# Chapter 3

1. a. 0.2 in. = **200 mils**

   b. $\frac{1}{32}$ in. = 0.03152 in. = **31.52 mils**

   c. $\frac{1}{4}$ in. = $0.25\ \not{\text{in.}}\left[\frac{1000\text{ mils}}{1\ \not{\text{in.}}}\right]$ = **250 mils**

   d. $10\text{ mm} = 10 \times 10^{-3}\ \not{\text{m}}\left[\frac{39.37\text{ in}}{1\ \not{\text{m}}}\right]\left[\frac{1000\text{ mils}}{1\text{ in}}\right]$ = **393.7 mils**

   e. $0.01\ \not{\text{ft}}\left[\frac{12\ \not{\text{in.}}}{1\ \not{\text{ft}}}\right]\left[\frac{10^3\text{ mils}}{1\ \not{\text{in.}}}\right]$ = **120 mils**

   f. $1\ \not{\text{m}}\left[\frac{39.37\text{ in.}}{1\ \not{\text{m}}}\right]$ = 39.37 in. = $\mathbf{39.37 \times 10^3}$ **mils**

2. a. $A_{CM} = (30\text{ mils})^2$ = **900 CM**

   b. 0.08 in. = 80 mils, $A_{CM} = (80\text{ mils})^2$ = $\mathbf{6.4 \times 10^3}$ **CM**

   c. $\left[\frac{1''}{16}\right]$ = 0.0625 in. = 62.5 mils, $A_{CM} = (62.5\text{ mils})^2$ = $\mathbf{3.91 \times 10^3}$ **CM**

   d. $2\ \not{\text{cm}}\left[\frac{1\ \not{\text{in.}}}{2.54\ \not{\text{cm}}}\right]\left[\frac{1000\text{ mils}}{1\ \not{\text{in.}}}\right]$ = 787.4 mils, $A_{CM} = (787.4\text{ mils})^2$ = $\mathbf{620 \times 10^3}$ **CM**

   e. $0.02\ \not{\text{ft}}\left[\frac{12\ \not{\text{in.}}}{1\ \not{\text{ft}}}\right]\left[\frac{1000\text{ mils}}{1\ \not{\text{in.}}}\right]$ = 240 mils, $A_{CM} = (240\text{ mils})^2$ = $\mathbf{57.60 \times 10^3}$ **CM**

   f. $4 \times 10^{-3}\ \not{\text{m}}\left[\frac{39.37\ \not{\text{in.}}}{1\ \not{\text{m}}}\right]\left[\frac{1000\text{ mils}}{1\ \not{\text{in}}}\right]$ = **157.48 mils**, $A_{CM} = (157.48\text{ mils})^2$ = $\mathbf{24.8 \times 10^3}$ **CM**

3. $A_{CM} = (d_{mils})^2 \rightarrow d_{mils} = \sqrt{A_{CM}}$

   a. $d = \sqrt{1600\text{ CM}}$ = 40 mils = **0.04 in.**

   b. $d = \sqrt{640\text{ CM}}$ = 25.3 mils = $\mathbf{25.3 \times 10^{-3}}$ **in.**

   c. $d = \sqrt{40{,}000\text{ CM}}$ = 200 mils = **0.2 in.**

d. $d = \sqrt{2400 \text{ CM}} = 48.99 \text{ mils} = \mathbf{48.99 \times 10^{-3} \text{ in.}}$

e. $d = \sqrt{6.25 \text{ CM}} = 2.5 \text{ mils} = \mathbf{0.0025 \text{ in.}}$

f. $d = \sqrt{4 \times 10^3 \text{ CM}} = 63.25 \text{ mils} = \mathbf{63.25 \times 10^{-3} \text{ in.}}$

4. $0.016'' = 16 \text{ mils}, A_{CM} = (16 \text{ mils})^2 = 256 \text{ CM}$

$$R = \rho \frac{l}{A} = (10.37) \frac{(200')}{256 \text{ CM}} = \mathbf{8.10\ \Omega}$$

5. a. $A = \rho \frac{l}{R} = 17\left(\frac{80'}{2.5\ \Omega}\right) = \mathbf{544 \text{ CM}}$

b. $d = \sqrt{A_{CM}} = \sqrt{544 \text{ CM}} = 23.32 \text{ mils} = \mathbf{23.3 \times 10^{-3} \text{ in.}}$

