

Chapter 3

1.
 - a. 0.5 in. = **500 mils**
 - b. $0.02 \cancel{\text{in.}} \left[\frac{1000 \text{ mils}}{1 \cancel{\text{in.}}} \right] = \mathbf{20 \text{ mils}}$
 - c. $\frac{1}{4} \text{ in.} = 0.25 \cancel{\text{in.}} \left[\frac{1000 \text{ mils}}{1 \cancel{\text{in.}}} \right] = \mathbf{250 \text{ mils}}$
 - d. $10 \text{ mm} = 10 \times 10^{-3} \cancel{\text{m}} \left[\frac{39.37 \text{ in}}{1 \cancel{\text{m}}} \right] \left[\frac{1000 \text{ mils}}{1 \text{ in}} \right] = \mathbf{393.7 \text{ mils}}$
 - e. $0.01 \cancel{\text{ft}} \left[\frac{12 \cancel{\text{in.}}}{1 \cancel{\text{ft}}} \right] \left[\frac{10^3 \text{ mils}}{1 \cancel{\text{in.}}} \right] = \mathbf{120 \text{ mils}}$
 - f. $0.1 \cancel{\text{cm}} \left[\frac{1 \cancel{\text{in.}}}{2.54 \cancel{\text{cm}}} \right] \left[\frac{1000 \text{ mils}}{1 \cancel{\text{in.}}} \right] = \mathbf{39.37 \text{ mils}}$
2.
 - a. $A_{\text{CM}} = (30 \text{ mils})^2 = \mathbf{900 \text{ CM}}$
 - b. $0.016 \text{ in.} = 16 \text{ mils}, A_{\text{CM}} = (16 \text{ mils})^2 = \mathbf{256 \text{ CM}}$
 - c. $\frac{1}{8}'' = 0.125'' = 125 \text{ mils}, A_{\text{CM}} = (125 \text{ mils})^2 = \mathbf{15.63 \times 10^3 \text{ CM}}$
 - d. $1 \cancel{\text{cm}} \left[\frac{1 \cancel{\text{in.}}}{2.54 \cancel{\text{cm}}} \right] \left[\frac{1000 \text{ mils}}{1 \cancel{\text{in.}}} \right] = 393.7 \text{ mils}, A_{\text{CM}} = (393.7 \text{ mils})^2 = \mathbf{155 \times 10^3 \text{ CM}}$
 - e. $0.02 \cancel{\text{ft}} \left[\frac{12 \cancel{\text{in.}}}{1 \cancel{\text{ft}}} \right] \left[\frac{1000 \text{ mils}}{1 \cancel{\text{in.}}} \right] = 240 \text{ mils}, A_{\text{CM}} = (240 \text{ mils})^2 = \mathbf{57.60 \times 10^3 \text{ CM}}$
 - f. $4 \times 10^{-3} \cancel{\text{m}} \left[\frac{39.37 \cancel{\text{in.}}}{1 \cancel{\text{m}}} \right] \left[\frac{1000 \text{ mils}}{1 \cancel{\text{in.}}} \right] = \mathbf{157.48 \text{ mils}}, A_{\text{CM}} = (157.48 \text{ mils})^2 = \mathbf{24.8 \times 10^3 \text{ CM}}$
3. $A_{\text{CM}} = (d_{\text{mils}})^2 \rightarrow d_{\text{mils}} = \sqrt{A_{\text{CM}}}$
 - a. $d = \sqrt{1600 \text{ CM}} = 40 \text{ mils} = \mathbf{0.04 \text{ in.}}$
 - b. $d = \sqrt{820 \text{ CM}} = 28.64 \text{ mils} = \mathbf{0.029 \text{ in.}}$
 - c. $d = \sqrt{40,000 \text{ CM}} = 200 \text{ mils} = \mathbf{0.2 \text{ in.}}$

