25 $J = E/\rho = (0.49\text{V/m})/(2.44\times10^{-8}\Omega\cdot\text{m}) = 2.0\times10^{7}\text{A/m}^2$. Current = current/area · area = $(2.0\times10^{7}\text{A/m}^2)\pi(0.00042\text{m})^2 = 11.1\text{A}$. (b) $0.49\text{V/m}\cdot6.4\text{m} = 3.14\text{V}$. (c) $R = \Delta V/I = (3.14\text{V})/11.1\text{A} = 0.283\Omega$

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48 Suppose I guess I is clockwise. Starting from the negative of the 16V and going counterclockwise, I'll always be going across resistors *opposite* I, so V will increase. $+16 + I\,(1.6\Omega) + I\,(5\Omega) + I\,(1.4\Omega) - 8 + I\,(9\Omega) = 0$, or $8 + I\,(17\Omega) = 0$ or $I = -0.47\text{A}$. I conclude that the current is actually counterclockwise, at 0.47A. The power dissipated in the 5Ω is $I^2R = (0.47\text{A})(5\Omega) = 1.11\text{W}$. $P_{9\Omega} = (0.47\text{A})^2(9\Omega) = 1.99\text{W}$. Total: 3.1W. Current coming out of the 16V means its does work at the expense of its chemical energy, $P = IV = (0.47\text{A})(16\text{V}) = 7.53\text{W}$. Current going into the 8V means it stores energy, $P = IV = (0.47\text{A})(8\text{V}) = 3.76\text{W}$. Between the 16V and 8V "emf"s", there is 7.53W−3.76W = 3.76W of power delivered. 3.1W is burned up in the 5Ω and 9Ω, leaving 0.66W "unaccounted for". $P_{1.6\Omega} = I^2R = (0.47\text{A})^2(1.6\Omega) = 0.35\text{W}$. $P_{1.4\Omega} = (0.47\text{A})^2(1.4\Omega) = 0.31\text{W}$. Thus, these "internal resistances" are where the rest goes. So far as "power delivered by the 16V battery" goes, I guess you could say its 7.53W − 0.35W = 7.18W, if we consider it as including its internal resistance, and the power "converted to other forms" in the 8V is 3.76W+0.31W = 4.07W, and the difference between these is the 3.1W burned up in the 5Ω and 9Ω.

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60 This is resistors is series. $R = R_{Ag}+R_{cu} = 1.47\times10^{-8}\Omega\cdot\text{m}\frac{1.2\text{m}}{\pi(0.0006\text{m}/2)^2} + 1.72\times10^{-8}\Omega\cdot\text{m}\frac{0.8\text{m}}{\pi(0.0006\text{m}/2)^2}$ $= 0.0624\Omega + 0.0487\Omega = 0.111\Omega$. $I = V/R = 5\text{V}/0.111\Omega = 45\text{A}$. Both sections!
(c) $E_{Cu} = j\,\rho_{Cu} = \frac{45\text{A}}{\pi(0.0006\text{m}/2)^2}\,1.72\times10^{-8}\Omega\cdot\text{m} = 2.74\text{N/C}$. (d) $E_{Ag} = \frac{45\text{A}}{\pi(0.0006\text{m}/2)^2}\,1.47\times10^{-8}\Omega\cdot\text{m} = 2.34\text{N/C}$
(e) $\Delta V = I\,R = (45\text{A})(0.0624\Omega) = 2.81\text{V}$ or $\Delta V = E\,\Delta x = (2.34\text{V/m})(1.2\text{m}) = 2.81\text{V}$