6. $\frac{1}{32}'' = 0.03125'' = 31.25 \text{ mils}, A_{CM} = (31.25 \text{ mils})^2 = 976.56 \text{ CM}$

$$R = \rho \frac{l}{A} \Rightarrow l = \frac{RA}{\Omega} = \frac{(2.2\ \Omega)(976.56 \text{ CM})}{600} = \mathbf{3.58 \text{ ft}}$$

7. a. $A_{CM} = \rho \frac{l}{A} = \frac{(10.37)(300')}{3.3\ \Omega} = \mathbf{942.73 \text{ CM}}$

$d = \sqrt{942.73 \text{ CM}} = 30.70 \text{ mils} = \mathbf{30.7 \times 10^{-3} \text{ in.}}$

b. larger

c. smaller

8. $\rho = \frac{RA}{l} = \frac{(500\ \Omega)(94 \text{ CM})}{1000'} = 47 \Rightarrow$ **nickel**

9. a. $1/32'' = 0.03125'' = 31.25 \text{ mils}, A_{CM} = (31.25 \text{ mils})^2 = 976.56 \text{ CM}$

$$R = \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho} = \frac{(3.14\ \Omega)(976.56 \text{ CM})}{10.37} = \mathbf{295.7 \text{ ft}}$$

b. $\frac{295.7'}{x} = \frac{1000'}{5 \text{ lb}} \Rightarrow x = \frac{(5)(295.7)}{1000} = \mathbf{1.48 \text{ lbs}}$

c. $-40° \text{ C}: F = \frac{9}{5}C + 32° = \frac{9}{5}(-40) + 32 = -40°$

$105° \text{ C}: F = \frac{9}{5}C = 32° = \frac{9}{5}(105) + 32 = 221°$

$\mathbf{F° = -40° \rightarrow 221°}$

10. a. $\frac{3''}{8} = 0.375'' = 375$ mils

$4.8'' = 4800$ mils

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

b. $\frac{1''}{12} = 0.083$ in. = 83 mils

$A_{CM} = \; = (83 \text{ mils})^2 = 6.89 \times 10^3$ CM

(#12) $\frac{2.29 \times 10^6 \text{ CM}}{6.89 \times 10^3 \text{ CM}} = \mathbf{332.37\ wires}$

11. a. 3" = 3000 mils, 1/2" = 0.5 in. = 500 mils

Area = $(3 \times 10^3 \text{ mils})(5 \times 10^2 \text{ mils}) = 15 \times 10^5$ sq. mils

$15 \times 10^5 \text{ sq mils} \left[\frac{4/\pi \text{ CM}}{1 \text{ sq mil}}\right] = 19.108 \times 10^5$ CM

$R = \rho\frac{l}{A} = \frac{(10.37)(4')}{19.108 \times 10^5 \text{ CM}} = \mathbf{21.71\ \mu\Omega}$

b. $R = \rho\frac{l}{A} = \frac{(17)(4')}{19.108 \times 10^5 \text{ CM}} = \mathbf{35.59\ \mu\Omega}$

Aluminum bus-bar has almost 64% higher resistance.

c. —

12. $l_2 = 2l_1$, $A_2 = A_1/4$, $\rho_2 = \rho_1$

$$\frac{R_2}{R_1} = \frac{\frac{\rho_2 l_2}{A_2}}{\frac{\rho_1 l_1}{A_1}} = \frac{\rho_2 l_2 A_1}{\rho_1 l_1 A_2} = \frac{2l_1 A_1}{l_1 A_1/4} = 8$$

and $R_2 = 8R_1 = 8(0.2\ \ ) = 1.6$

$\Delta R = 1.6\ \ - 0.2\ \ = \mathbf{1.4}$

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

$d_{mils} = 225.7$ mils

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

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

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

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

$$\frac{6{,}529.9\text{ CM} - 4{,}106.8\text{ CM}}{4{,}106.8\text{ CM}} \times 100\% = \mathbf{59\%\ larger}$$

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

$$\frac{1.59 - 1.33}{1.33} \times 100\% = \mathbf{19.55\%\ higher\ ratio\ for\ area}$$

15. a. $\frac{\#9}{\#12} = \frac{13{,}094\text{ CM}}{6{,}529.9\text{ CM}} = \mathbf{2}$ **yes**

b. $\frac{\#0}{\#12} = \frac{105{,}530\text{ CM}}{6{,}529.9\text{ CM}} = \mathbf{16.16}$ **yes**

