since $d = N$

$$A_{CM} = (d_{mils})^2$$



$A = (2\text{ mils})^2 = 4\text{ CM}$ $\quad$ $A = (3\text{ mils})^2 = 9\text{ CM}$

At a fixed temperature of 20°C (room temperature), the resistance is related to the other three factor by

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

(ohms, Ω)

ρ : resistivity of the sample (CM-Ω/ft at T=20° C)
l : the length of the sample (ft)
A : cross-sectional area of the sample (CM)

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

$$\rho(\Omega \cdot cm) = (1.662 \times 10^{-7}) \times \rho(CM \cdot \Omega / ft)$$

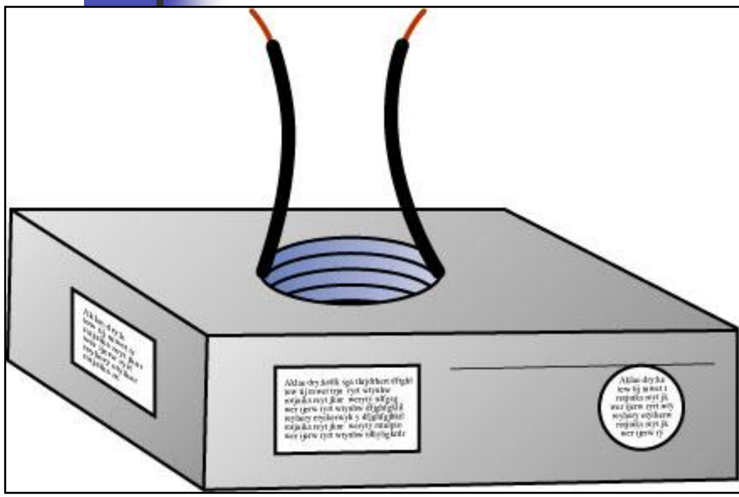
Example3: What is the resistance of 100-ft length of copper wire with a diameter of 0.020 inch at 20°C

0.020inch=20 mils

$A_{CM} = (d_{mils})^2 = 400\ CM$

$$R = \rho \frac{l}{A} = 10.37 \frac{CM \cdot \Omega}{ft} \frac{100\, ft}{400 CM} = 2.59(\Omega)$$

Example4. An undetermined number of feet of wire have been used from the carton. Find the length of the reminding copper wire if it has a diameter of 1/16 in. and resistance of 0.5 Ω.



$\rho = 10.37\ CM \cdot \Omega/ft$

$$\frac{1}{16}\ in. = 0.0625\ in. = 62.5\ mils$$

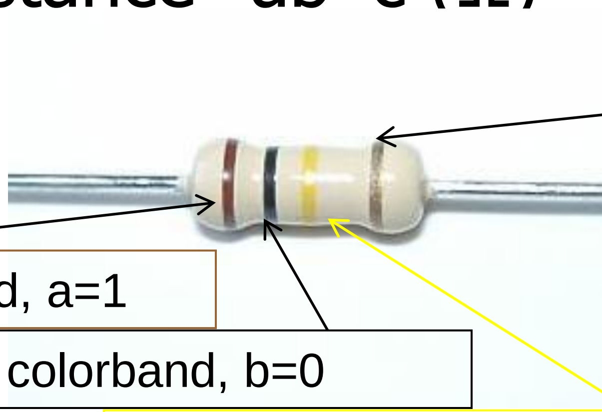
$$A_{CM} = (d_{mils})^2 = (62.5 mils)^2 = 3906.25 CM$$

$$R = \rho \frac{l}{A} \Rightarrow l = \frac{R \cdot A}{\rho} = \frac{(0.5\Omega)(3906.25 CM)}{10.37 \frac{CM \cdot \Omega}{ft}} = \frac{1953.125}{10.37} = 188.34\ ft$$

