5) (a) WHAT IS THE AREA IN CM OF AN ALUMINUM CONDUCTOR 80 ft LONG WITH $R = 2.5\,\Omega$

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

REARRANGING YIELDS: $A = \rho \cdot \frac{l}{R}$, ASSUMING 20°C:

$$A = \left(\underset{\text{TABLE 3.1}}{17.0\ \text{CM}\cdot\Omega/\text{ft.}}\right)\left(\frac{80\ \text{feet}}{2.5\,\Omega}\right) = \boxed{544\ \text{CM}}$$

(b) WHAT IS ITS DIAMETER IN INCHES?

$$A_{CM} = (d_{MILS})^2 \qquad (3.2)$$

$$\therefore\ d_{MILS} = \sqrt{A_{CM}} = \sqrt{544} = 23.32\ \text{MILS}$$

$$\boxed{23.32 \times 10^{-3}\ \text{INCHES}}$$

(a)

7) WHAT IS THE DIAMETER IN INCHES OF A COPPER WIRE THAT HAS A RESISTANCE OF 3.3Ω & 100YD LONG (AT 20°C)?

$A = \rho\left(\frac{\ell}{R}\right)$ FROM P6, $\rho = 10.37$ CM·Ω/ft AT 20°C FOR Cu (TABLE 3.1)

$$A = \left(10.37\ \frac{CM\cdot\Omega}{ft}\right)\left(\frac{300\ ft}{3.3\Omega}\right) = 942.7\ CM$$

$$d_{MILS} = \sqrt{A_{CM}} = \sqrt{942.7\,CM} = 30.70\ MILS$$

OR

$\boxed{30.70 \times 10^{-3}\ ''}$

(b) WITHOUT CALCULATING: WILL THE AREA OF AN Al WIRE THE SAME LENGTH & RESISTANCE BE SMALLER OR LARGER? EXPLAIN

$\rho = 17.0\ \frac{CM\cdot\Omega}{ft}$ FOR Al

∴ AN ALUMINUM WIRE WOULD BE ABOUT 1.6X $\boxed{\text{LARGER IN AREA}}$

(c) REPEAT (b) FOR A SILVER WIRE:

$\rho = 9.9\ \frac{CM\cdot\Omega}{ft}$ FOR SILVER

∴ A SILVER WIRE WOULD BE ABOUT 0.95X $\boxed{\text{SMALLER IN AREA}}$

8) A WIRE 1000 FEET LONG HAS $R = 0.5\,k\Omega$ & $A = 94$ CM AT 20°C. FIND THE WIRE MATERIAL

$$R = \rho \frac{l}{A} \xrightarrow{\text{REARRANGING}} \rho = R \cdot \frac{A}{l}$$

$$\text{HERE } \rho = \left(0.5\times10^{3}\,\Omega\right)\left(\frac{94\,\text{CM}}{1000\,ft}\right) = \underline{47\,\frac{\text{CM}\cdot\Omega}{ft}}$$

FROM TABLE 3.1, $\rho = 47\,\frac{\text{CM}\cdot\Omega}{ft}$ FOR $\boxed{\text{NICKEL}}$

12) DETERMINE THE INCREASE IN RESISTANCE OF A COPPER CONDUCTOR IF THE AREA IS REDUCED BY 4x & THE LENGTH IS DOUBLED. $R_{ORIGINAL} = 0.2\,\Omega$, $T \Rightarrow$ FIXED