- d. $d = \sqrt{625 \text{ CM}} = 25 \text{ mils} = \mathbf{0.025 \text{ in.}}$
- e. $d = \sqrt{6.25 \text{ CM}} = 2.5 \text{ mils} = \mathbf{0.0025 \text{ in.}}$
- f. $d = \sqrt{3 \times 10^3 \text{ CM}} = 54.77 \text{ mils} = \mathbf{0.055 \text{ in.}}$
4. $0.02 \text{ in.} = 20 \text{ mils}, A_{\text{CM}} = (20 \text{ mils})^2 = 400 \text{ CM}$
 $R = \rho \frac{l}{A} = (10.37) \frac{(200')}{400 \text{ CM}} = \mathbf{5.19 \Omega}$
5. a. $A = \rho \frac{l}{R} = 17 \left(\frac{80'}{2.5 \Omega} \right) = \mathbf{544 \text{ CM}}$
b. $d = \sqrt{A_{\text{CM}}} = \sqrt{544 \text{ CM}} = 23.32 \text{ mils} = \mathbf{23.3 \times 10^{-3} \text{ in.}}$
6. $\frac{1}{32}'' = 0.03125'' = 31.25 \text{ mils}, A_{\text{CM}} = (31.25 \text{ mils})^2 = 976.56 \text{ CM}$
 $R = \rho \frac{l}{R} \Rightarrow l = \frac{RA}{\rho} = \frac{(2.2 \Omega)(976.56 \text{ CM})}{600} = \mathbf{3.58 \text{ ft}}$
7. a. $A_{\text{CM}} = \rho \frac{l}{A} = \frac{(10.37)(300')}{3.3 \Omega} = \mathbf{942.73 \text{ CM}}$
 $d = \sqrt{942.73 \text{ CM}} = 30.70 \text{ mils} = \mathbf{30.7 \times 10^{-3} \text{ in.}}$
b. larger
c. smaller
8. $\rho = \frac{RA}{l} = \frac{(500 \Omega)(94 \text{ CM})}{1000'} = 47 \Rightarrow \mathbf{\text{nickel}}$
9. a. $1/32'' = 0.03125'' = 31.25 \text{ mils}, A_{\text{CM}} = (31.25 \text{ mils})^2 = 976.56 \text{ CM}$
 $R = \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho} = \frac{(3.12 \Omega)(976.56 \text{ CM})}{10.37} = \mathbf{293.82 \text{ ft}}$
b. $\frac{293.82'}{x} = \frac{1000'}{5 \text{ lb}} \Rightarrow x = \frac{(5)(293.82)}{1000} = \mathbf{1.47 \text{ lbs}}$
c. $-40^\circ \text{ C: } F = \frac{9}{5}C + 32^\circ = \frac{9}{5}(-40) + 32 = -40^\circ$
 $105^\circ \text{ C: } F = \frac{9}{5}C + 32^\circ = \frac{9}{5}(105) + 32 = 221^\circ$
 $\mathbf{F^\circ = -40^\circ \rightarrow 221^\circ}$

10. a. $\frac{3}{8}'' = 0.375'' = 375 \text{ mils}$
 $4.8'' = 4800 \text{ mils}$
 $A = (375 \text{ mils})(4800 \text{ mils}) = 1.8 \times 10^6 \text{ sq. mils} \left[\frac{4/\pi \text{ CM}}{1 \text{ sq. mil}} \right] = 2.29 \times 10^6 \text{ CM}$

b. $\frac{1}{12}'' = 0.083 \text{ in.} = 83 \text{ mils}$
 $A_{\text{CM}} = (83 \text{ mils})^2 = 6.89 \times 10^3 \text{ CM}$
 $(\#12) \frac{2.29 \times 10^6 \text{ CM}}{6.89 \times 10^3 \text{ CM}} = 332.37 \text{ wires}$