Resistor color code

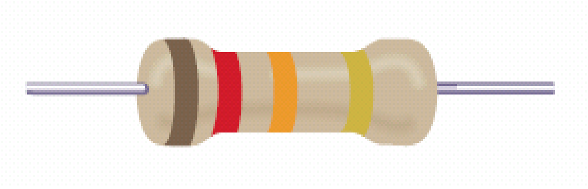
- Put tolerance band on the right side
- Read each colorband (1^{st} =a, 2^{nd}=b, 3^{rd}=c)
- resistance=ab*c (Ω)

Color	Color	Value	Multiplier	Tolerance
	Black	0	X 1	N/A
	Brown	1	X 10	N/A
	Red	2	X 100	2%
	Orange	3	X 1000	N/A
	Yellow	4	X 10000	N/A
	Green	5	X 100000	N/A
	Blue	6	X 1000000	N/A
	Violet	7	X 10000000	N/A
	Gray	8	X 100000000	N/A
	White	9	X 1000000000	N/A
	Gold	N/A	X 0.1	5%
	Silver	N/A	X 0.01	10%



R=10*10000=100K(Ω)

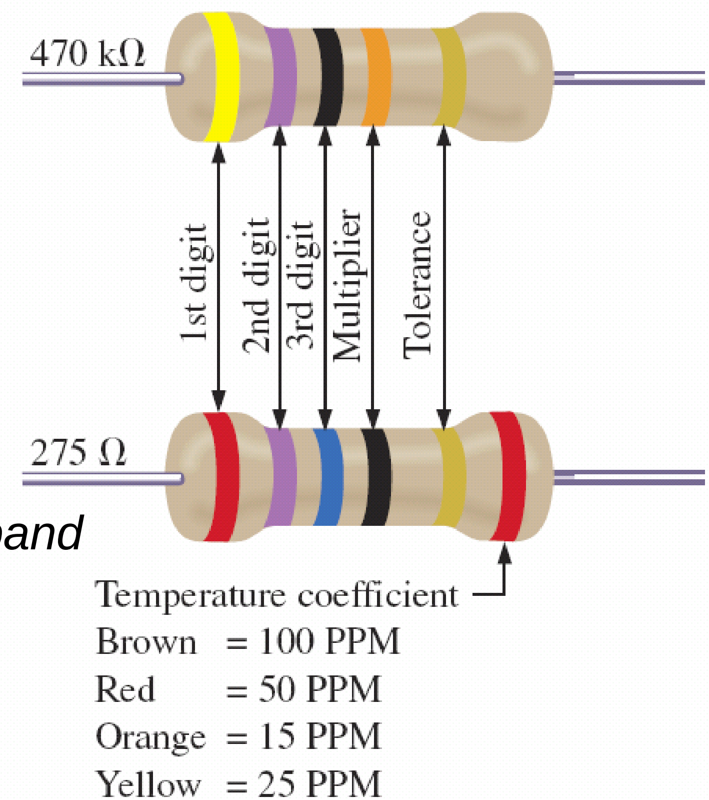
Example5. Find the resistance of this following resistor.



$12\times10^3 \pm 5\%\ \Omega$

Range =11.4 kΩ to 12.6 kΩ

Five band



Six band

5 Band color code resistor

Color	1st digit	2nd digit	3rd digit	Multiplier	Tolerance
Black	0	0	0	10^0	
Brown	1	1	1	10^1	1% (F)
Red	2	2	2	10^2	2% (G)
Orange	3	3	3	10^3	
Yellow	4	4	4	10^4	
Green	5	5	5	10^5	0.5% (D)
Blue	6	6	6	10^6	0.25% (C)
Violet	7	7	7	10^7	0.10% (B)
Gray	8	8	8	10^8	0.05%
White	9	9	9	10^9	
Gold				10^{-1}	5% (J)
Silver				10^{-2}	10% (K)

6 Band color code Resistor

Color	1st digit	2nd digit	3rd digit	Multiplier	Tolerance	TCR (ppm/k)
Black	0	0	0	10^0		
Brown	1	1	1	10^1	1% (F)	100
Red	2	2	2	10^2	2% (G)	50
Orange	3	3	3	10^3		15
Yellow	4	4	4	10^4		25
Green	5	5	5	10^5	0.5% (D)	
Blue	6	6	6	10^6	0.25% (C)	10
Violet	7	7	7	10^7	0.10% (B)	5
Gray	8	8	8	10^8	0.05%	
White	9	9	9	10^9		
Gold				10^{-1}	5% (J)	
Silver				10^{-2}	10% (K)	

