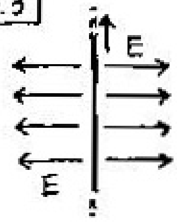
$\boxed{4.3}$



$E = 40$ statvolts/cm Total σ on belt (both sides) $= 2 \times \frac{40}{4\pi} = \frac{20}{\pi}$ esu/cm^2
Current carried by 30 cm wide belt with speed 2000 cm/sec:

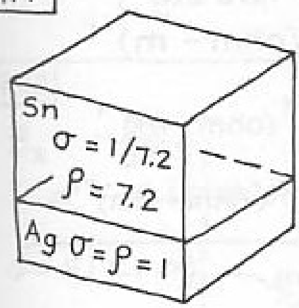
$$I = 30 \times \left(\frac{20}{\pi}\right) \times 2000 = 3.82 \times 10^5 \text{ esu/sec} = 0.127 \text{ milliamp}$$

$\boxed{4.5}$ The normal component of the current density $\underset{\sim}{J}$ (esu sec^{-1} cm^{-2}) must be the same on the left as on the right of the junction. $E_1 = J/\sigma_1$; $E_2 = J/\sigma_2$
Apply Gauss's law to a thin box that encloses 1 cm^2 of the junction: $E_2 - E_1 = 4\pi$ times the charge enclosed in the box. The charge on 1 cm^2 of junction must therefore be $\frac{J}{4\pi}\left(\frac{1}{\sigma_2} - \frac{1}{\sigma_1}\right)$. The relation of the total charge Q at such a junction to the total current I is independent of the area:

$$Q = \frac{I}{4\pi}\left(\frac{1}{\sigma_2} - \frac{1}{\sigma_1}\right).$$

4.6 For constant volume $L \propto 1/d^2$ since resistance $R \propto L/d^2$, reducing d by the factor 3/4, thus increasing L by 16/9, increases R by $(16/9)^2$ or 3.16. An overall increase in L by the factor 2 would increase R by 4.00.

4.7



The ratio of conductivities, 7.2/1 and the ratio of layer thicknesses, 1/2, is all that matters. Let's take $\sigma_{Ag} = \rho_{Ag} = 1$ and consider the cube that is 1/3 silver, 2/3 tin. For vertical currents the layers are in series and resistances add:

$$\rho_{\perp} = \frac{1}{3} + \frac{2}{3} \times 7.2 = 5.133 \qquad \sigma_{\perp} = \frac{1}{\rho_{\perp}} = 0.1948$$

For horizontal currents the layers are in parallel:

$$\sigma_{\parallel} = \frac{1}{3} + \frac{2}{3} \times \frac{1}{7.2} = 0.4259 \qquad \sigma_{\perp}/\sigma_{\parallel} = 0.4566$$

4.8 $R = \frac{L\rho}{A} = 10^5\,\text{cm} \times 1.7 \times 10^{-6}\,\text{ohm-cm}/A$

cross-section of wire; not given, but it will cancel out

current density $J = V/AR = V/L\rho = 6/.17\ \text{amp/cm}^2$

$J = ne\bar{v} \quad \bar{v} = J/ne = (6/.17)/(8 \times 10^{22} \times 1.6 \times 10^{-19})$

$= 0.0028\ \text{cm/sec} \quad t = \frac{10^5\ \text{cm}}{.0028\ \text{cm/sec}} \approx 3 \times 10^7\ \text{sec}$

≈ 1 year

4.12 From Fig. 4.10 $\sigma = 0.3\,(\text{ohm-cm})^{-1}$ and $N_+ = N_- = 10^{15}\,\text{cm}^{-3}$. We shall assume that $m_+ = m_- = 10^{-27}$ gm. In CGS units of sec^{-1}, $\sigma = 0.3/1.11 \times 10^{-12}\ \text{sec}^{-1} = 2.7 \times 10^{11}\ \text{sec}^{-1}$. Solving Eq. 20 for τ, we obtain in this case :

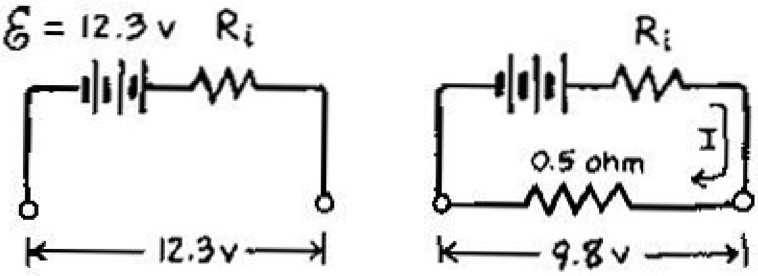
$$\tau = \frac{m\sigma}{2e^2N} = \frac{10^{-27} \times 2.7 \times 10^{11}}{2 \times 23 \times 10^{-20} \times 10^{15}} = 6 \times 10^{-13}\ \text{sec}.$$

4.16

$$R_0 = \frac{R_1\,(R_0 + R_1)}{R_1 + (R_0 + R_1)} + R_1 \qquad \text{Solve for } R_1 :$$

$$2\cancel{R_0 R_1} + R_0^2 = \cancel{R_0 R_1} + R_1^2 + 2R_1^2 + \cancel{R_0 R_1} \qquad R_1 = R_0/\sqrt{3}$$

