Chapter 27.

11. The current in a single-loop circuit with one resistance $R$ is 5.0 A. When an additional resistance of 2.0 $\Omega$ is inserted in series with $R$, the current drops to 4.0 A. What is $R$?

Let the emf be $V$. Then $V = iR = i'(R + R')$, where $i = 5.0$ A, $i' = 4.0$ A and $R' = 2.0$ $\Omega$.

We solve for $R$:

$$R = \frac{i'R'}{i - i'} = \frac{(4.0)(2.0)}{5.0 - 4.0} = 8.0 \Omega.$$

19. In Figure 27-34 (in HRW6, Fig. 28-28 on p. 655), $R_1 = 100$ $\Omega$, $R_2 = 50$ $\Omega$, and the ideal batteries have emfs $E_1 = 6.0$ V, $E_2 = 5.0$ V, and $E_3 = 4.0$ V. Find (a) the current in resistor 1, (b) the current in resistor 2, and (c) the potential difference between points $a$ and $b$.

Let $i_1$ be the current in $R_1$ and take it to be positive if it is to the right. Let $i_2$ be the current in $R_2$ and take it to be positive if it is upward.

(a) When the loop rule is applied to the lower loop, the result is

$$\varepsilon_2 - i_1R_1 = 0$$

The equation yields

$$i_1 = \frac{\varepsilon_2}{R_1} = \frac{5.0 \text{ V}}{100 \Omega} = 0.050 \text{ A}.$$

(b) When it is applied to the upper loop, the result is

$$\varepsilon_1 - \varepsilon_2 - \varepsilon_3 - i_2R_2 = 0.$$

The equation yields

$$i_2 = \frac{\varepsilon_1 - \varepsilon_2 - \varepsilon_3}{R_2} = \frac{6.0 \text{ V} - 5.0 \text{ V} - 4.0 \text{ V}}{50 \Omega} = -0.060 \text{ A},$$

or $|i_2| = 0.060 \text{ A}$. The negative sign indicates that the current in $R_2$ is actually downward.

(c) If $V_b$ is the potential at point $b$, then the potential at point $a$ is $V_a = V_b + \varepsilon_3 + \varepsilon_2$, so $V_a - V_b = \varepsilon_3 + \varepsilon_2 = 4.0$ V + 5.0 V = 9.0 V.
40. When the lights of a car are switched on, an ammeter in series with them reads 10.0 A and a voltmeter connected across them reads 12.0 V (Fig. 27-48 – In HRW6 its Fig. 28-39). When the electric starting motor is turned on, the ammeter reading drops to 8.00 A and the lights dim somewhat. If the internal resistance of the battery is 0.0500 Ω and that of the ammeter is negligible, what are (a) the emf of the battery and (b) the current through the starting motor when the lights are on?

(a) \[ \varepsilon = V + ir = 12 \text{ V} + (10.0 \text{ A}) (0.0500 \text{ \Omega}) = 12.5 \text{ V}. \]

(b) Now \( \varepsilon = V' + (i_{\text{motor}} + 8.00 \text{ A})r \), where \( V' = i_{\text{A}}R_{\text{light}} = (8.00 \text{ A}) (12.0 \text{ V}/10 \text{ A}) = 9.60 \text{ V} \). Therefore,

\[ i_{\text{motor}} = \frac{\varepsilon - V'}{r} - 8.00 \text{ A} = \frac{12.5 \text{ V} - 9.60 \text{ V}}{0.0500 \text{ \Omega}} - 8.00 \text{ A} = 50.0 \text{ A}. \]

46. In a RC series circuit, \( E = 12.0 \text{ V}, R = 1.40 \text{ M\Omega}, \text{ and } C = 1.80 \text{ \mu F}. \) (a) Calculate the time constant. (b) Find the maximum charge that will appear on the capacitor during charging. (c) How long does it take for the charge to build up to 16.0 \text{ \mu F}?

(a) \( \tau = RC = (1.40 \times 10^6 \text{ \Omega})(1.80 \times 10^{-6} \text{ F}) = 2.52 \text{ s}. \)

(b) \( q_0 = \varepsilon C = (12.0 \text{ V})(1.80 \text{ \mu F}) = 21.6 \text{ \mu C}. \)

(c) The time \( t \) satisfies \( q = q_0(1 - e^{-t/RC}), \) or

\[ t = RC \ln \left( \frac{q_0}{q_0 - q} \right) = (2.52 \text{ s}) \ln \left( \frac{21.6 \text{ \mu C}}{21.6 \text{ \mu C} - 16.0 \text{ \mu C}} \right) = 3.40 \text{ s}. \]
Figure 27-53 (in HRW6 its Fig. 28-42) shows the circuit of a flashing lamp, like those attached to barrels at highway construction sites. The fluorescent lamp L (of negligible capacitance) is connected in parallel across the capacitor C of an RC circuit. There is a current through the lamp only when the potential difference across it reaches the breakdown voltage $V_L$; then the capacitor discharges completely through the lamp and the lamp flashes briefly. For a lamp with breakdown voltage $V_L = 72.0 \text{ V}$, wired to a 95.0 V ideal battery and a 0.150 μF capacitor, what resistance $R$ is needed for two flashes per second?

The time it takes for the voltage difference across the capacitor to reach $V_L$ is given by $V_L = e^{(1-e^{-t/RC})}$. We solve for $R$:

\[
R = \frac{t}{C \ln\left[{e/(e-V_L)}\right]} = \frac{0.500 \text{s}}{\left(0.150 \times 10^{-6} \text{ F}\right) \ln\left[95.0 \text{ V}/(95.0 \text{ V} - 72.0 \text{ V})\right]} = 2.35 \times 10^{6} \Omega
\]

where we used $t = 0.500 \text{ s}$ given (implicitly) in the problem.