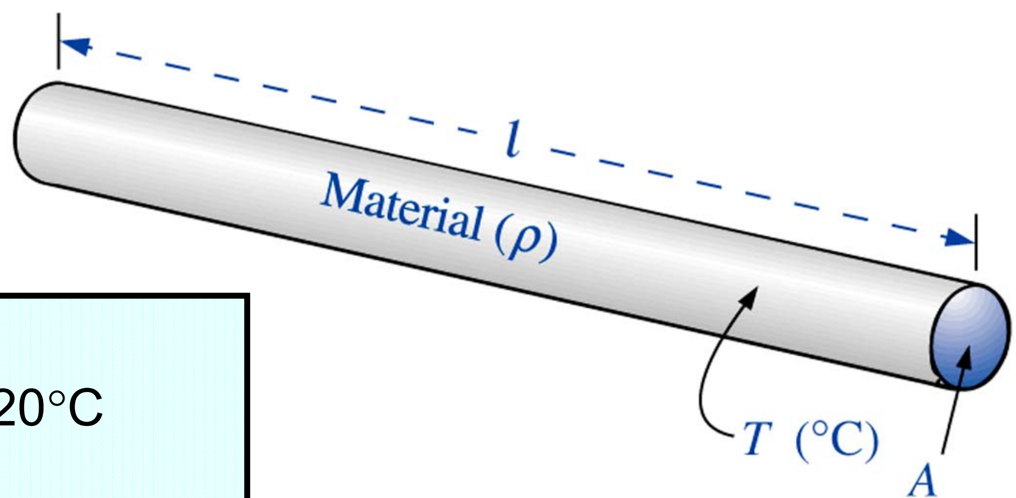
Resistance

The resistance of any material is due primarily to four factors :

1. Material (resistivity)
2. Length
3. Cross-Sectional Area
4. Temperature



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

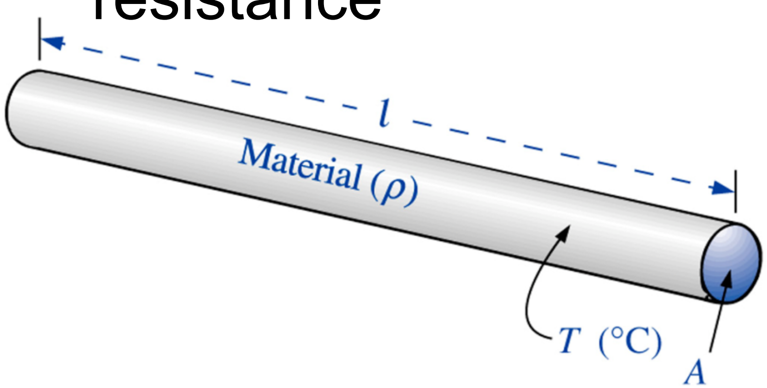
$\rho = CM\ \Omega/ft\ @\ T = 20°C$

$l = feet$

A = area in circular mils (CM)

Resistivity : Rho (ρ)

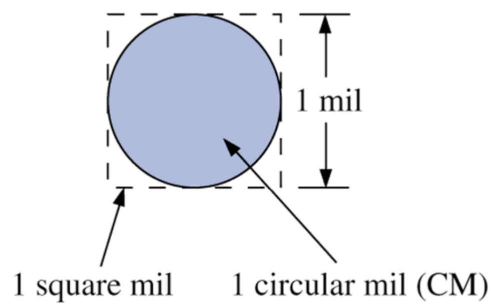
- Resistivity varies by material.
- The higher the resistivity, the greater the resistance of a conductor
- The longer the conductor, the greater the resistance
- The greater the area of a conductor, the less the resistance



Material	***Rho (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

Circular Mils (CM)

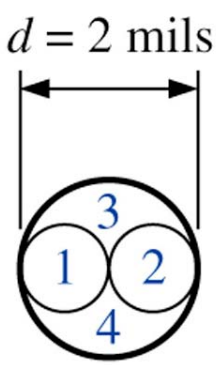
- By definition, a wire with a diameter of 1 mil has an area of 1 CM.