$\frac{\#0}{\#12} = \frac{150\text{ A}}{20\text{ A}} = \mathbf{7.5}$

16. a. $\frac{\#10}{\#20} = \frac{10{,}381\text{ CM}}{1{,}021.5\text{ CM}} = 10.16 \cong \mathbf{10}$ **yes**

b. $\frac{\#20}{\#40} = \frac{1{,}021.5\text{ CM}}{9.89\text{ CM}} = 103.28$

**yes** $\cong$ **100**

17. a. $A = \rho\frac{l}{R} = \frac{(10.37)(30')}{6\text{ m}\Omega} = \frac{311.1\text{ CM}}{6\times10^{-3}} = 51{,}850\text{ CM} \Rightarrow \#3$

but 110 A $\Rightarrow$ **#2**

b. $A = \rho\frac{l}{R} = \frac{(10.37)(30')}{3\text{ m}\Omega} = \frac{311.1\text{ CM}}{3\times10^{-3}} = 103{,}700\text{ CM} \Rightarrow$ **#0**

18. a. A/CM = 230 A/211,600 CM = **1.09 mA/CM**

b. $\frac{1.09\text{ mA}}{\text{CM}}\left[\frac{1\text{ CM}}{\frac{\pi}{4}\text{ sq mils}}\right]\left[\frac{1000\text{ mils}}{1\text{ in.}}\right]\left[\frac{1000\text{ mils}}{1\text{ in.}}\right] = \mathbf{1.39\ kA/in.^2}$

c. $5\text{ kA}\left[\frac{1\text{ in.}^2}{1.39\text{ kA}}\right] = \mathbf{3.6\ in.^2}$

19. $\dfrac{234.5+20}{2\ \Omega} = \dfrac{234.5+100}{R_2}$, $R_2 = \dfrac{(334.5)(2\ \Omega)}{254.5} = \mathbf{2.63\ \Omega}$

20. $\dfrac{236+0}{0.02\ \Omega} = \dfrac{236+100}{R_2}$

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

21. $C = \dfrac{5}{9}(°F-32) = \dfrac{5}{9}(32-32) = 0°$ (=32°F)

$C = \dfrac{5}{9}(68-32) = 20°$ (=68°F)

$\dfrac{234.5° + 20°}{1.2\ \Omega} = \dfrac{234.5° + 0°}{R_2}$

$R_2 = \dfrac{(234.5)(1.2\ \Omega)}{254.5} = \mathbf{1.11\ \Omega}$

22. a. $°C = \dfrac{5}{9}(°F - 32°) = \dfrac{5}{9}(70° - 32°) = 21.11°$

$°C = \dfrac{5}{9}(60° - 32°) = 15.56°$

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

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

b. $°C = \dfrac{5}{9}(50° - 32°) = 10°$

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

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

c. Part a: 25 mΩ − 24.46 mΩ = 0.54 mΩ
Part b: 24.45 mΩ − 23.91 mΩ = 0.55 mΩ
**Linear** 40°F ⇒ 23.91 mΩ − 0.55 mΩ = **23.36 mΩ**

d. $°C = \dfrac{5}{9}(-30° - 32°) = -34.44°$

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

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

**Yes**, 25 mΩ − 19.57 mΩ = **5.43 mΩ**

e. $°C = \frac{5}{9}(120° - 32°) = 48.89°$

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

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

**Yes, 2.72 mΩ**

23. a. $\frac{234.5 + 20}{1\ \Omega} = \frac{234.5 + t_2}{1.1\ \Omega}$, $t_2 = \mathbf{45.45°}$

b. $\frac{234.5 + 20}{1\ \Omega} = \frac{234.5 + t_2}{0.1\ \Omega}$, $t_2 = \mathbf{-209.05°}$

24. a. 68°F = 20°C

$$\frac{234.5 + 20}{1\ \Omega} = \frac{234.5 + T_2}{2\ \Omega}$$

$$\frac{2(254.5)}{1} - 234.5 = T_2$$

$T_2 = \mathbf{274.5°C}$

b. #10 = **0.9989 Ω/1000′**

c. 

