1. (a) The total resistance is \( R = (5 + 0.08) \, \Omega = 5.08 \, \Omega \). The current drawn is thus \( I = \frac{12.6 \, V}{5.08 \, \Omega} = 2.48 \, A \) and the potential difference across the headlights is \( 2.48 \, A \cdot 5 \, \Omega = 12.4 \, V \). (b) Assume that the starter motor is in parallel with the headlights. Since the motor draws an additional 35 A, the total current is 35 + 2.48 = 36.48 A. The potential difference across the headlights is then \( E - I' r = 12.6 - (36.48)(0.08) = 9.68 \, V \).  

2. First, the equivalent resistance of the parallel portion of the circuit is \( \frac{R_1 R_2}{R_1 + R_2} = 3/4 \, \Omega \). The total resistance of the circuit is 2 + 0.75 + 4 = 6.75 \, \Omega \). Thus, the total current in the circuit is \( 18 \, V / 6.75 \, \Omega = \frac{8}{3} \, A \). So the power across the 2 \, \Omega resistor is \( \left( \frac{8}{3} \right)^2 \cdot 2 = \frac{128}{9} \) watts and the power across the 4 \, \Omega resistor is \( \left( \frac{8}{3} \right)^2 \cdot 4 = \frac{256}{9} \) watts. Now the potential drop across the parallel portion is \( \Delta V = I R_{eq} = \left( \frac{8}{3} \, A \right) \cdot \left( \frac{3}{4} \, \Omega \right) = 2 \) volts, so the current through the 3 \, \Omega resistor is \( I = \frac{2}{3} \, A \) and the power across the 3 \, \Omega resistor is \( \left( \frac{2}{3} \right)^2 \cdot 3 \, \Omega = \frac{4}{3} \) watts. The current through the 1 \, \Omega resistor is \( I = \frac{2}{3} \, A = 2 \, A \) and the power through it is 4 watts.  

3. Let \( I_1 \) be the current flowing out of the 12 V battery, \( I_2 \) the current down the middle branch, and \( I_3 \) the current down the left branch. Then \( I_1 = I_2 + I_3 \) by the node rule. Choose Loop 1 to flow counterclockwise in the right-hand portion of the circuit. Then by Kirchhoff’s loop rule we have \( 12 \, V - (1 + 3)I_1 - (5 + 1)I_2 - 4 = 0 \) → \( 4I_1 + 6I_2 = 8 \). Choose Loop 2 to flow counterclockwise in the left-hand portion of the circuit. Here \( 4V + (5 + 1)I_2 - 8I_3 = 0 \) → \( 6I_2 - 8I_3 = -4 \). Use the node equation to eliminate \( I_1 \): (i) \( 4(I_2 + I_3) + 6I_2 = 8 \) → \( 10I_2 + 4I_3 = 8 \). Multiply this last result by 2: \( 20I_2 + 8I_3 = 16 \). Adding this to the Loop 2 equations gives \( 20I_2 + 8I_3 = 16 \) + \( 6I_2 - 8I_3 = -4 \) = \( 26I_2 = 12 \) or \( I_2 = 12/26 = 6/13 \, A \). From Loop 2 we have \( 8I_3 = 6I_2 + 4 \) → \( I_3 = \frac{22}{26} \, A \). Finally, \( I_1 = \frac{12 + 22}{26} = 34/26 \, A \).  

4. Construct Loop 1 from \( E_1 \) through \( E_2 \), \( R_2 \), and \( R_1 \), with \( I_1 \) flowing out of \( E_1 \) and \( I_2 \) downward against \( E_2 \). Take Loop 2 with \( I_3 \) coming out of \( E_3 \) through \( R_3 \), and \( I_2 \) downward against \( E_2 \). The equations read \( (1) E_1 - E_2 - I_2 R_2 - I_1 R_1 = 0 \) and \( (2) E_3 - E_2 - I_2 R_2 - I_3 R_3 = 0 \) or \( (1) 2000I_1 + 3000I_2 = 10 \) and \( 3000I_2 + 4000I_3 = 20 \). The node equation is \( (3) I_1 + I_3 = I_2 \). Solving these equations simultaneously gives
\[ I_1 = (1/2600) A, \ I_2 = (8/2600) A, \text{ and } I_3 = (7/2600) A. \] Since the current \( I_2 \) flows from \( c \) to \( f \), we conclude that \( c \) is at the higher potential.