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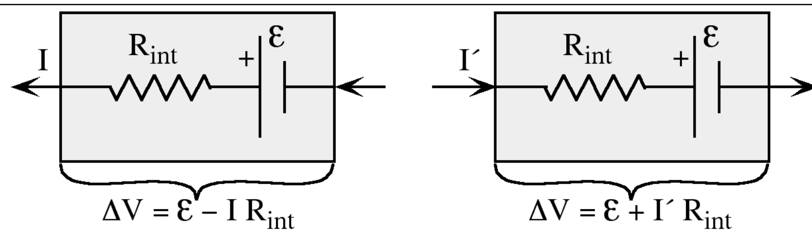
69 While *delivering* power, from terminal to terminal ΔV is $\mathcal{E} - I\,R_{int}$. So

$$\mathcal{E} - (1.5\text{A})\,R_{int} = 8.4\text{V}.$$

When current goes the other way and it stores energy, the terminal to terminal potential difference is $\mathcal{E} + I'\,R_{int}$. So

$$\mathcal{E} + (3.5\text{A})\,R_{int} = 9.4\text{V}$$



Solve the two equations in two unknowns however you like. $R_{int} = 0.2\Omega$ and $\mathcal{E} = 8.7\text{V}$

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71 (a) $\rho\frac{L}{A} = (5\Omega\cdot\text{m})\frac{1.6\text{m}}{\pi(0.05\text{m})^2} = 1.02\text{k}\Omega$. (b) $IR = (0.1\text{A})(1.02\times10^{3}\Omega) \cong 100\text{V}$. Carpet variety shocks are kilovolts, but there is very little charge and the current lasts just an instant. (c) $I\Delta V = (0.1\text{A})(100\text{V}) = 10\text{W}$.

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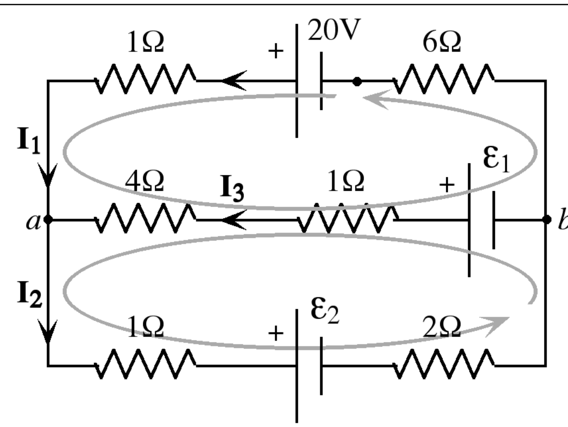
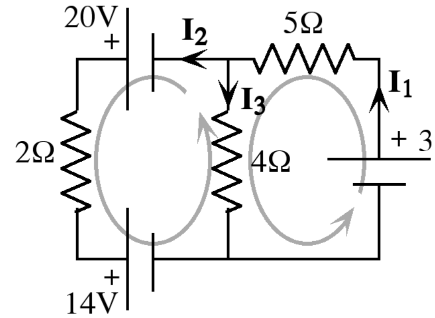
22 Looking at the top loop,
$+20\text{V} - (1\text{A})(1\Omega) + I_3\,(4\Omega) + I_3\,(1\Omega) - \mathcal{E}_1 = 0$
We could look at another loop now, but we'll save time by noting that by considering what goes on at either "node" *a* or *b*, where $I_1+I_3 = I_2$, it must be that I_3 is 1A.
$+20\text{V} - 1\text{V} + (1\text{A})(4\Omega) + (1\text{A})(1\Omega) - \mathcal{E}_1 - (1\text{A})(6\Omega) = 0$
$\Rightarrow \mathcal{E}_1 = 18\text{V}$. Looking at the bottom loop and using $I_3 = 1\text{A}$,
$\mathcal{E}_1 - (1\text{A})(1\Omega) - (1\text{A})(4\Omega) - (2\text{A})(1\Omega) - \mathcal{E}_2 - (2\text{A})(2\Omega) = 0$
$\Rightarrow \mathcal{E}_2 = \mathcal{E}_1 - 11\text{V} = 7\text{V}$.
From *a* to *b*, potential goes up by $(1\text{A})(4\Omega) + (1\text{A})(1\Omega) - 18\text{V} = -13$, so *b* is 13V lower in potential than *a*.