$d_{in} = 0.102\text{ in} \cong \mathbf{\frac{1}{10}''}$

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

b. $R = R_{20}[1 + \alpha_{20}(t - 20°C)]$

$1\ \Omega = 0.8\ \Omega\ [1 + 0.00393(t - 20°)]$

$1.25 = 1 + 0.00393t - 0.0786$

$1.25 - 0.9214 = 0.00393t$

$0.3286 = 0.00393t$

$t = \frac{0.3286}{0.00393} = \mathbf{83.61°C}$

26. $R = R_{20}[1 + \alpha_{20}(t - 20°C)]$

$= 0.4\ \Omega\ [1 + 0.00393(16 - 20)] = 0.4\ \Omega\ [1 - 0.01572] = \mathbf{0.39\ \Omega}$

27. Table: 1000′ of #12 copper wire = 1.588 Ω @ 20°C

$$C° = \frac{5}{9}(F° - 32) = \frac{5}{9}(115 - 32) = 46.11°C$$

$R = R_{20}[1 + \alpha_{20}(t - 20°C)]$
$= 1.588\ \Omega\ [1 + 0.00393(46.11 - 20)]$
$= \mathbf{1.75\ \Omega}$

28. $\Delta R = \frac{R_{nominal}}{10^6}(PPM)(\Delta T) = \frac{22\ \Omega}{10^6}(200)(65° - 20°) = 0.198\ \Omega$

$R = R_{nominal} + \Delta R = \mathbf{22.198\ \Omega}$

29. $\Delta R = \frac{R_{nominal}}{10^6}(PPM)(\Delta T) = \frac{100\ \Omega}{10^6}(100)(50° - 20°) = 0.30\ \Omega$

$R = R_{nominal} + \Delta R = 100\ \Omega + 0.30\ \Omega = \mathbf{100.30\ \Omega}$

30. a. 2 times larger b. 4 times larger

31. 10 k − 3.5 k = **6.5 kΩ**

32. **6.25 kΩ** and **18.75 kΩ**

33. –

34. a. 820 Ω ± 5%, 820 Ω ± 41 Ω, **779 Ω ↔ 861 Ω**
b. 220 Ω ± 10%, 220 Ω ± 22 Ω, **198 Ω ↔ 242 Ω**
c. 91 kΩ ± 20%, 91 kΩ ± 18.2 kΩ, **77.8 kΩ ↔ 109.2 kΩ**
d. 9.1 kΩ ± 5%, 9100 Ω ± 455 Ω, **8,645 Ω ↔ 9,555 kΩ**
e. 3.9 MΩ ± 20%, 3.9 MΩ ± 0.78 MΩ, **3.12 MΩ ↔ 4.68 MΩ**

35. a. 68 Ω = **Blue, Gray, Black, Silver**
b. 0.33 Ω = **Orange, Orange, Silver, Silver**
c. 22 kΩ = **Red, Red, Orange, Silver**
d. 5.6 MΩ = **Green, Blue, Green, Silver**

36. a. 10 Ω ± 20% ⇒ 8 Ω − 12 Ω
15 Ω ± 20% ⇒ 12 Ω − 18 Ω } no overlap, continuance

b. 10 Ω ± 10% ⇒ 9 Ω − 11 Ω
15 Ω ± 10% ⇒ 13.5 Ω − 16.5 Ω } no overlap

37. 470 Ω ± 10% = 470 Ω ± 47 Ω
= **423 Ω ↔ 517 Ω**
**Yes**

38. **No change**

39. a. $621 = 62 \times 10^1\ \Omega = 620\ \Omega =$ **0.62 kΩ**
b. $333 = 33 \times 10^3\ \Omega =$ **33 kΩ**
c. $Q2 = 3.9 \times 10^2\ \Omega =$ **390 Ω**
d. $C6 = 1.2 \times 10^6\ \Omega =$ **1.2 MΩ**

40. a. $G = \frac{1}{R} = \frac{1}{120\ \Omega} =$ **8.33 mS**

b. $G = \frac{1}{4\ \text{k}\Omega} =$ **0.25 mS**

c. $G = \frac{1}{2.2\ \text{M}\Omega} =$ **0.46 μS**

$G_a > G_b > G_c$ vs. $R_c > R_b > R_a$

41. a. Table 3.2, Ω/1000′ = 1.588 Ω

$G = \frac{1}{R} = \frac{1}{1.588\ \Omega} =$ **629.72 mS**

or $G = \frac{A}{\rho l} = \frac{6529.9\ \text{CM (Table 3.2)}}{(10.37)(1000')} =$ **629.69 mS** (Cu)

b. $G = \frac{6529.9\ \text{CM}}{(17)(1000')} =$ **384.11 mS** (Al)