11. a. $3'' = 3000 \text{ mils}$, $1/2'' = 0.5 \text{ in.} = 500 \text{ mils}$
 $\text{Area} = (3 \times 10^3 \text{ mils})(5 \times 10^2 \text{ mils}) = 15 \times 10^5 \text{ sq. mils}$
 $15 \times 10^5 \text{ sq. mils} \left[\frac{4/\pi \text{ CM}}{1 \text{ sq. mil}} \right] = 19.108 \times 10^5 \text{ CM}$
 $R = \rho \frac{l}{A} = \frac{(10.37)(4')}{19.108 \times 10^5 \text{ CM}} = 21.71 \mu\Omega$

b. $R = \rho \frac{l}{A} = \frac{(17)(4')}{19.108 \times 10^5 \text{ CM}} = 35.59 \mu\Omega$
 Aluminum bus-bar has almost 64% higher resistance.

12. $l_2 = 2l_1$, $A_2 = A_1/4$, $\rho_2 = \rho_1$
 $\frac{R_2}{R_1} = \frac{\frac{\rho_2 l_2}{A_2}}{\frac{\rho_1 l_1}{A_1}} = \frac{\cancel{\rho_2} l_2 A_1}{\cancel{\rho_1} l_1 A_2} = \frac{2l_1 A_1}{l_1 A_1/4} = 8$
 and $R_2 = 8R_1 = 8(0.2 \Omega) = 1.6 \Omega$
 $\Delta R = 1.6 \Omega - 0.2 \Omega = 1.4 \Omega$

13. $A = \frac{\pi d^2}{4} \Rightarrow d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4(0.04 \text{ in.}^2)}{\pi}} = 0.2257 \text{ in.}$

$d_{\text{mils}} = 225.7 \text{ mils}$

$A_{\text{CM}} = (225.7 \text{ mils})^2 = 50,940.49 \text{ CM}$

$\frac{R_1}{R_2} = \frac{\frac{\rho_1 l_1}{A_1}}{\frac{\rho_2 l_2}{A_2}} = \frac{\cancel{\rho_1} l_1 A_2}{\cancel{\rho_2} l_2 A_1} = \frac{l_1 A_2}{l_2 A_1} \quad (\rho_1 = \rho_2)$

and $R_2 = \frac{R_1 l_2 A_1}{l_1 A_2} = \frac{(800 \text{ m}\Omega)(300 \text{ ft})(40,000 \text{ CM})}{(200 \text{ ft})(50,940.49 \text{ CM})} = 942.28 \text{ m}\Omega$

14. a. #12 = 6,529.9 CM, #14 = 4,106.8 CM

$$\frac{6,529.9 \text{ CM} - 4,106.8 \text{ CM}}{4,106.8 \text{ CM}} \times 100\% = \mathbf{59\% \text{ larger}}$$
- b. $\frac{\#12}{\#14} = \frac{20 \text{ A}}{15 \text{ A}} = 1.33$, $\frac{\#12}{\#14} = \frac{6,529.9 \text{ CM}}{4,106.8 \text{ CM}} = 1.59$
 $I_{\max}$ ratio = 1.33 vs Area ratio = 1.59