ORIG: $R_1 = \rho_{cu} \frac{L_1}{A_1}$

NEW: $R_2 = \rho_{cu} \frac{L_2}{A_2}$, WHERE $L_2 = 2L_1$, $A_2 = A_1/4$

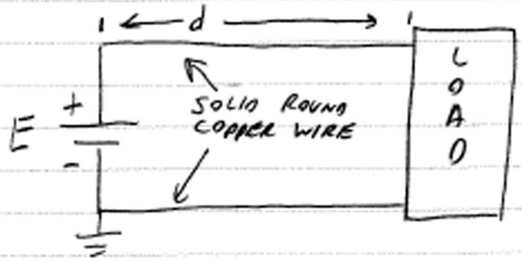
$$\frac{R_2}{R_1} = \frac{\rho_{cu} \frac{L_2}{A_2}}{\rho_{cu} \frac{L_1}{A_1}} = \frac{L_2/A_2}{L_1/A_1} = \frac{2L_1/(A_1/4)}{L_1/A_1} = \frac{\left(\frac{4\cdot 2L_1}{A_1}\right)}{\left(\frac{L_1}{A_1}\right)}$$

$\therefore \frac{R_2}{R_1} = \underline{8}$ OR AN INCREASE OF 8X

$\therefore R_2 = (0.2\,\Omega)(8) = 1.6\,\Omega$

$\boxed{\text{AN INCREASE OF } 1.4\,\Omega}$

17) a. FOR THE SYSTEM IN FIG 3.48, THE RESISTANCE OF EACH LINE CANNOT EXCEED 0.006Ω, & THE MAXIMUM CURRENT DRAWN BY THE LOAD IS 110A. WHAT MINIMUM SIZE WIRE GAGE SHOULD BE USED?



$d = 30\,ft$

#2 (FROM TABLE 3.2) $\rightarrow$ $115A_{MAX}$ ✓ $(115A > 110A)$

$0.1563 \frac{\Omega}{1000\,ft}$

$$\left(\frac{0.1563\,\Omega}{1000\,ft}\right)(30\,ft) = 4.69\times10^{-3}\,\Omega < 0.006\,\Omega \quad ✓$$

$\therefore$ $\boxed{\text{USE AWG \#2}}$

b. REPEAT a. FOR $R_{MAX} = 0.003\,\Omega$?

$$\#1 \rightarrow \frac{0.1240\,\Omega}{1000\,ft}(30\,ft) = 3.7\times10^{-3}\,\Omega \quad \times \quad \text{TOO HIGH}$$

$$\boxed{\text{USE \#0}} \rightarrow \frac{0.0983\,\Omega}{1000\,ft}(30\,ft) = 2.95\times10^{-3}\,\Omega < 0.003\,\Omega \quad ✓$$

$\& \; I_{MAX} = 150\,A$

26) USING EQ (3.10) FIND R_{CU} AT $16°C$ IF $R = 0.4\,\Omega$ AT $T = 20°C$:

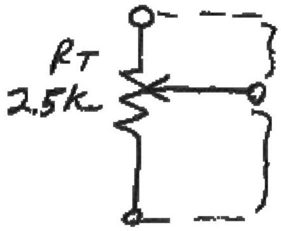
$$R_1 = R_{20}\left[1 + \alpha_{20}(T_1 - 20°C)\right] \qquad (3.10)$$

$R_{20} = 0.4\,\Omega$
$T_1 = 16°C$
$\alpha_{20} = 0.00393$ FOR COPPER

Solve FOR R_1: $\quad R_1 = 0.4\,\Omega\left[1 + 0.00393(16°C - 20°C)\right]$

$$\boxed{R_1 = 0.394\,\Omega}$$

32) IF THE WIPER ARM OF A LINEAR POTENTIOMETER IS 1/4 THE WAY AROUND THE CONTACT SURFACE, FIND R BETWEEN EACH TERMINAL & THE WIPER ARM IF $R_{TOTAL} = 2{,}500\,\Omega$:



1/4, $R = 0.25(2.5k\Omega) = \boxed{625\,\Omega}$

3/4, $R = 0.75(2.5k\Omega) = \boxed{1{,}875\,\Omega}$

36a) IS THERE AN OVERLAP IN COVERAGE BETWEEN 20% RESISTORS? THAT IS, DETERMINE THE TOLERANCE RANGE FOR A 10Ω, 20% RESISTOR & A 15Ω, 20% RESISTOR & NOTE ANY OVERLAP.

