College of Engineering
Dept. of the electrical power
and Machine engineering
Subject / Electrical Eng. Fundamental I

stage / first
Date: 15/11/2017
Lecture:2
Time/ 2 hours

## TEMPERATURE EFFECTS

### Conductors

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

### Semiconductors

for semiconductor materials, an increase in temperature results in a decrease in the resistance level. Consequently, semiconductors have negative temperature coefficients.

### Insulators

As with semiconductors, an increase in temperature results in a decrease in the resistance of an insulator. The result is a negative temperature coefficient.

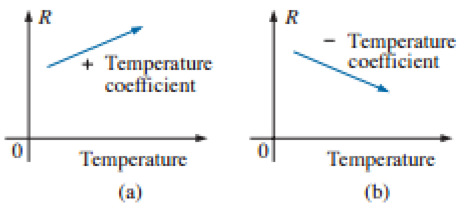


**FIG. 10**
*Demonstrating the effect of a positive and a negative temperature coefficient on the resistance of a conductor.*

### Inferred Absolute Temperature

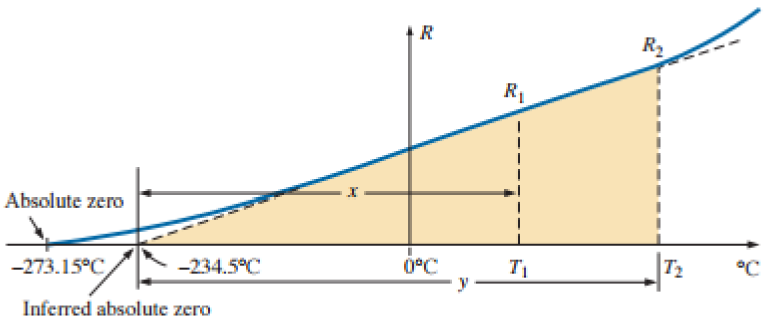


**FIG. 11**
*Effect of temperature on the resistance of copper.*

$$\frac{x}{R_1} = \frac{y}{R_2}$$

or

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

where |T1| indicates that the inferred absolute temperature of the material

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**EXAMPLE 8** If the resistance of a copper wire at freezing (0°C) is 30 Ω, what is its resistance at −40°C?

***Solution:*** Eq. (5):

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

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

**EXAMPLE 9** If the resistance of an aluminum wire at room temperature (20°C) is 100 mΩ (measured by a milliohmmeter), at what temperature will its resistance increase to 120 mΩ?

***Solution:*** Eq. (5):

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

and

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

$$T_2 = \mathbf{71.2°C}$$

**Temperature Coefficient of Resistance**

$$\boxed{\alpha_{20} = \frac{1}{|T_1| + 20°C}} \qquad (\Omega/°C/\Omega)$$

as the temperature coefficient of resistance at a temperature of 20°C and R20 as the resistance of the sample at 20°C, we determine the resistance R1 at a temperature T1 by

$$\boxed{R_1 = R_{20}[1 + \alpha_{20}(T_1 - 20°C)]}$$ **or** $$\alpha_{20} = \frac{\left(\frac{R_1 - R_{20}}{T_1 - 20°C}\right)}{R_{20}} = \frac{\frac{\Delta R}{\Delta T}}{R_{20}} \qquad \boxed{R = \rho\frac{l}{A}[1 + \alpha_{20}\,\Delta T]}$$

the higher the temperature coefficient of resistance for a material, the more sensitive is the resistance level to changes in temperature.

**PPM/°C;** The specification is normally provided in parts per million per degree Celsius (PPM/°C), providing an immediate indication of the sensitivity level of the resistor to temperature.

$$\boxed{\Delta R = \frac{R_{\text{nominal}}}{10^6}(\text{PPM})(\Delta T)}$$

where $R_{nominal}$ is the nameplate value of the resistor at room temperature and ΔT is the change in temperature from the reference level of 20°C.

**EXAMPLE 10** For a 1 kΩ carbon composition resistor with a PPM of 2500, determine the resistance at 60°C.

***Solution:***

$$\Delta R = \frac{1000\ \Omega}{10^6}(2500)(60°C - 20°C) = 100\ \Omega$$

and

$$R = R_{\text{nominal}} + \Delta R = 1000\ \Omega + 100\ \Omega = \mathbf{1100\ \Omega}$$