$$\frac{1.59 - 1.33}{1.33} \times 100\% = \mathbf{19.55\% \text{ higher ratio for area}}$$
15. a. $\frac{\#9}{\#12} = \frac{13,094 \text{ CM}}{6,529.9 \text{ CM}} = \mathbf{2 \text{ yes}}$
- b. $\frac{\#0}{\#12} = \frac{105,530 \text{ CM}}{6,529.9 \text{ CM}} = \mathbf{16.16 \text{ yes}}$
- $$\frac{\#0}{\#12} = \frac{150 \text{ A}}{20 \text{ A}} = \mathbf{7.5}$$
16. a. $\frac{\#10}{\#20} = \frac{10,381 \text{ CM}}{1,021.5 \text{ CM}} = 10.16 \cong \mathbf{10 \text{ yes}}$
- b. $\frac{\#20}{\#40} = \frac{1,021.5 \text{ CM}}{9.89 \text{ CM}} = 103.28$
 $\mathbf{\text{yes} \cong 100}$
17. a. $A = \rho \frac{l}{R} = \frac{(10.37)(30')}{6 \text{ m}\Omega} = \frac{311.1 \text{ CM}}{6 \times 10^{-3}} = 51,850 \text{ CM} \Rightarrow \#3$
but 110 A $\Rightarrow \mathbf{\#2}$
- b. $A = \rho \frac{l}{R} = \frac{(10.37)(30')}{3 \text{ m}\Omega} = \frac{311.1 \text{ CM}}{3 \times 10^{-3}} = 103,700 \text{ CM} \Rightarrow \mathbf{\#0}$
18. a. $A/\text{CM} = 230 \text{ A}/211,600 \text{ CM} = \mathbf{1.09 \text{ mA/CM}}$
- b.
$$\frac{1.09 \text{ mA}}{\cancel{\text{CM}}} \left[\frac{1 \cancel{\text{CM}}}{\frac{\pi}{4} \text{ sq mils}} \right] \left[\frac{1000 \cancel{\text{mils}}}{1 \text{ in.}} \right] \left[\frac{1000 \cancel{\text{mils}}}{1 \text{ in.}} \right] = \mathbf{1.39 \text{ kA/in.}^2}$$
- c.
$$5 \text{ kA} \left[\frac{1 \text{ in.}^2}{1.39 \cancel{\text{kA}}} \right] = \mathbf{3.6 \text{ in.}^2}$$

$$19. \quad \frac{234.5 + 10}{2 \, \Omega} = \frac{234.5 + 80}{R_2}, \quad R_2 = \frac{(314.5)(2 \, \Omega)}{244.5} = \mathbf{2.57 \, \Omega}$$

$$20. \quad \frac{236 + 0}{0.02 \, \Omega} = \frac{236 + 100}{R_2}$$

$$R_2 = \frac{(0.02 \, \Omega)(336)}{236} = \mathbf{0.028 \, \Omega}$$

$$21. \quad C = \frac{5}{9}(\text{°F} - 32) = \frac{5}{9}(32 - 32) = 0^\circ (=32^\circ\text{F})$$

$$C = \frac{5}{9}(68 - 32) = 20^\circ (=68^\circ\text{F})$$

$$\frac{234.5^\circ + 20^\circ}{4 \, \Omega} = \frac{234.5^\circ + 0^\circ}{R_2}$$

$$R_2 = \frac{(234.5)(4 \, \Omega)}{254.5} = \mathbf{3.69 \, \Omega}$$

$$22. \quad \text{a.} \quad \text{°C} = \frac{5}{9}(\text{°F} - 32^\circ) = \frac{5}{9}(70^\circ - 32^\circ) = 21.11^\circ$$

$$\text{°C} = \frac{5}{9}(60^\circ - 32^\circ) = 15.56^\circ$$

$$\frac{234.5 + 21.11}{0.025 \, \Omega} = \frac{234.5 + 15.56}{R_2}$$

$$R_2 = \frac{(250.06)(0.025 \, \Omega)}{255.61} = \mathbf{24.46 \, m\Omega}$$

$$\text{b.} \quad \text{°C} = \frac{5}{9}(50^\circ - 32^\circ) = 10^\circ$$

$$\frac{234.5 + 21.11}{0.025 \, \Omega} = \frac{234.5 + 10}{R_2}$$

$$R_2 = \frac{(244.5)(0.025 \, \Omega)}{255.61} = \mathbf{23.91 \, m\Omega}$$

$$\text{c.} \quad \text{Part a: } 25 \, m\Omega - 24.46 \, m\Omega = 0.54 \, m\Omega$$

$$\text{Part b: } 24.45 \, m\Omega - 23.91 \, m\Omega = 0.55 \, m\Omega$$

$$\mathbf{\text{Linear } 40^\circ\text{F} \Rightarrow 23.91 \, m\Omega - 0.55 \, m\Omega = 23.36 \, m\Omega}$$