10Ω +/- 20% : 8 – 12Ω
15Ω +/- 20% : 12Ω – 18Ω

$\boxed{\text{NO OVERLAP}}$

40) FIND THE CONDUCTANCE:

(a) 120Ω $\qquad G = 1/R$, siemens (S) $\qquad$ (3.14)

$G = 1/120\Omega = \boxed{8.33\ mS} \leftarrow G_1$

(b) 4kΩ

$G = 1/4k\Omega = \boxed{250\,\mu S} \leftarrow G_2$

(c) 2.2MΩ

$G = \frac{1}{2.2M\Omega} = \boxed{454.5\ nS} \leftarrow G_3$

(d) COMPARE

$G_1 > G_2 > G_3$

$R_1 < R_2 < R_3$ $\quad (R_1 = 120\Omega,\ R_2 = 4k\Omega,\ R_3 = 2.2M\Omega)$

45) HOW WOULD YOU CHECK A FUSE W/ AN OHM-METER?

MEASURE R_{FUSE}.

$R_{FUSE} \sim 0\,\Omega$, GOOD

$R_{FUSE} \sim \infty\,\Omega$, BAD (OPEN-CIRCUIT)

47) HOW WOULD YOU USE AN OHMETER TO CHECK A LIGHT-BULB?

MEASURE R_{BULB}

$R_{BULB} \sim \infty\,\Omega$, BAD (OPEN-CIRCUIT)

$R_{BULB} \sim R_{NOMINAL}$, GOOD

FYI, USE OHMS-LAW TO FIND $R_{NOMINAL}$

$$R_{NOMINAL} = \frac{V_{BULB\,(RATED)}}{I_{BULB\,(RATED)}}$$

48) USING METRIC UNITS, DETERMINE THE LENGTH OF A COPPER WIRE W/ $R = 0.2\,\Omega$ + $d = \frac{1}{12}$ inch

$$\frac{1}{12}'' = 0.08\overline{33}''\left(\frac{2.54\text{ cm}}{\text{INCH}}\right) = \underline{211.67 \times 10^{-3}\text{ cm}}$$

$$A = \frac{\pi d^2}{4} = \frac{\pi(211.67 \times 10^{-3}\text{ cm})^2}{4} = \underline{35.19 \times 10^{-3}\text{ cm}^2}$$

$$R = \rho\frac{\ell}{A} \quad \therefore \quad \ell = \frac{R \cdot A}{\rho} = \frac{(0.2\,\Omega)(35.19 \times 10^{-3}\text{ cm}^2)}{1.723 \times 10^{-6}\ \Omega\text{-cm}}$$

FROM TABLE 3.3

$$\boxed{\begin{gathered}\ell = 4{,}085\text{ cm}\\ \text{OR}\\ 40.85\text{ m}\end{gathered}}$$

50) IF THE SHEET RESISTANCE OF A TIN OXIDE SAMPLE IS $100\,\Omega$, WHAT IS THE THICKNESS OF THE OXIDE LAYER?

$R_s = \frac{\rho}{d}$, EXAMPLE 3.8
d = THICKNESS (SEE FIG 3.11)

$\therefore\ d = \frac{\rho}{R_s} = \frac{250\times10^{-6}\ \Omega\cdot cm}{100\,\Omega} = \boxed{2.5\times10^{-6}\ cm \text{ OR } 25\times10^{-9}\ m\ (25\ nm)}$ ← TABLE 3.3

59) (a) USE FIG 3.38, FIND R_{CELL} AT 10 & 1000 ft-CANDLES

AT 10 foot-candles, $R_{CELL} \sim 3\ k\Omega$
100 " " , $R_{CELL} \sim 0.4\ k\Omega$
} LOG-SCALE

(b) DOES THE CELL HAVE POSITIVE OR NEGATIVE ILLUMINATION COEFFICIENT?

NEGATIVE

R↓ AS ILLUMINATION INCREASES

(c) IS THE COEFFICIENT FIXED FOR THE RANGE 0.1 TO 1000 foot-candles? Why?