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## TYPES OF RESISTORS

### Fixed Resistors

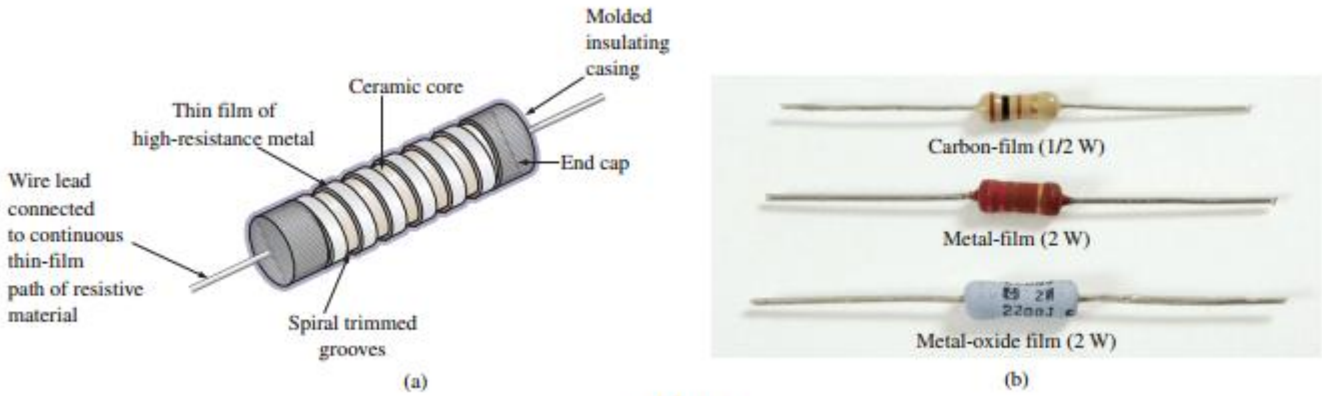


**FIG. 12**
*Film resistors: (a) construction; (b) types.*

For a particular style and manufacturer, the size of a resistor increases with the power or wattage rating. the size of a resistor does not define its resistance level.