$$\text{d.} \quad \text{°C} = \frac{5}{9}(-30^\circ - 32^\circ) = -34.44^\circ$$

$$\frac{234.5 + 21.11}{25 \, m\Omega} = \frac{234.5 - 34.44}{R_2}$$

$$R_2 = \frac{(25 \, m\Omega)(200.06)}{255.61} = \mathbf{19.57 \, m\Omega}$$

$$\mathbf{\text{Yes, } 25 \, m\Omega - 19.57 \, m\Omega = 5.43 \, m\Omega}$$

$$e. \quad ^\circ\text{C} = \frac{5}{9}(120^\circ - 32^\circ) = 48.89^\circ$$

$$\frac{234.5 + 21.11}{25 \text{ m}\Omega} = \frac{234.5 + 48.89}{R_2}$$

$$R_2 = \frac{(25 \text{ m}\Omega)(283.39)}{255.61} = \mathbf{27.72 \text{ m}\Omega}$$

Yes, 2.72 mΩ

$$23. \quad a. \quad \frac{234.5 + 4}{1 \text{ }\Omega} = \frac{234.5 + t_2}{1.1 \text{ }\Omega}, \quad t_2 = \mathbf{27.85^\circ\text{C}}$$

$$b. \quad \frac{234.5 + 4}{1 \text{ }\Omega} = \frac{234.5 + t_2}{0.1 \text{ }\Omega}, \quad t_2 = \mathbf{-210.65^\circ\text{C}}$$

$$24. \quad a. \quad \begin{aligned} 68^\circ\text{F} &= 20^\circ\text{C} \\ \frac{234.5 + 20}{1 \text{ }\Omega} &= \frac{234.5 + T_2}{2 \text{ }\Omega} \\ \frac{2(254.5)}{1} - 234.5 &= T_2 \\ T_2 &= \mathbf{274.5^\circ\text{C}} \end{aligned}$$

$$b. \quad \#10 = \mathbf{0.9989 \text{ }\Omega/1000'}$$

$$c. \quad \begin{aligned} d_{\text{mils}} &= \sqrt{A_{\text{CM}}} = \sqrt{10,381 \text{ CM}} = 101.89 \text{ mils} \\ d_{\text{in}} &= 0.102 \text{ in} \cong \frac{\mathbf{1}}{\mathbf{10}}'' \end{aligned}$$

$$25. \quad a. \quad \alpha_{20} = \frac{1}{|T_i| + 20^\circ\text{C}} = \frac{1}{234.5 + 20} = \frac{1}{254.5} = 0.003929 \cong \mathbf{0.00393}$$

$$b. \quad \begin{aligned} R &= R_{20}[1 + \alpha_{20}(t - 20^\circ\text{C})] \\ 1 \text{ }\Omega &= 0.8 \text{ }\Omega[1 + 0.00393(t - 20^\circ)] \\ 1.25 &= 1 + 0.00393t - 0.0786 \\ 1.25 - 0.9214 &= 0.00393t \\ 0.3286 &= 0.00393t \\ t &= \frac{0.3286}{0.00393} = \mathbf{83.61^\circ\text{C}} \end{aligned}$$

$$26. \quad \begin{aligned} R &= R_{20}[1 + \alpha_{20}(t - 20^\circ\text{C})] \\ &= 0.4 \text{ }\Omega[1 + 0.00393(16 - 20)] = 0.4 \text{ }\Omega[1 - 0.01572] = \mathbf{0.39 \text{ }\Omega} \end{aligned}$$

- Table: $1000'$ of #12 copper wire = 1.588Ω @ 20°C
 $C^\circ = \frac{5}{9}(F^\circ - 32) = \frac{5}{9}(115 - 32) = 46.11^\circ\text{C}$
 $R = R_{20}[1 + \alpha_{20}(t - 20^\circ\text{C})]$
 $= 1.588 \Omega[1 + 0.00393(46.11 - 20)]$
 $= 1.75 \Omega$