NO

NOT A LINEAR RELATIONSHIP (LOG SCALE)

(d) WHAT IS THE APPROX. RATE OF CHANGE OF R_{CELL} AT 10 foot-CANDLES?

$1k\Omega \approx 30$ ft-candles
$10k\Omega \approx 2$ ft-candles

$\therefore \frac{\Delta R}{\Delta fc} = \frac{10k\Omega - 1k\Omega}{2fc - 30fc} = \boxed{-321.4\ \frac{\Omega}{fc}}$

60) (a) SEE FIG. 3.40(a), FIND THE TERMINAL VOLTAGE OF THE DEVICE AT 0.5 mA, 1 mA, 3 mA, + 5 mA

I	$V_{TERMINAL}$	
0.5 mA	190V	APPROX. VALUES FROM FIG 3.39a
1 mA	200V	
3 mA	205V	
5 mA	215V	

(b) WHAT IS THE TOTAL ΔV FOR THE INDICATED CURRENT LEVELS?

$$\Delta V = 215V - 190V = \underline{25V}$$

(c) COMPARE I_{MAX}/I_{MIN} TO V_{MAX}/V_{MIN}

$$\frac{I_{MAX}}{I_{MIN}} = \frac{5}{0.5} = \boxed{10:1}$$

$$\frac{V_{MAX}}{V_{MIN}} = \frac{215}{190} = \boxed{1.13:1}$$

TEAM

(13) $R_1 = 800\ m\Omega$ $\qquad$ $R_2 = ?$

$\ell_1 = 200\ ft$ $\qquad$ $\ell_2 = 100\ yd$

$A_1 = 40{,}000\ CM$ $\qquad$ $A_2 = 0.04''^2$

$\left(\rho_1 = 10.37\ CM \cdot \Omega / ft \longrightarrow \rho_2 = \rho_1 \right)$

@ $20°C$ ← NOT NECC AT 20°C HERE

FIND R_2

$$R_1 = \rho \frac{\ell_1}{A_1} \qquad (1)$$

$$R_2 = \rho \frac{\ell_2}{A_2} \qquad (2)$$

$$(1) \div (2) = \frac{R_1}{R_2} = \frac{\ell_1 / A_1}{\ell_2 / A_2}$$

$$\frac{0.8\Omega}{R_2} = \frac{5 \times 10^{-3}\ ft/CM}{5.89 \times 10^{-3}\ ft/CM}$$

$$\boxed{R_2 = 942.4\ m\Omega}$$

$100\ yd = \underline{300\ ft}$

$0.04\ SQ\ IN = ?$

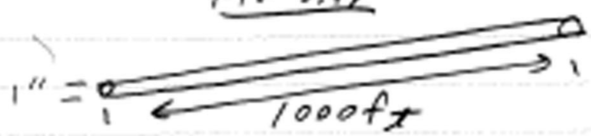
$A = \frac{\pi d^2}{4}$

$\therefore d = 225.68\ MILS$

OR $A = 50.931 \times 10^3\ CM$

52) DERIVE THE CONVERSION FACTOR BETWEEN $\rho\ (CM\text{-}\Omega/ft)$ & $\rho\ (\Omega \cdot cm)$ BY:

a. SOLVING FOR ρ FOR FIG **3.47** IN $CM\text{-}\Omega/ft$



$$R = \rho \frac{l}{A} \quad , \quad \begin{matrix} \rho \Rightarrow CM \cdot \Omega / ft \\ l \Rightarrow ft \\ A \Rightarrow CM \end{matrix}$$

$$\rho = \frac{R \cdot A}{l} = \frac{(1 \times 10^{-3}\ \Omega)(1000\ MILS)^2}{1000\ ft} = 1\ \frac{CM \cdot \Omega}{ft}$$