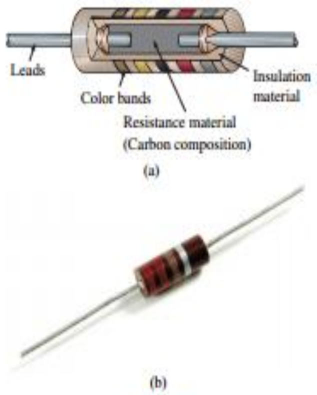


**FIG. 13**
*Fixed-composition resistors: (a) construction; (b) appearance.*

ACTUAL SIZE

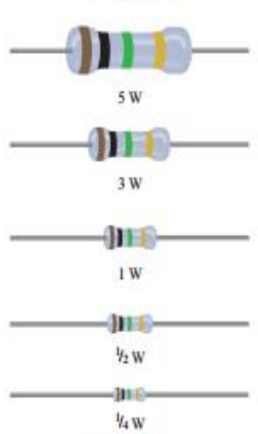


**FIG. 14**
*Fixed metal-oxide resistors of different wattage rating*

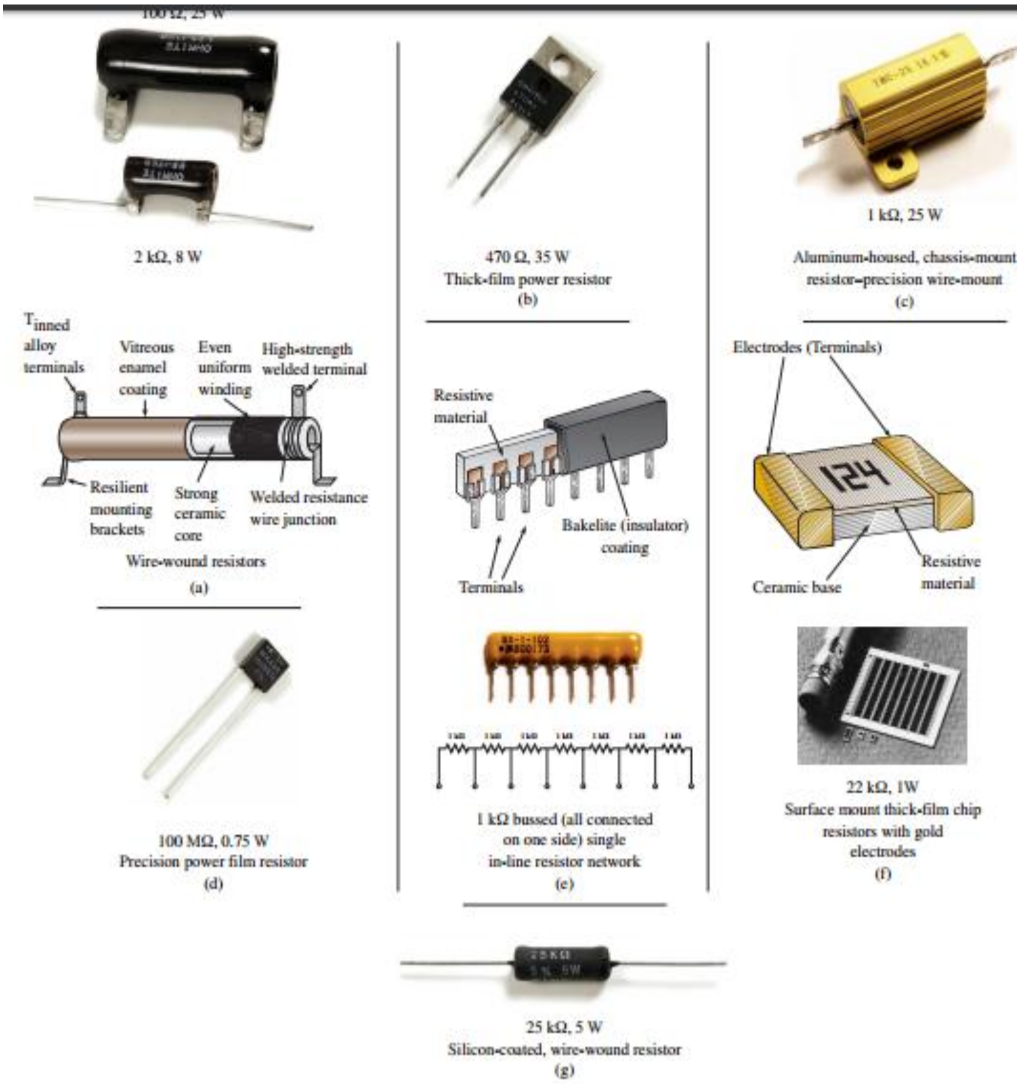


**FIG. 15**
*Various types of fixed resistors.*

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**Variable Resistors**

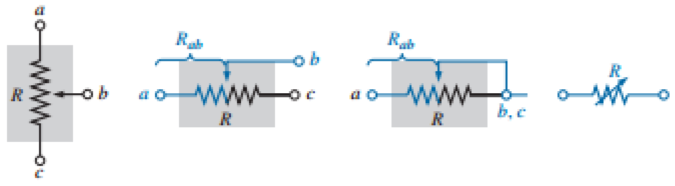


FIG. 16
*Potentiometer: (a) symbol; (b) and (c) rheostat connections; (d) rheostat symbol.*

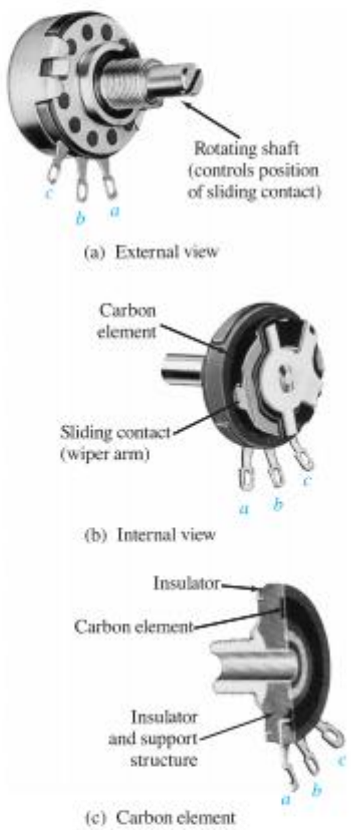


FIG. 17
*Molded composition-type potentiometer.*
(Courtesy of Allen-Bradley Co.)

The resistance between the outside terminals a and c in Fig. 18(a) (and Fig. 17) is always fixed at the full rated value of the potentiometer, regardless of the position of the wiper arm b.

The resistance between the wiper arm and either outside terminal can be varied from a minimum of 0 to a maximum value equal to the full rated value of the potentiometer.

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

**CONDUCTANCE:** we have a measure of how well the material conducts electricity, has the symbol G, and is measured in siemens (S).

$$\boxed{G = \frac{1}{R}} \quad \text{(siemens, S)} \qquad \boxed{G = \frac{A}{\rho l}} \quad \text{(S)}$$

**RESISTANCE: METRIC UNITS**

| | |
|---|---|
| $\rho$: | ohm-centimeters |
| $l$: | centimeters |
| $A$: | square centimeters |

The units for $\rho$ can be derived from

$$\rho = \frac{RA}{l} = \frac{\Omega\text{-cm}^2}{\text{cm}} = \Omega\text{-cm}$$

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**EXAMPLE 15** Determine the resistance of 100 ft of #28 copper telephone wire if the diameter is 0.0126 in.