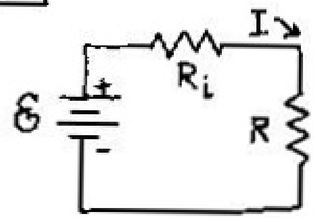
4.17 $\mathcal{E} = 12.3$ v



$9.8\text{v} = 0.5 \times I \qquad I = 19.6$ amp

$(12.3 - 9.8)\text{v} = IR_i \qquad R_i = \dfrac{2.5\text{v}}{19.6\ \text{amp}} = 0.128$ ohm

4.18



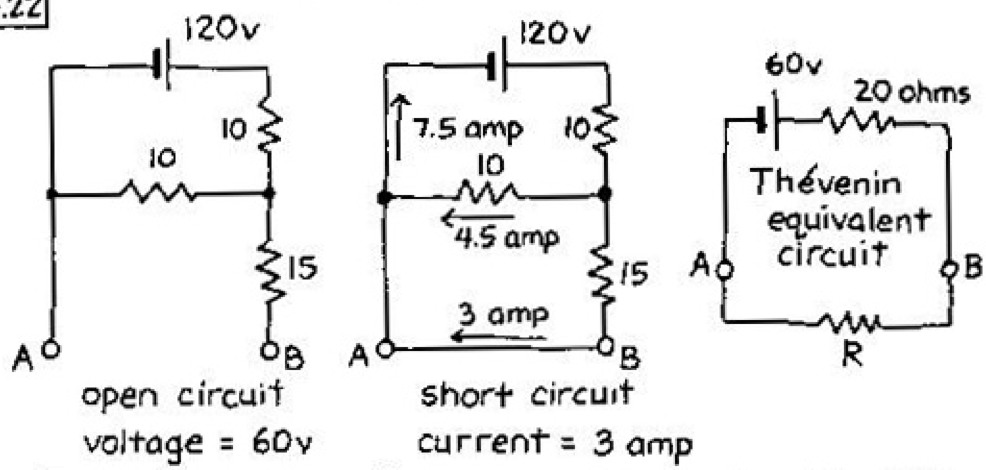
Let P = power dissipated in resistor R

$$P = I^2 R \quad I = \frac{\mathcal{E}}{R + R_i} \quad P = \frac{\mathcal{E}^2 R}{(R + R_i)^2}$$

$$\frac{dP}{dR} = \mathcal{E}^2 \frac{(R + R_i)^2 - 2R(R + R_i)}{(R + R_i)^4} = \mathcal{E}^2 \frac{R_i - R}{(R + R_i)^3}$$

For $R = R_i$ $\frac{dP}{dR} = 0$. Also, $\frac{dP}{dR} < 0$ for $R > R_i$, and $\frac{dP}{dR} > 0$ for $R < R_i$. Hence this is condition for maximum P.

4.22



For max. power in R: R = 20 ohms ; P = 45 watts

4.25 Eq. 34 p. 160 $I = \frac{dQ}{dt} = \frac{V_0}{R} e^{-t/RC}$

At any instant after $t = 0$, the power dissipated in the resistor is $P = I^2 R = \frac{V_0^2}{R} e^{-2t/RC}$

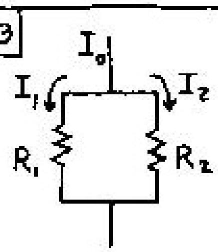
The total energy dissipated is $\int_0^\infty P\,dt = \int_0^\infty \frac{V_0^2}{R} e^{-2t/RC}\,dt$

$$= \frac{V_0^2}{R}\,\frac{RC}{2}\int_0^\infty e^{-x}\,dx = \frac{1}{2} C V_0^2$$

Suppose we have a 1 microfarad capacitor charged to 100 volts. $Q = CV = 10^{-4}$ coulombs. One electron charge is 1.6×10^{-19} coulombs. If $t_0 = RC$ is the time constant, we shall have one electron left when $e^{-t/t_0} = \frac{1.6 \times 10^{-19}}{10^{-4}}$, or $\frac{-t}{t_0} = \ln 1.6 \times 10^{-15}$

This gives $t = t_0 \times 2.3 \log_{10}(6 \times 10^{14}) = 34 t_0$. So if the time constant were ≈ 1 sec, we'd be down to "one electron" in a little over half a minute!

4.33



$$P = I_1^2 R_1 + I_2^2 R_2 = I_1^2 R_1 + (I_0 - I_1)^2 R_2$$
$$= I_1^2 (R_1 + R_2) - 2 I_0 R_2 I_1 + R_2 I_0^2$$
$$\frac{dP}{dI_1} = 2 I_1 (R_1 + R_2) - 2 I_0 R_2$$

To minimize P, set $\frac{dP}{dI_1} = 0$. This gives the condition $I_1 = I_0 \frac{R_2}{R_1 + R_2}$, which we also get from Ohm's law. Observe that P is minimum, not maximum, for $dP/dI_1 < 0$ if I_1 is less than $I_0 R_2/(R_1 + R_2)$