42. a. $G_1 = \frac{1}{10\ \Omega} = 100$ mS, $G_2 = \frac{1}{20\ \Omega} = 50$ mS, $G_3 = \frac{1}{100\ \Omega} = 10$ mS

b. $G_2{:}G_1 = 50$ mS: 100 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. $A_2 = 1\frac{2}{3}\ A_1 = \frac{5}{3}\ A_1$, $l_2 = \left(1 - \frac{2}{3}\right)l_1 = \frac{l_1}{3}$, $\rho_2 = \rho_1$

$$\frac{G_1}{G_2} = \frac{\rho_1 \frac{A_1}{l_1}}{\rho_2 \frac{A_2}{l_2}} = \frac{\not\rho_2 l_2 A_1}{\not\rho_1 l_1 A_2} = \frac{\left(\frac{l_1}{3}\right)A_1}{l_1\left(\frac{5}{3}A_1\right)} = \frac{1}{5}$$

$G_2 = 5G_1 = 5(100\ \text{S}) =$ **500 S**

44. –

45. –

46. –

47. –

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

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

$$l = \frac{RA}{\rho} = \frac{(2\ \Omega)(0.035\text{ cm}^2)}{1.724\times10^{-6}} = 40{,}603\text{ cm} = \mathbf{406.03\ m}$$

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

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

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

b. $$R = \rho\frac{\ell}{A} = \frac{(2.825\times10^{-6})(121.92\text{ cm})}{(1.27\text{ cm})(7.62\text{ cm})} = \mathbf{35.59\ \mu\Omega}$$

c. increases

d. decreases

50. $$R_s = \frac{\rho}{d} = 100 \Rightarrow d = \frac{\rho}{100} = \frac{250\times10^{-6}}{100} = \mathbf{2.5\ \mu cm}$$

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

52. a. $d = 1$ in. $= 1000$ mils

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

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

b. 1 in. = 2.54 cm

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

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

$$\rho_2 = \frac{RA}{l} = \frac{(1\text{ m}\Omega)(5.067\text{ cm}^2)}{30{,}480\text{ cm}} = \mathbf{1.66\times10^{-7}\ \Omega\text{-cm}}$$

c. $k = \dfrac{\rho_2}{\rho_1} = \dfrac{1.66\times10^{-7}\ \Omega\text{-cm}}{1\ \text{CM-}\Omega/\text{ft}} = \mathbf{1.66 \times 10^{-7}}$

53. –

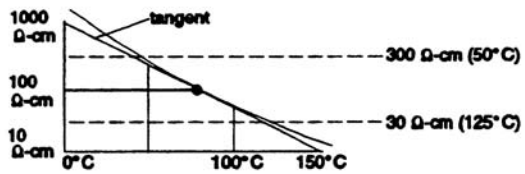
54. –

55. –

56. –

57. –

58. a. $-50°$C specific resistance ≅ $10^5$ Ω-cm
50°C specific resistance ≅ 500 Ω-cm
200°C specific resistance ≅ 7 Ω-cm




b. negative

c. No

d. $\rho = \dfrac{\Delta\Omega - \text{cm}}{\Delta T} = \dfrac{300-30}{125-50} = \dfrac{270\ \Omega - \text{cm}}{75°\ \text{C}} \cong$ **3.6 Ω-cm/°C**

59. a. Log scale: 10 fc ⇒ **3 kΩ**
100 fc ⇒ **0.4 kΩ**

b. negative

c. no—log scales imply linearity

d. 1 kΩ ⇒ ≅ 30 fc
10 kΩ ⇒ ≅ 2 fc
$\left|\dfrac{\Delta R}{\Delta fc}\right| = \dfrac{10\ \text{k}\Omega - 1\text{k}}{30\ \text{fc} - 2\ \text{fc}} = 321.43\ \Omega/\text{fc}$

and $\dfrac{\Delta R}{\Delta \text{fc}} = \mathbf{-321.43\ \Omega/fc}$

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

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

c. 5 mA:0.5 mA = **10:1**
compared to
215 V: 200 V = **1.08:1**