63 Right loop:



$+36V - I_1\,5\Omega - I_3\,4\Omega = 0$
Left loop:
$+20V - I_2\,2\Omega - 14V + I_3\,4\Omega = 0$ or $\mathbf{6V - I_2\,2\Omega + I_3\,4\Omega} = 0$
$I_1 = I_2 + I_3$. The rest is math. Substituting for I_1 in the first,
$+36V - (I_2 + I_3)\,5\Omega - I_3\,4\Omega = 0$ or $\mathbf{36V - I_2\,5\Omega - I_3\,9\Omega} = 0$.
Subtracting 5 times the first equation in bold from 2 times the second causes I_2 to drop out: $2\cdot 36V - 2\cdot I_3\,9\Omega - 5\cdot 6V - 5\cdot I_3\,4\Omega = 0$.
$\Rightarrow I_3 = 1.11A$. Plug back in: $6V - I_2\,2\Omega + (1.11A)\,4\Omega = 0$
$\Rightarrow I_2 = 5.21A$, and $I_1 = I_2 + I_2 = 6.32A$. All are positive, so we guessed direction correctly. In the right branch the current is 6.32A counterclockwise, in the center 1.11A downward, and in the left 5.21A counterclockwise.

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74 (a&b) There will be twice the drop ($V_R = IR$) across the 6Ω as across the 3Ω, so the potential at *a* is 6V. For the capacitors, on the other hand, V_C = Q\C. *Assuming the switch was not previously closed (see end of problem)*, the capacitors are in series, with the same charge, so the *smaller* capacitance has the larger potential difference, again by a factor of 2. Thus, *b* is at 12V. (c) Once the switch is closed and the capacitors reach some final charged state, there will (again) just be a current through the resistors, so *b*, connected now to *a* by a perfect wire, will be at 6V. $Q_{6\mu F} = CV = (6\times10^{-6}F)(12V) = 7.2\times10^{-5}C$, $Q_{3\mu F} = CV = (3\times10^{-6}F)(6V) = 1.8\times10^{-5}C$. There is now a negative 7.2×10^{-5} on the lower plate of the 6μF and a positive 1.8×10^{-5} on the upper plate of the 3μF, where before that conductor was (assumed) neutral. $5.4\times10^{-5}C$ of positive must have left this conductor through the switch. Because the capacitors' charges *aren't* equal now, opening the switch would *not* return everything to where it was at the beginning.

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85 $Q = Q_o\,e^{-t/RC} \rightarrow 1.6\times10^{-19}C = 7\times10^{-6}C\;e^{-t/(670\times10^3\Omega\cdot 9.2\times10^{-7}F)} \Rightarrow t = 19.4s.$

$RC = (670\times10^3\Omega)(9.2\times10^{-7}F) = 0.616s.\ \frac{19.4}{0.616} = 31.4$. (b) A given Q_o and a given Q_f, i.e., a single elementary charge, means that $e^{-t/RC}$ is fixed, so t/RC is fixed, so t is a fixed multiple of RC. So it's always the same *number* of time constants, independent of what value the product RC might be. Of course, this does depend on the fact that Q_o is fixed. A higher Q_o would imply a longer wait till $Q_f = 1.6\times10^{-19}C$.

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87 $\int \text{power}\cdot dt = \int_0^\infty \mathcal{E}\frac{\mathcal{E}}{R}e^{-t/RC}\,dt = \frac{\mathcal{E}^2}{R}(RC) = C\,\mathcal{E}^2$. (b) $\int \text{power}\cdot dt = \int_0^\infty \left(\frac{\mathcal{E}}{R}e^{-t/RC}\right)^2 R\,dt = \frac{\mathcal{E}^2}{R}(\tfrac{1}{2}RC) = \tfrac{1}{2}C\,\mathcal{E}^2$

(c) $U = \tfrac{1}{2}C\,\mathcal{E}^2$. Adds up. (d) Half. Doesn't depend on R. This is an irreversible process––you can't incrementally close a switch. And it will cause a certain entropy increase, whether it takes a long time (large R) or a short time (small R).