18.1 From $\Delta V = I(R + r)$, the internal resistance is

$$r = \frac{\Delta V}{I} - R = \frac{9.00 \text{ V}}{0.117 \text{ A}} - 72.0\ \Omega = \boxed{4.92\ \Omega}$$

18.46 (a) The circuit reduces as shown below to an equivalent resistance of $R_{eq} = \boxed{14\ \Omega}$.

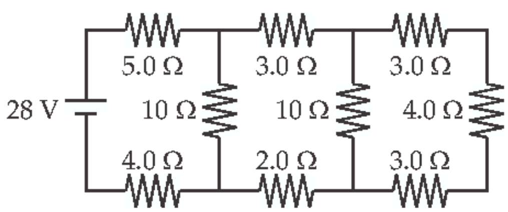


Figure 1

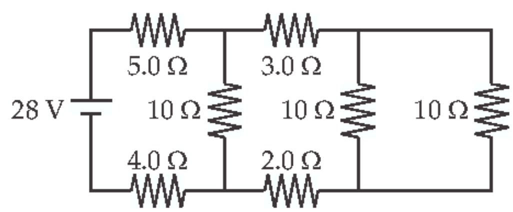


Figure 2

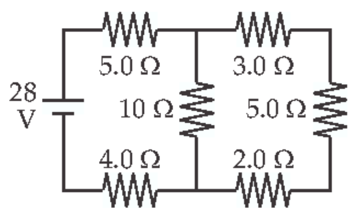


Figure 3

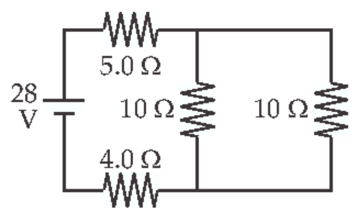


Figure 4

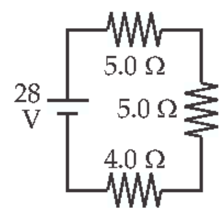


Figure 5

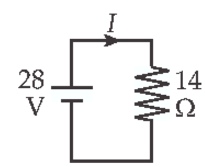


Figure 6

(b) The power dissipated in the circuit is $\mathcal{P} = \frac{(\Delta V)^2}{R_{eq}} = \frac{(28 \text{ V})^2}{14\ \Omega} = \boxed{56 \text{ W}}$

(c) The current in the original $5.0\text{-}\Omega$ resistor (in Figure 1) is the total current supplied by the battery. From Figure 6, this is

$$I = \frac{\Delta V}{R_{eq}} = \frac{28 \text{ V}}{14\ \Omega} = \boxed{2.0 \text{ A}}$$

18.18 Observe that the center branch of this circuit, that is the branch containing points *a* and *b*, is not a continuous conducting path, so no current can flow in this branch. The only current in the circuit flows counterclockwise around the perimeter of this circuit. Going counterclockwise around the this outer loop and applying Kirchhoff's loop rule gives

$$-8.0\text{ V}-(2.0\ \Omega)I-(3.0\ \Omega)I+12\text{ V}-(10\ \Omega)I-(5.0\ \Omega)I=0$$

or $$I=\frac{12\text{ V}-8.0\text{ V}}{20\ \Omega}=0.20\text{ A}$$

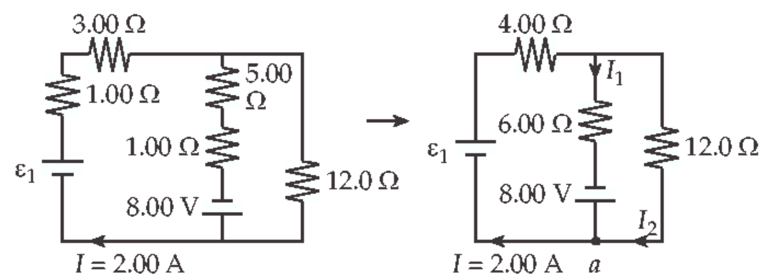
Now, we start at point *b* and go around the upper panel of the circuit to point *a*, keeping track of changes in potential as they occur. This gives

$$\Delta V_{ab}=V_a-V_b=-4.0\text{ V}+(6.0\ \Omega)(0)-(3.0\ \Omega)(0.20\text{ A})+12\text{ V}-(10\ \Omega)(0.20\text{ A})=+5.4\text{ V}$$

Since $\Delta V_{ab}>0$, $\boxed{\text{point } a \text{ is 5.4 V higher in potential than point } b}$

18.21 First simplify the circuit by combining the series resistors. Then, apply Kirchhoff's junction rule at point *a* to find

$$I_1+I_2=2.00\text{ A}$$



Next, we apply Kirchhoff's loop rule to the rightmost loop to obtain

$$-8.00\text{ V}+(6.00)I_1-(12.0)I_2=0$$

or $-8.00\text{ V}+(6.00)I_1-(12.0)(2.00\text{ A}-I_1)=0$ This yields $I_1=1.78\text{ A}$

Finally, apply Kirchhoff's loop rule to the leftmost loop to obtain

$$+\varepsilon_1-(4.00)(2.00\text{ A})-(6.00)I_1+8.00\text{ V}=0$$

or $$\varepsilon_1=(4.00)(2.00\text{ A})+(6.00)(1.78\text{ A})-8.00\text{ V}=\boxed{10.7\text{ V}}$$

18.30 The time constant is $\tau = RC$. Considering units, we find

$$RC \to (\text{Ohms})(\text{Farads}) = \left(\frac{\text{Volts}}{\text{Amperes}}\right)\left(\frac{\text{Coulombs}}{\text{Volts}}\right) = \left(\frac{\text{Coulombs}}{\text{Amperes}}\right)$$

$$= \left(\frac{\text{Coulombs}}{\text{Coulombs/Second}}\right) = \text{Second}$$

or $\tau = RC$ has units of time.

