26

DIRECT-CURRENT CIRCUITS

26.38. **IDENTIFY:** An uncharged capacitor is placed into a circuit. Apply the loop rule at each time.

SET UP: The voltage across a capacitor is $V_C = q/C$.

EXECUTE: **(a)** At the instant the circuit is completed, there is no voltage over the capacitor, since it has no charge stored.

(b) Since $V_C = 0$, the full battery voltage appears across the resistor $V_R = \mathcal{E} = 125$ V.

(c) There is no charge on the capacitor.

(d) The current through the resistor is $i = \dfrac{\mathcal{E}}{R_{\text{total}}} = \dfrac{125\text{ V}}{7500\ \Omega} = 0.0167$ A.

(e) After a long time has passed the full battery voltage is across the capacitor and $i = 0$. The voltage across the capacitor balances the emf: $V_C = 125$ V. The voltage across the resister is zero. The capacitor's charge is $q = CV_C = (4.60\times10^{-6}\text{ F})(125\text{ V}) = 5.75\times10^{-4}$ C. The current in the circuit is zero.

EVALUATE: The current in the circuit starts at 0.0167 A and decays to zero. The charge on the capacitor starts at zero and rises to $q = 5.75\times10^{-4}$ C.

26.41. **IDENTIFY:** The capacitors, which are in parallel, will discharge exponentially through the resistors.

SET UP: Since V is proportional to Q, V must obey the same exponential equation as Q, $V = V_0\, e^{-t/RC}$. The current is $I = (V_0/R)\, e^{-t/RC}$.

EXECUTE: **(a)** Solve for time when the potential across each capacitor is 10.0 V:

$$t = -RC\ln(V/V_0) = -(80.0\ \Omega)(35.0\ \mu\text{F})\ln(10/45) = 4210\ \mu\text{s} = 4.21\text{ ms}$$

(b) $I = (V_0/R)\, e^{-t/RC}$. Using the above values, with $V_0 = 45.0$ V, gives $I = 0.125$ A.

EVALUATE: Since the current and the potential both obey the same exponential equation, they are both reduced by the same factor (0.222) in 4.21 ms.

26.72. **IDENTIFY and SET UP:** Just after the switch is closed the charge on the capacitor is zero, the voltage across the capacitor is zero and the capacitor can be replaced by a wire in analyzing the circuit. After a long time the current to the capacitor is zero, so the current through R_3 is zero. After a long time the capacitor can be replaced by a break in the circuit.

EXECUTE: **(a)** Ignoring the capacitor for the moment, the equivalent resistance of the two parallel resistors is $\dfrac{1}{R_{\text{eq}}} = \dfrac{1}{6.00\ \Omega} + \dfrac{1}{3.00\ \Omega} = \dfrac{3}{6.00\ \Omega}$; $R_{\text{eq}} = 2.00\ \Omega$. In the absence of the capacitor, the total current in the circuit (the current through the $8.00\ \Omega$ resistor) would be $i = \dfrac{\mathcal{E}}{R} = \dfrac{42.0\text{ V}}{8.00\ \Omega + 2.00\ \Omega} = 4.20$ A, of which $2/3$, or 2.80 A, would go through the $3.00\ \Omega$ resistor and $1/3$, or 1.40 A, would go through the $6.00\ \Omega$ resistor. Since the current through the capacitor is given by $i = \dfrac{V}{R}e^{-t/RC}$, at the instant $t = 0$ the circuit behaves as through the capacitor were not present, so the currents through the various resistors are as calculated above.

(b) Once the capacitor is fully charged, no current flows through that part of the circuit. The $8.00\ \Omega$ and the $6.00\ \Omega$ resistors are now in series, and the current through them is $i = \mathcal{E}/R = (42.0\text{ V})/(8.00\ \Omega + 6.00\ \Omega) = 3.00$ A. The voltage drop across both the $6.00\ \Omega$ resistor and the capacitor is thus $V = iR = (3.00\text{ A})(6.00\ \Omega) = 18.0$ V.

(There is no current through the $3.00\ \Omega$ resistor and so no voltage drop across it.) The charge on the capacitor is $Q = CV = (4.00\times10^{-6}\ \text{F})(18.0\ \text{V}) = 7.2\times10^{-5}\ \text{C}$.

EVALUATE: The equivalent resistance of R_2 and R_3 in parallel is less than R_3, so initially the current through R_1 is larger than its value after a long time has elapsed.

26.75. **IDENTIFY:** The current through the galvanometer for full-scale deflection is 0.0200 A. For each connection, there are two parallel branches and the voltage across each is the same.
SET UP: The sum of the two currents in the parallel branches for each connection equals the current into the meter for that connection.
EXECUTE: From the circuit we can derive three equations:
(i) $(R_1 + R_2 + R_3)(0.100\ \text{A} - 0.0200\ \text{A}) = (48.0\ \Omega)(0.0200\ \text{A})$ and $R_1 + R_2 + R_3 = 12.0\ \Omega$.
(ii) $(R_1 + R_2)(1.00\ \text{A} - 0.0200\ \text{A}) = (48.0\ \Omega + R_3)(0.0200\ \text{A})$ and $R_1 + R_2 - 0.0204R_3 = 0.980\ \Omega$.
(iii) $R_1(10.0\ \text{A} - 0.0200\ \text{A}) = (48.0\ \Omega + R_2 + R_3)(0.0200\ \text{A})$ and $R_1 - 0.002R_2 - 0.002R_3 = 0.096\ \Omega$.
From (i) and (ii), $R_3 = 10.8\ \Omega$. From (ii) and (iii), $R_2 = 1.08\ \Omega$. Therefore, $R_1 = 0.12\ \Omega$.
EVALUATE: For the 0.100 A setting the circuit consists of $48.0\ \Omega$ and $R_1 + R_2 + R_3 = 12.0\ \Omega$ in parallel and the equivalent resistance of the meter is $9.6\ \Omega$. For each of the other two settings the equivalent resistance of the meter is less than $9.6\ \Omega$.