Type of resistors

- Fixed resistor
  - Thin-film resistor
  - Fixed metal oxide resistor
  - Fixed composition resistor
- Variable resistor

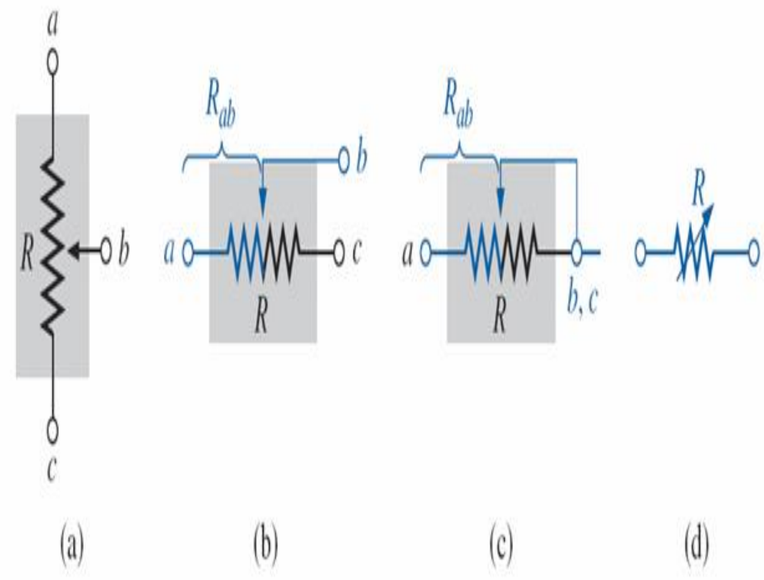
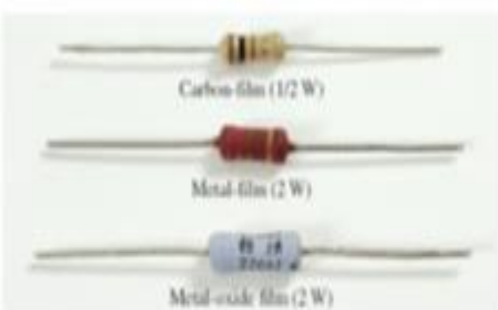


FIG. 3.16 *Potentiometer: (a) symbol; (b) and (c) rheostat connections; (d) rheostat symbol.*



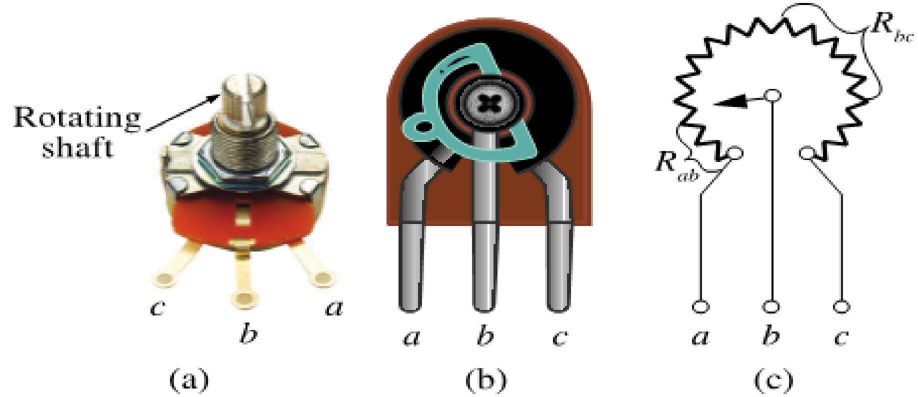


FIG. 3.17 *Potentiometer. (a) External, (b) Internal, (c) Circuit equivalent.*

$R_{ac} = R_{ab} + R_{bc}$

Temperature effect

- Conductor: *for good conductors, an increase in temperature will result in an increase in the resistance level. Consequently, conductors have a positive temperature coefficient*.