b. SOLVING FOR ρ (SAME WIRE) IN $\Omega - cm$

$$R = \rho \frac{l}{A} \quad , \quad \begin{matrix} \rho \Rightarrow \Omega \cdot cm \\ l \Rightarrow cm \\ A \Rightarrow cm^2 \end{matrix}$$

$$l:\ 1000\ ft \left(\frac{30.48\ cm}{ft}\right) = \underline{30,480\ cm}$$

$$A:\ d = 1''\left(2.54\ \frac{cm}{in}\right) = 2.54\ cm$$

$$\therefore A = \frac{\pi d^2}{4} = \underline{5.067\ cm^2}$$

$$\rho = \frac{R \cdot A}{l} = \frac{(1 \times 10^{-3}\ \Omega)(5.067\ cm^2)}{30,480\ cm} = \underline{166.2 \times 10^{-9}\ \Omega \cdot cm}$$

c. USING $\rho_2 = k \rho_1$, FIND k $\left(\begin{matrix} \rho_1 = \rho\ \text{r a SOL} \\ \rho_2 = \rho\ \text{r b SOL} \end{matrix} \right)$

$$k = \frac{\rho_2}{\rho_1} = \frac{166.2 \times 10^{-9}\ \Omega \cdot cm}{1\ \frac{CM \cdot \Omega}{ft}} = \boxed{166.2 \times 10^{-9}\ ft}$$

56) USING $1 MA/cm^2$ (CURRENT DENSITY) DETERMINE THE RESULTING CURRENT THROUGH #12 HOUSE WIRE.

#12: AREA = 6529.9CM , TABLE 3.2

$$d_{MILS} = \sqrt{A_{CM}} = \sqrt{6529.9\,CM} = 80.81 \text{ MILS}$$

$$\therefore d_{CM} = 0.08181 \text{ IN} \cdot \left(\frac{2.54 \text{ cm}}{\text{IN}}\right) = 205.3 \times 10^{-3} \text{ cm}$$

$$A = \frac{\pi d^2}{4} = \frac{\pi (205.3 \times 10^{-3} \text{ cm})^2}{4} = 33.09 \times 10^{-3} \text{ cm}^2$$

$$\left(\frac{1 MA}{cm^2}\right) \cdot \left(33.09 \times 10^{-3} \text{ cm}^2\right) = \boxed{33.09 kA}$$

COMPARE THE # TO THE LIMIT FOR #12 IN TABLE 3.2.

$$\#12: I_{MAX} = \boxed{20A << 33.09 kA}$$

58) (a) FIND THE RESISTANCE OF THE THERMISTOR HAVING THE CHARACTERISTICS OF FIG 3.36 AT $-50°C$, $50°C$ & $200°C$.

* LOTS OF ROOM FOR INTERPRETATION *

$-50°C$	, $T \sim 10^5$	$\Omega \cdot cm$
$50°C$	, $T \sim 750$	$\Omega \cdot cm$
$200°C$	, $T \sim 7.5$	$\Omega \cdot cm$

APPROX. VALUES FROM FIG. 3.36

(b) IS THIS A POSITIVE OR NEGATIVE TEMP. COEFFICIENT?

$\boxed{\text{NEGATIVE}}$ AS $T\uparrow$, $R\downarrow$

(c) IS THE COEFFICIENT FIXED FROM $-100°C$ TO $400°C$? WHY?

$\boxed{\text{NO}}$ NONLINEAR RELATIONSHIP

(d) WHAT IS THE APPROX. RATE OF CHANGE OF ρ WITH TEMP. AT $100°C$?

$50°C \overset{\approx}{\rightarrow} 750\ \Omega \cdot cm$

$150°C \rightarrow 25\ \Omega \cdot cm$

* LOTS OF ROOM FOR INTERPRETATION *

$$\frac{\Delta \rho}{\Delta T} = \frac{750\,\Omega \cdot cm - 25\,\Omega \cdot cm}{50\,°C - 150\,°C} \cong \boxed{-7.3\,\frac{\Omega \cdot cm}{°C}}$$