28. $\Delta R = \frac{R_{\text{nominal}}}{10^6}(\text{PPM})(\Delta T) = \frac{22 \Omega}{10^6}(200)(65^\circ - 20^\circ) = 0.198 \Omega$
 $R = R_{\text{nominal}} + \Delta R =$ **22.198Ω**

29. $\Delta R = \frac{R_{\text{nominal}}}{10^6}(\text{PPM})(\Delta T) = \frac{100 \Omega}{10^6}(100)(50^\circ - 20^\circ) = 0.30 \Omega$
 $R = R_{\text{nominal}} + \Delta R = 100 \Omega + 0.30 \Omega =$ **100.30Ω**

30. a. 2 times largerb. 4 times larger

31. $10 \text{ k}\Omega - 3.5 \text{ k}\Omega =$ **$6.5 \text{ k}\Omega$**

32. **$6.25 \text{ k}\Omega$ and $18.75 \text{ k}\Omega$**

33. —

34. a. $820 \Omega \pm 5\%$, $820 \Omega \pm 41 \Omega$, **$779 \Omega \leftrightarrow 861 \Omega$**
 b. $220 \Omega \pm 10\%$, $220 \Omega \pm 22 \Omega$, **$198 \Omega \leftrightarrow 242 \Omega$**
 c. $91 \text{ k}\Omega \pm 20\%$, $91 \text{ k}\Omega \pm 18.2 \text{ k}\Omega$, **$77.8 \text{ k}\Omega \leftrightarrow 109.2 \text{ k}\Omega$**
 d. $9.1 \text{ k}\Omega \pm 5\%$, $9100 \Omega \pm 455 \Omega$, **$8,645 \Omega \leftrightarrow 9,555 \text{ k}\Omega$**
 e. $3.9 \text{ M}\Omega \pm 20\%$, $3.9 \text{ M}\Omega \pm 0.78 \text{ M}\Omega$, **$3.12 \text{ M}\Omega \leftrightarrow 4.68 \text{ M}\Omega$**

35. a. $68 \Omega =$ **Blue, Gray, Black, Silver**
 b. $0.33 \Omega =$ **Orange, Orange, Silver, Silver**
 c. $22 \text{ k}\Omega =$ **Red, Red, Orange, Silver**
 d. $5.6 \text{ M}\Omega =$ **Green, Blue, Green, Silver**

36.	a.	$10 \Omega \pm 20\%$	8	12	no overlap, continuance
		$15 \Omega \pm 20\%$	12	18	
	b.	$10 \Omega \pm 10\%$	9	11	no overlap
		$15 \Omega \pm 10\%$	13.5	16.5	

37. $470 \Omega \pm 10\% = 470 \Omega \pm 47 \Omega$
 = **$423 \Omega \leftrightarrow 517 \Omega$**
 Yes