5. Choose the currents as follows: \( I_1 \) flows out of the 12 V source, \( I_2 \) out of the 10 V source, and \( I_1 + I_2 = I_3 \). Take Loop 1 clockwise in the left interior portion of the circuit: 12 − 0.01I_1 + 1I_2 − 10 = 0 and Loop 2 clockwise in the right interior portion: 10 − 1I_2 − 0.06I_3 = 0. Simultaneous solution gives \( I_1 \approx 172.4 \), \( I_2 = -0.2834 \), and \( I_3 \approx 17.4 \). Note that \( I_2 \) is negative, meaning that the current flows against the dead battery (which is what we want to accomplish!)

6. Let \( I \) be the current flowing out of node \( a \) and into node \( b \). Let \( I_1 \) be the current through the left one ohm resistor and \( I - I_1 \) be the current through the 3 ohm resistor, and \( I_2 \) the current downwards through the middle 1 ohm resistor. Choose three paths: (1) \( I_1 + 1(I_1 - I_2) = \Delta V \), (2) \( I_1 + I_2 + 5(I - I_1 + I_2) = \Delta V \), (3) \( 3(I - I_1) + 5(I - I_1 + I_2) = \Delta V \). Now choose \( I = 1.A, \ I_1 = x, \text{ and } I_2 = y \). Then we have \( (1) x + (x - y) = \Delta V \to 2x - y = \Delta V \), (2) \( x + y + 5(1 - x + y) = \Delta V \to -4x + 6y + 5 = \Delta V \), and (3) \( 3(1 - x) + 5(1 - x + y) = \Delta V \to -8x + 5y + 8 = \Delta V \). Rewrite (1) as \( y = 2x - \Delta V \). Substituting for \( y \) in (2) gives \( -4x + 6(2x - \Delta V) + 5 = \Delta V \) or \( 8x + 5 = 7\Delta V \). Substituting for \( y \) in (3) gives \( -8x + 5(2x - \Delta V) + 8 = \Delta V \) or \( 2x + 8 = 6\Delta V \). Multiplying the latter equation by 4 gives \( 8x + 32 = 24\Delta V \). Then \( (8x + 32 = 24\Delta V) - (8x + 5 = 7\Delta V) = 27 = 17\Delta V \Rightarrow \Delta V = 1R_{eq} = 27/17\Omega \)

7. (a) The time constant is \( RC = 150k\Omega \cdot 10pF = \frac{15}{10^{-6}} \). (b) Recall that the current flowing out of a battery must be the same as the current flowing into it. Take \( I_1 \) to be the current flowing out of the battery. Then \( I_1 \) flows through the 50 k\Omega resistor and down the center wire. \( I_2 \) then is the current flowing out of the capacitor, down the center wire, and through the 100 k\Omega resistor. The time constant in this case is \( 100 k\Omega \cdot 10pF = \frac{100}{10^{-6}} \).

(c) By Kirchoff’s loop rules, we have \( 10 - 50,000\Omega \cdot I_1 = 0 \) and \( Q/C - 100,000I_2 = 0 \). Then \( I_1 = \frac{10}{50000} = 2 \times 10^{-4} A \) and \( I_2 = \frac{Q_0}{RC} \cdot e^{-\frac{t}{RC}} \). Here \( Q_0 = CE = 100\mu C \), so \( I_2 = \frac{100\mu C}{100 \cdot 100 \mu F} e^{-\frac{t}{RC}} = \frac{1}{10} e^{-\frac{t}{RC}} \). Finally \( I_3 = I_1 + I_2 = (100e^{-\frac{t}{RC}} + 0.2)mA \).
8. Since the potential difference across the capacitor is proportional to the charge, and the charge "decays" as $Q(t) = Q_0 e^{-\frac{t}{RC}}$, we have $\ln(2) = \frac{t}{RC}$ or $R = \frac{t}{C \ln(2)}$.

9. The current entering node $a$ flows into three branches. Each branch is symmetric: after flowing through one resistor the current encounters a node where the current is split into two branches. After the current travels through one resistor in this second branch, it enters a node along with some of the current from one other branch. This combined current passes through one more resistor before entering node $b$. Since this is true for all paths from $a$ to $b$, the current is $I/3$ in each resistor just after $a$ and just before $b$ and $I/6$ in the two-branch split. (b) For each path we can write $V_a - V_b = IR_{eq} = (I/3)r + (I/6)r + (I/3)r = I(\frac{2+1+2}{6})r = I(\frac{5}{6})r$ or $R_{eq} = (5/6)r$. 