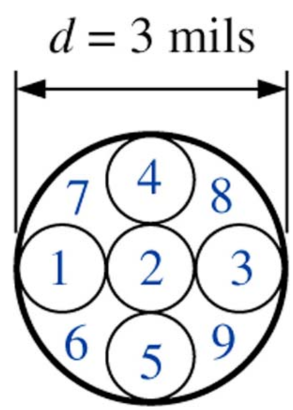
$$1\,\text{mil} = \frac{1}{1000}\,\text{inch}$$

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

- Examples



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



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

Example - Resistance

An unknown length of copper wire has a measured resistance of 1.25 Ω and a diameter of 1/32 inch. What is the length of the wire.

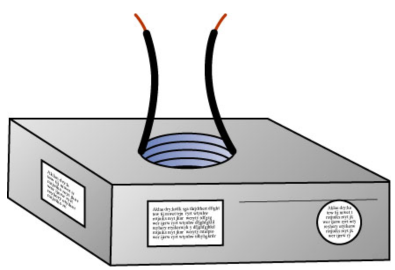
$$\rho_{copper} = 10.37 \frac{\text{CM-}\Omega}{\text{foot}} \qquad \frac{1}{32}\text{in} = 0.03125\text{ in} = 31.25\text{ mils}$$

$$A_{CM} = (d_{mils})^2 = (31.25\text{ mils})^2 = 976.563\text{ CM}$$

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

$$\therefore l = \frac{RA}{\rho} = \frac{1.25\,\Omega \times 976.563\text{ CM}}{10.37\frac{\text{CM-}\Omega}{\text{foot}}} = \frac{1220.7038}{10.37}\text{ft}$$

$$l = 117.715\text{ ft}$$



American Wire Gage (AWG) Sizes – Copper

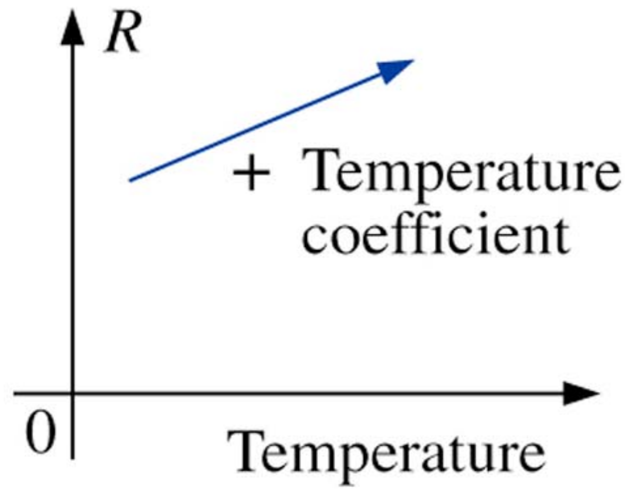
Gauge	Area (CM)	Ohms/1000 ft	Maximum amps	Gauge	Area (CM)	Ohms/1000 ft	Maximum amps
0000	212000	0.049	380	19	1289	8.051	14
000	168000	0.0618	328	20	1024	10.15	11
00	133000	0.0779	283	21	812	12.8	9
0	105531	0.0983	245	22	640	16.14	7
1	83694	0.1239	211	23	511	20.36	4.7
2	66358	0.1563	181	24	404	25.67	3.5
3	52624	0.197	158	25	320	32.37	2.7
4	41738	0.2485	135	26	253	40.81	2.2
5	33088	0.3133	118	27	202	51.47	1.7
6	26244	0.3951	101	28	159	64.9	1.4
7	20822	0.4982	89	29	128	81.83	1.2
8	16512	0.6282	73	30	100	103.2	0.86
9	13087	0.7921	64	31	79	130.1	0.7
10	10384	0.9989	55	32	64	164.1	0.53
11	8226	1.26	47	33	50.125	206.9	0.43
12	6529	1.588	41	34	39.75	260.9	0.33
13	5184	2.003	35	35	31.5	329	0.27
14	4109	2.525	32	36	25.0	414.8	0.21
15	3260	3.184	28	37	19.83	523.1	0.17
16	2581	4.016	22	38	15.7	659.6	0.13
17	2052	5.064	19	39	12.47	831.8	0.11
18	1624	6.385	16	40	9.89	1049	0.09

Breakout Exercise #1

Phone and data (i.e. Cat-5 cable) wire is normally 24 gauge (AWG) twisted pair cables. What is the diameter, in inches, of this wire and the total resistance of one-mile of this wire.

Temperature Effects

- For conductors, an increase in temperature results in an increase in resistance. Consequently, conductors have a positive temperature coefficient.



- For insulators & semiconductors, an increase in temperature results in a decrease in resistance. Consequently, insulators and semiconductors have a negative temperature coefficient.