18.33 $Q_{\text{max}} = C\varepsilon = (5.0\times10^{-6}\text{ F})(30\text{ V}) = 1.5\times10^{-4}\text{ C}$, and

$$\tau = RC = (1.0\times10^{6}\ \Omega)(5.0\times10^{-6}\text{ F}) = 5.0\text{ s}$$

Thus, at $t = 10\text{ s} = 2\tau$

$$Q = Q_{\text{max}}\left(1 - e^{-t/\tau}\right) = (1.5\times10^{-4}\text{ C})\left(1 - e^{-2}\right) = \boxed{1.3\times10^{-4}\text{ C}}$$

18.38 (a) The equivalent resistance of the parallel combination is

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{150\ \Omega} + \frac{1}{25\ \Omega} + \frac{1}{50\ \Omega}\right)^{-1} = 15\ \Omega$$

so the total current supplied to the circuit is

$$I_{total} = \frac{\Delta V}{R_{eq}} = \frac{120\text{ V}}{15\ \Omega} = \boxed{8.0\text{ A}}$$

(b) Since the appliances are connected in parallel,

the voltage across each one is $\Delta V = \boxed{120\text{ V}}$.

(c) $I_{lamp} = \dfrac{\Delta V}{R_{lamp}} = \dfrac{120\text{ V}}{150\ \Omega} = \boxed{0.80\text{ A}}$

(d) $\mathcal{P}_{heater} = \dfrac{(\Delta V)^2}{R_{heater}} = \dfrac{(120\text{ V})^2}{25\ \Omega} = \boxed{5.8\times10^{2}\text{ W}}$

18.41 (a) The area of each surface of this axon membrane is

$$A = \ell(2\pi r) = (0.10\text{ m})\left[2\pi\left(10\times10^{-6}\text{ m}\right)\right] = 2\pi\times10^{-6}\text{ m}^2$$

and the capacitance is

$$C = \kappa\epsilon_0\frac{A}{d} = 3.0\left(8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2\right)\left(\frac{2\pi\times10^{-6}\text{ m}^2}{1.0\times10^{-8}\text{ m}}\right) = 1.67\times10^{-8}\text{ F}$$

In the resting state, the charge on the outer surface of the membrane is

$$Q_i = C(\Delta V)_i = \left(1.67\times10^{-8}\text{ F}\right)\left(70\times10^{-3}\text{ V}\right) = 1.17\times10^{-9}\text{ C} \rightarrow \boxed{1.2\times10^{-9}\text{ C}}$$

The number of potassium ions required to produce this charge is

$$N_{K^+} = \frac{Q_i}{e} = \frac{1.17\times10^{-9}\text{ C}}{1.6\times10^{-19}\text{ C}} = \boxed{7.3\times10^{9}\text{ K}^+\text{ ions}}$$

and the charge per unit area on this surface is

$$\sigma = \frac{Q_i}{A} = \frac{1.17\times10^{-9}\text{ C}}{2\pi\times10^{-6}\text{ m}^2}\left(\frac{1\,e}{1.6\times10^{-19}\text{ C}}\right)\left(\frac{10^{-20}\text{ m}^2}{1\text{ Å}^2}\right) = \frac{1\,e}{8.6\times10^{4}\text{ Å}^2} = \boxed{\frac{1\,e}{\left(290\text{ Å}\right)^2}}$$

This corresponds to a low charge density of one electronic charge per square of side 290 Å, compared to a normal atomic spacing of one atom per several Å^2.

(b) In the resting state, the net charge on the inner surface of the membrane is $-Q_i = -1.17\times10^{-9}\text{ C}$, and the net positive charge on this surface in the excited state is

$$Q_f = C(\Delta V)_f = \left(1.67\times10^{-8}\text{ F}\right)\left(+30\times10^{-3}\text{ V}\right) = +5.0\times10^{-10}\text{ C}$$

The total positive charge which must pass through the membrane to produce the excited state is therefore

$$\Delta Q = Q_f - Q_i$$

$$= +5.0\times10^{-10}\text{ C} - \left(-1.17\times10^{-9}\text{ C}\right) = 1.67\times10^{-9}\text{ C} \rightarrow \boxed{1.7\times10^{-9}\text{ C}}$$

corresponding to

$$N_{Na^+} = \frac{\Delta Q}{e} = \frac{1.67\times10^{-9}\text{ C}}{1.6\times10^{-19}\text{ C/Na}^+\text{ ion}} = \boxed{1.0\times10^{10}\text{ Na}^+\text{ ions}}$$