38. No change

39. a. $621 = 62 \times 10^1 \Omega = 620 \Omega = \mathbf{0.62 \text{ k}\Omega}$
 b. $333 = 33 \times 10^3 \Omega = \mathbf{33 \text{ k}\Omega}$
 c. $Q2 = 3.9 \times 10^2 \Omega = \mathbf{390 \Omega}$
 d. $C6 = 1.2 \times 10^6 \Omega = \mathbf{1.2 \text{ M}\Omega}$
40. a. $G = \frac{1}{R} = \frac{1}{120 \Omega} = \mathbf{8.33 \text{ mS}}$
 b. $G = \frac{1}{4 \text{ k}\Omega} = \mathbf{0.25 \text{ mS}}$
 c. $G = \frac{1}{2.2 \text{ M}\Omega} = \mathbf{0.46 \mu\text{S}}$
 $G_a > G_b > G_c$ vs. $R_c > R_b > R_a$
41. a. Table 3.2, $\Omega/1000' = 1.588 \Omega$
 $G = \frac{1}{R} = \frac{1}{1.588 \Omega} = \mathbf{629.72 \text{ mS}}$
 or $G = \frac{A}{\rho l} = \frac{6529.9 \text{ CM (Table 3.2)}}{(10.37)(1000')} = \mathbf{629.69 \text{ mS (Cu)}}$
 b. $G = \frac{6529.9 \text{ CM}}{(17)(1000')} = \mathbf{384.11 \text{ mS (Al)}}$
42. a. $G_1 = \frac{1}{10 \Omega} = 100 \text{ mS}$, $G_2 = \frac{1}{20 \Omega} = 50 \text{ mS}$, $G_3 = \frac{1}{100 \Omega} = 10 \text{ mS}$
 b. $G_2:G_1 = 50 \text{ mS}: 100 \text{ mS} = 1:2$ whereas $R_2:R_1 = 20 \Omega:10 \Omega = 2:1$. The rate of change is the same although one is increasing and the other decreasing.
 c. inverse – linear
43. $A_2 = 1\frac{2}{3} A_1 = \frac{5}{3} A_1$, $l_2 = \left(1 - \frac{2}{3}\right)l_1 = \frac{l_1}{3}$, $\rho_2 = \rho_1$

$$\frac{G_1}{G_2} = \frac{\rho_1 \frac{A_1}{l_1}}{\rho_2 \frac{A_2}{l_2}} = \frac{\cancel{\rho_2} l_2 A_1}{\cancel{\rho_1} l_1 A_2} = \frac{\left(\frac{l_1}{3}\right) A_1}{l_1 \left(\frac{5}{3} A_1\right)} = \frac{1}{5}$$

$$G_2 = 5G_1 = 5(100 \text{ S}) = \mathbf{500 \text{ S}}$$
44. –
45. –
46. –

47. —

$$48. \quad \frac{1}{12} \text{ in.} = 0.083 \cancel{\text{in.}} \left(\frac{2.54 \text{ cm}}{1 \cancel{\text{in.}}} \right) = 0.21 \text{ cm}$$

$$A = \frac{\pi d^2}{4} = \frac{(3.14)(0.21 \text{ cm})^2}{4} = 0.035 \text{ cm}^2$$

$$l = \frac{RA}{\rho} = \frac{(2 \Omega)(0.035 \text{ cm}^2)}{1.724 \times 10^{-6}} = 40,603 \text{ cm} = \mathbf{406.03 \text{ m}}$$

$$49. \quad \text{a.} \quad \frac{1''}{2} \left[\frac{2.54 \text{ cm}}{1''} \right] = 1.27 \text{ cm}, \quad 3 \cancel{\text{in.}} \left[\frac{2.54 \text{ cm}}{1 \cancel{\text{in.}}} \right] = 7.62 \text{ cm}$$

$$4 \cancel{\text{ft}} \left[\frac{12 \cancel{\text{in.}}}{1 \cancel{\text{ft}}} \right] \left[\frac{2.54 \text{ cm}}{1 \cancel{\text{in.}}} \right] = 121.92 \text{ cm}$$

$$R = \rho \frac{l}{A} = \frac{(1.724 \times 10^{-6})(121.92 \text{ cm})}{(1.27 \text{ cm})(7.62 \text{ cm})} = \mathbf{21.71 \mu\Omega}$$

$$\text{b.} \quad R = \rho \frac{\ell}{A} = \frac{(2.825 \times 10^{-6})(121.92 \text{ cm})}{(1.27 \text{ cm})(7.62 \text{ cm})} = \mathbf{35.59 \mu\Omega}$$

c. increases

d. decreases

$$50. \quad R_s = \frac{\rho}{d} = 100 \Rightarrow d = \frac{\rho}{100} = \frac{250 \times 10^{-6}}{100} = \mathbf{2.5 \mu\text{cm}}$$

