Chapter 3

1. a. 0.5 in. = **500 mils**

b. $0.02\ \text{in.}\left[\dfrac{1000\ \text{mils}}{1\ \text{in.}}\right] = \mathbf{20\ mils}$

c. $\dfrac{1}{4}\ \text{in.} = 0.25\ \text{in.}\left[\dfrac{1000\ \text{mils}}{1\ \text{in.}}\right] = \mathbf{250\ mils}$

d. $10\ \text{mm} = 10 \times 10^{-3}\ \text{m}\left[\dfrac{39.37\ \text{in}}{1\ \text{m}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \text{in}}\right] = \mathbf{393.7\ mils}$

e. $0.01\ \text{ft}\left[\dfrac{12\ \text{in.}}{1\ \text{ft}}\right]\left[\dfrac{10^3\ \text{mils}}{1\ \text{in.}}\right] = \mathbf{120\ mils}$

f. $0.1\ \text{cm}\left[\dfrac{1\ \text{in.}}{2.54\ \text{cm}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \text{in.}}\right] = \mathbf{39.37\ mils}$

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

b. 0.016 in. = 16 mils, $A_{CM} = (16\ \text{mils})^2 = \mathbf{256\ CM}$

c. $\dfrac{1}{8}'' = 0.125'' = 125\ \text{mils},\ A_{CM} = (125\ \text{mils})^2 = \mathbf{15.63 \times 10^3\ CM}$

d. $1\ \text{cm}\left[\dfrac{1\ \text{in.}}{2.54\ \text{cm}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \text{in.}}\right] = 393.7\ \text{mils},\ A_{CM} = (393.7\ \text{mils})^2 = \mathbf{155 \times 10^3\ CM}$

e. $0.02\ \text{ft}\left[\dfrac{12\ \text{in.}}{1\ \text{ft}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \text{in.}}\right] = 240\ \text{mils},\ A_{CM} = (240\ \text{mils})^2 = \mathbf{57.60 \times 10^3\ CM}$

f. $4 \times 10^{-3}\ \text{m}\left[\dfrac{39.37\ \text{in.}}{1\ \text{m}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \text{in}}\right] = \mathbf{157.48\ mils},\ A_{CM} = (157.48\ \text{mils})^2 = \mathbf{24.8 \times 10^3\ CM}$

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

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

b. $d = \sqrt{820\ \text{CM}} = 28.64\ \text{mils} = \mathbf{0.029\ in.}$

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

d. $d = \sqrt{625\,\text{CM}}$ = 25 mils = **0.025 in.**

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

f. $d = \sqrt{3 \times 10^3\ \text{CM}}$ = 54.77 mils = **0.055 in.**

4. 0.02 in. = 20 mils, A_{CM} = (20 mils)^2 = 400 CM

$R = \rho\dfrac{l}{A} = (10.37)\dfrac{(200')}{400\ \text{CM}}$ = **5.19 Ω**

5. a. $A = \rho\dfrac{l}{R} = 17\left(\dfrac{80'}{2.5\,\Omega}\right)$ = **544 CM**

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

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

$R = \rho\dfrac{l}{R} \Rightarrow l = \dfrac{RA}{\rho} = \dfrac{(2.2\ \Omega)(976.56\,\text{CM})}{600}$ = **3.58 ft**

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

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

b. larger

c. smaller

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

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

$R = \dfrac{\rho l}{A} \Rightarrow l = \dfrac{RA}{\rho} = \dfrac{(3.12\ \Omega)(976.56\ \text{CM})}{10.37}$ = **293.82 ft**

b. $\dfrac{293.82'}{x} = \dfrac{1000'}{5\ \text{lb}} \Rightarrow x = \dfrac{(5)(293.82)}{1000}$ = **1.47 lbs**

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

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

F° = −40° → 221°

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

$4.8'' = 4800$ mils

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

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

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

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

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

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

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

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.