***Solution:*** Unit conversions:

$$l = 100\,\cancel{\text{ft}}\left(\frac{12\,\cancel{\text{in.}}}{1\,\cancel{\text{ft}}}\right)\left(\frac{2.54\text{ cm}}{1\,\cancel{\text{in.}}}\right) = 3048\text{ cm}$$

$$d = 0.0126\text{ in.}\left(\frac{2.54\text{ cm}}{1\text{ in.}}\right) = 0.032\text{ cm}$$

Therefore,

$$A = \frac{\pi d^2}{4} = \frac{(3.1416)(0.032\text{ cm})^2}{4} = 8.04 \times 10^{-4}\text{ cm}^2$$

$$R = \rho\frac{l}{A} = \frac{(1.723 \times 10^{-6}\Omega\text{-cm})(3048\text{ cm})}{8.04 \times 10^{-4}\text{ cm}^2} \cong \mathbf{6.5\ \Omega}$$

Using the units for circular wires and Table 2 for the area of a #28 wire, we find

$$R = \rho\frac{l}{A} = \frac{(10.37\text{ CM-}\Omega/\text{ft})(100\text{ ft})}{159.79\text{ CM}} \cong \mathbf{6.5\ \Omega}$$

The conversion factor between resistivity in circular mil-ohms per foot and ohm-centimeters is the following;

$$\boxed{\rho\,(\Omega\text{-cm}) = (1.662 \times 10^{-7}) \times (\text{value in CM-}\Omega/\text{ft})}$$

$$1.723 \times 10^{-6}\Omega\text{-}\cancel{\text{cm}}\left[\frac{1\text{ m}}{100\,\cancel{\text{cm}}}\right] = \frac{1}{100}[1.723 \times 10^{-6}]\Omega\text{-m}$$

or the value in ohm-meters is 1/100 the value in ohm-centimeters, and

$$\boxed{\rho(\Omega\text{-m}) = \left(\frac{1}{100}\right) \times (\text{value in }\Omega\text{-cm})} \qquad \textbf{(14)}$$

Similarly,

$$\boxed{\rho(\mu\Omega\text{-cm}) = (10^6) \times (\text{value in }\Omega\text{-cm})} \qquad \textbf{(15)}$$

EX: A coil of insulated copper wire has a resistance of 150 ohm at 20 C. when the coil is connected across 240 V supply, the current after several hours is 1.25A. a) By assuming the temperature coefficient of resistance of copper at 20 C to be 0.0039 /C, find the average temperature throughout the coil. b) find the temperature coefficient of resistance for copper at 0 C and 50 C c) What the resistance at -5 C, 5 C,0 C and 45 C.

**Solution**:

a) $R_2 = 240/1.25 = 192$ ohm

$R_2 = R_{20}\ (1+\alpha_{20}\ \Delta T\ )$

$192 = 150\ (1+0.0039 * \Delta T)$ , So $\Delta T = 71.795\,^{\circ}C$

$T_2 = 20+71.795 = 91.795\,^{\circ}C$

b ) $\alpha_y = \alpha_0 /(1+ \alpha_0 T_y)$ where $\alpha_y = \alpha_{20} = 0.0039/^{\circ}C$. $\alpha_0 = \alpha_y /(1- \alpha_y T_y ) = 0.0039/(1-(0.0039*20)) = 4.23*10^{-3}\ /^{\circ}C$

$\alpha_{50}$ = 4.23*10^-3 /(1+(4.23*10^-3*50) = 3.492*10^-3/°C

or $\alpha_y = \alpha_N /(1+ \alpha_N \Delta T)$ , So $\alpha_{50} = \alpha_{20} /(1+ \alpha_{20}(50-20)) = 3.49*10^{-3}$

or

c) $R_{-5} = R_{20}(1+ \alpha_{20}\Delta T)$
$R_5 = R_{20}(1+ \alpha_{20}\Delta T)$
$R_{45} = R_{20}(1+ \alpha_{20}\Delta T)$

**Homework**

17. a. For the system in Fig. 46, the resistance of each line cannot exceed 6 mΩ, and the maximum current drawn by the load is 110 A. What minimum size gage wire should be used? b. Repeat (a) for a maximum resistance of 3 mΩ, d= 30 ft, and a maximum current of 110 A.

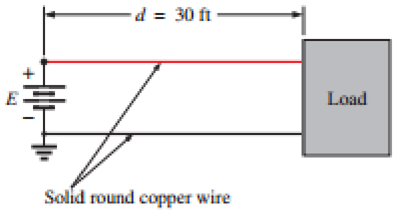


FIG. 46
*Problem 17.*

21. The resistance of a copper wire is 4 at room temperature (68°F). What is its resistance at a freezing temperature of 32°F?

23. a. The resistance of a copper wire is 1 at 4°C. At what temperature (°C) will it be 1.1 ? b. At what temperature will it be 0.1 ?