- Semiconductor: for semiconductor materials, an increase in temperature will result in a decrease in the resistance level. *Consequently, semiconductors have a negative temperature coefficient*.

- *Insulators: The result is a negative temperature coefficient*

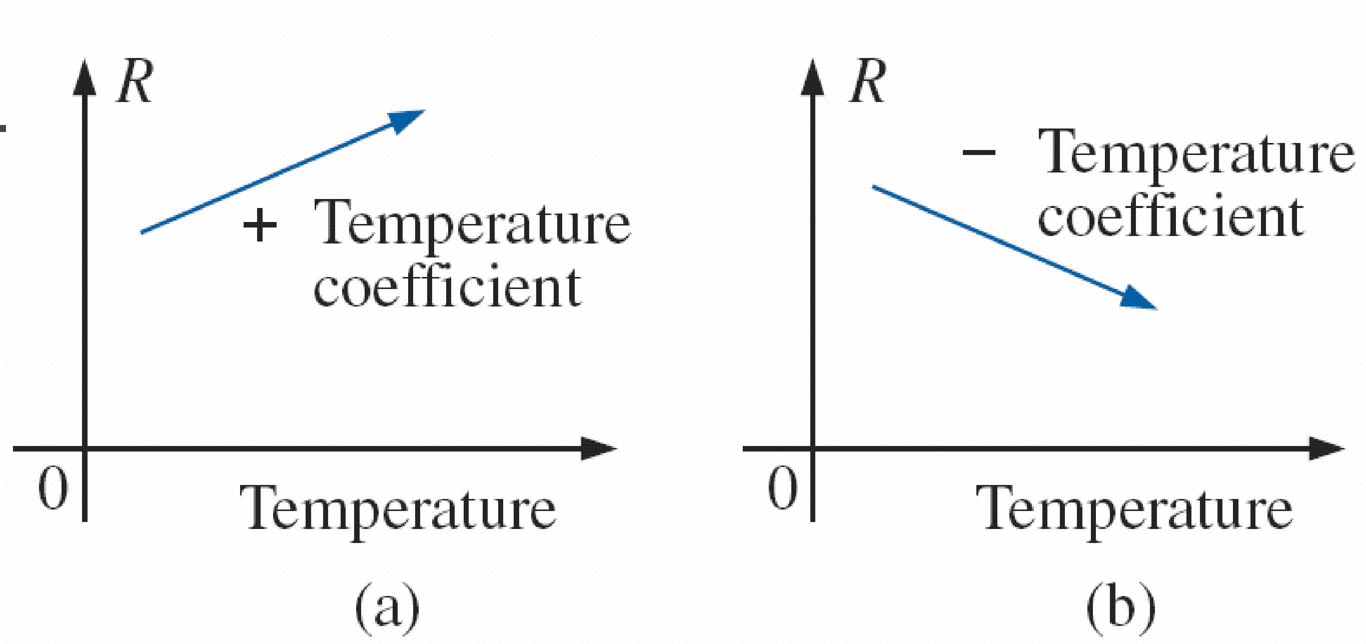


FIG. 3.10 *Demonstrating the effect of a positive and a negative temperature coefficient on the resistance of a conductor.*

Conductance

- The quantity of how well the material will conduct electricity is called **conductance**.
- Unit: Siemens (S)

$$G = \frac{1}{R}$$

$$G = \frac{A}{\rho \cdot l}$$

Indicating that increasing the area or decreasing either the length or the resistivity will increase the Conductance.

Ohmmeters

- The ohmmeter is an instrument used to perform the following tasks and several other useful functions.

1. Measure the resistance of individual or combined elements
2. Direct open-circuit (high-resistance) and short-circuit (low-resistance) situations
3. Check continuity of network connections and identify wires of a multi-lead cable
4. Test some semiconductor devices