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

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

13. $A = \frac{\pi d^2}{4} \Rightarrow d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4(0.04 \text{ in.}^2)}{\pi}} = 0.2257$ 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. $A = \rho\frac{l}{R} = \frac{(10.37)(30')}{3\text{ m}\Omega} = \frac{311.1\text{ CM}}{3\times10^{-3}} = 103{,}700\text{ CM} \Rightarrow \mathbf{\#0}$

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

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

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

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

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

$R_2 = \frac{(0.02\ \Omega)(336)}{236}$ = **0.028 Ω**

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

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

$\frac{234.5°+20°}{4\ \Omega} = \frac{234.5°+0°}{R_2}$

$R_2 = \frac{(234.5)(4\ \Omega)}{254.5}$ = **3.69 Ω**

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

$°C = \frac{5}{9}(60°-32°)$ = 15.56°

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

$R_2 = \frac{(250.06)(0.025\ \Omega)}{255.61}$ = **24.46 mΩ**

b. $°C = \frac{5}{9}(50°-32°) = 10°$

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

$R_2 = \frac{(244.5)(0.025\ \Omega)}{255.61}$ = **23.91 mΩ**

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

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

$R_2 = \frac{(25\ \text{m}\Omega)(200.06)}{255.61}$ = **19.57 mΩ**

Yes, 25 mΩ – 19.57 mΩ = **5.43 mΩ**

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

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

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

Yes, 2.72 mΩ

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

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

24. a. $68°\text{F} = 20°\text{C}$

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

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

$$T_2 = \mathbf{274.5°C}$$

b. #10 = **0.9989 Ω/1000′**

c. $d_{\text{mils}} = \sqrt{A_{\text{CM}}} = \sqrt{10{,}381\text{ CM}} = 101.89\text{ mils}$

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

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

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

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

$1.25 = 1 + 0.00393t - 0.0786$

$1.25 - 0.9214 = 0.00393t$

$0.3286 = 0.00393t$

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

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

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

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 kΩ − 3.5 kΩ = **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	12	no overlap, continuance
15 Ω ± 20%	12	18	

b.

10 Ω ± 10%	9	11	no overlap
15 Ω ± 10%	13.5	16.5	

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

38. **No change**

39. a. $621 = 62 \times 10^1\ \Omega = 620\ \Omega = \mathbf{0.62\ k\Omega}$
b. $333 = 33 \times 10^3\ \Omega = \mathbf{33\ k\Omega}$
c. $Q2 = 3.9 \times 10^2\ \Omega = \mathbf{390\ \Omega}$
d. $C6 = 1.2 \times 10^6\ \Omega = \mathbf{1.2\ M\Omega}$

40. a. $G = \dfrac{1}{R} = \dfrac{1}{120\ \Omega} = \mathbf{8.33\ mS}$

b. $G = \dfrac{1}{4\ \text{k}\Omega} = \mathbf{0.25\ mS}$

c. $G = \dfrac{1}{2.2\ \text{M}\Omega} = \mathbf{0.46\ \mu S}$

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

41. a. Table 3.2, Ω/1000′ = 1.588 Ω

$G = \dfrac{1}{R} = \dfrac{1}{1.588\ \Omega} = \mathbf{629.72\ mS}$

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

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

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

b. $G_2{:}G_1$ = 50 mS: 100 mS = 1:2 whereas $R_2{:}R_1$ = 20 Ω:10 Ω = 2:1. The rate of change is the same although one is increasing and the other decreasing.

c. inverse – linear

43. $A_2 = 1\frac{2}{3}\ A_1 = \frac{5}{3}\ A_1$, $l_2 = \left(1 - \frac{2}{3}\right)l_1 = \frac{l_1}{3}$, $\rho_2 = \rho_1$

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

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

44. –

45. –

46. –

47. –

48. $\frac{1}{12}$ in. = 0.083 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. $\frac{1''}{2}\left[\frac{2.54\text{ cm}}{1''}\right] = 1.27 \text{ cm}$, $3 \text{ in.}\left[\frac{2.54\text{ cm}}{1 \text{ in.}}\right] = 7.62 \text{ cm}$

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

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

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

$A_{\text{CM}} = (10^3 \text{ mils})^2 = 10^6$ 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. $k = \dfrac{\rho_2}{\rho_1} = \dfrac{1.66\times10^{-7}\ \Omega\text{-cm}}{1\ \text{CM-}\Omega/\text{ft}} = \mathbf{1.66\times10^{-7}}$

53. –

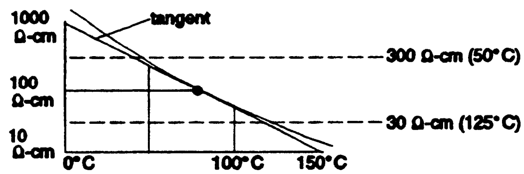
54. –

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

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

and $\dfrac{\Delta R}{\Delta\,\text{fc}}$ = **−321.43 Ω/fc**

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

b. ΔV_{total} = 215 V − 195 V = **20 V**

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