$$51. \quad R = R_s \frac{l}{w} \Rightarrow w = \frac{R_s l}{R} = \frac{(150 \Omega)(1/2 \text{ in.})}{500 \Omega} = \mathbf{0.15 \text{ in.}}$$

$$52. \quad \text{a.} \quad d = 1 \text{ in.} = 1000 \text{ mils}$$

$$A_{\text{CM}} = (10^3 \text{ mils})^2 = 10^6 \text{ CM}$$

$$\rho_1 = \frac{RA}{l} = \frac{(1 \text{ m}\Omega)(10^6 \text{ CM})}{10^3 \text{ ft}} = \mathbf{1 \text{ CM-}\Omega/\text{ft}}$$

$$\text{b.} \quad 1 \text{ in.} = 2.54 \text{ cm}$$

$$A = \frac{\pi d^2}{4} = \frac{\pi(2.54 \text{ cm})^2}{4} = 5.067 \text{ cm}^2$$

$$l = 1000 \text{ ft} \left[\frac{12 \text{ in.}}{1 \text{ ft}} \right] \left[\frac{2.54 \text{ cm}}{1 \text{ in.}} \right] = 30,480 \text{ cm}$$

$$\rho_2 = \frac{RA}{l} = \frac{(1 \text{ m}\Omega)(5.067 \text{ cm}^2)}{30,480 \text{ cm}} = \mathbf{1.66 \times 10^{-7} \Omega\text{-cm}}$$

c. $k = \frac{\rho_2}{\rho_1} = \frac{1.66 \times 10^{-7} \Omega\text{-cm}}{1 \text{ CM-}\Omega/\text{ft}} = 1.66 \times 10^{-7}$

53. —

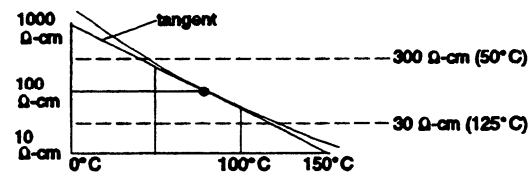
54. —

55. —

56. —

57. —

58. a. -50°C specific resistance $\cong 10^5 \Omega\text{-cm}$
 50°C specific resistance $\cong 500 \Omega\text{-cm}$
 200°C specific resistance $\cong 7 \Omega\text{-cm}$



b. negative

c. No

d. $\rho = \frac{\Delta\Omega\text{-cm}}{\Delta T} = \frac{300 - 30}{125 - 50} = \frac{270 \Omega\text{-cm}}{75^\circ\text{C}} \cong 3.6 \Omega\text{-cm}/^\circ\text{C}$

59. a. Log scale: $10 \text{ fc} \Rightarrow 3 \text{ k}\Omega$
 $100 \text{ fc} \Rightarrow 0.4 \text{ k}\Omega$

b. negative

c. no—log scales imply linearity

d. $1 \text{ k}\Omega \Rightarrow \cong 30 \text{ fc}$
 $10 \text{ k}\Omega \Rightarrow \cong 2 \text{ fc}$
 $\left| \frac{\Delta R}{\Delta \text{fc}} \right| = \frac{10 \text{ k}\Omega - 1 \text{ k}\Omega}{30 \text{ fc} - 2 \text{ fc}} = 321.43 \Omega/\text{fc}$
 and $\frac{\Delta R}{\Delta \text{fc}} = -321.43 \Omega/\text{fc}$

60. a. @ 0.5 mA , $V \cong 195 \text{ V}$
 @ 1 mA , $V \cong 200 \text{ V}$
 @ 5 mA , $V \cong 215 \text{ V}$

b. $\Delta V_{\text{total}} = 215 \text{ V} - 195 \text{ V} = 20 \text{ V}$

- c. $5 \text{ mA} : 0.5 \text{ mA} = 10:1$
 compared to
 $215 \text{ V} : 200 \text{ V} = 1.08:1$