Problem 1

Model: The connecting wires are ideal, but the battery is not.
Visualize: Please refer to Fig. P32.45. We will designate the current in the 5 Ω resistor I_5 and the voltage drop ΔV_5. Similar designations will be used for the other resistors.
Solve: Since the 10 Ω resistor is dissipating 40 W,

$$P_{10} = I_{10}^2 R_{10} = 40\text{ W} \Rightarrow I_{10} = \sqrt{\frac{P_{10}}{R_{10}}} = \sqrt{\frac{40\text{ W}}{10\ \Omega}} = 2.0\text{ A} \Rightarrow \Delta V_{10} = I_{10}R_{10} = (2.0\text{ A})(10\ \Omega) = 20\text{ V}$$

The 20 Ω resistor is in parallel with the 10 Ω resistor, so they have the same potential difference: $\Delta V_{20} = \Delta V_{10} =$ 20 V. From Ohm's law,

$$I_{20} = \frac{\Delta V_{20}}{R_{20}} = \frac{20\text{ V}}{20\ \Omega} = 1.0\text{ A}$$

The combined current through the 10 Ω and 20 Ω resistors first passes through the 5 Ω resistor. Applying Kirchhoff's junction law at the junction between the three resistors,

$$I_5 = I_{10} + I_{20} = 1.0\text{ A} + 2.0\text{ A} = 3.0\text{ A} \Rightarrow \Delta V_5 = I_5 R_5 = (3.0\text{ A})(5\ \Omega) = 15\text{ V}$$

Knowing the currents and potential differences, we can now find the power dissipated:

$$P_5 = I_5\Delta V_5 = (3.0\text{ A})(15\text{ V}) = 45\text{ W} \qquad P_{20} = I_{20}\Delta V_{20} = (1.0\text{ A})(20\text{ V}) = 20\text{ W}$$

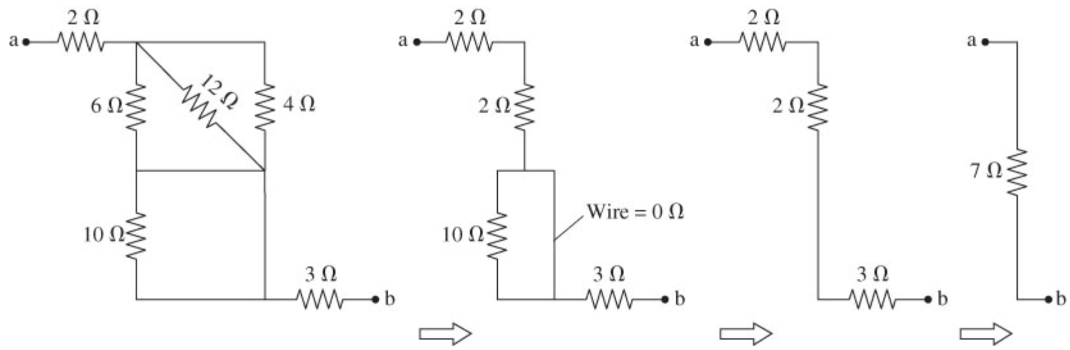
Problem 2

Visualize: Please refer to Figure P32.36.
Solve: Bulbs D and E are in series, so the same current will go through both and make them equally bright (D = E). Bulbs B and C are in parallel, so they have the same potential difference across them. Because they are identical bulbs with equal resistances, they will have equal currents and be equally bright (B = C). Now the equivalent resistance of B + C in parallel is less than the resistance of E, so the total resistance along the path through A is less than the total resistance along path through D. The two paths have the same total potential difference—the emf of the battery—so more current will flow through the A path than through the D path. Consequently, A will have more current than D and E and will be brighter than D and E (A > D = E). Bulbs B and C each have half the current of A, because the current splits at the junction, so A is also brighter than B and C (A > B = C).

The remaining issue is how B and C compare to D and E. Suppose B and C were replaced by wires with zero resistance, leaving just bulb A in the middle path. Then the resistance of the path through A would be half of the resistance of the path through D. This would mean that the current through A would be twice the current through D, so $I_A = 2I_D$. When B and C are present, their resistance adds to the resistance of A to lower the current through the middle path. So in reality, $I_A < 2I_D$. We already know that $I_B = I_C = \frac{1}{2}I_A$, so we can conclude that $I_B = I_C < I_D$. Since the current through B and C is less than the current through D and E, D and E are brighter than B and C. The final result of our analysis is A > D = E > B = C.

Problem 3

Model: Use the laws of series and parallel resistances.
Visualize:



Solve: Despite the diagonal orientation of the 12 Ω resistor, the 6 Ω, 12 Ω, and 4 Ω resistors are in parallel because they have a common connection at both the top end and at the bottom end. Their equivalent resistance is

$$R_{\text{eq}} = \left(\frac{1}{6\ \Omega} + \frac{1}{12\ \Omega} + \frac{1}{4\ \Omega}\right)^{-1} = 2\ \Omega$$

The trickiest issue is the 10 Ω resistor. It is in parallel with a *wire*, which is the same thing as a resistor with R = 0 Ω . The equivalent resistance of 10 Ω in parallel with 0 Ω is

$$R_{\text{eq}} = \left(\frac{1}{10\ \Omega} + \frac{1}{0\ \Omega}\right)^{-1} = (\infty)^{-1} = \frac{1}{\infty} = 0\ \Omega$$

In other words, the wire is a short circuit around the 10 Ω, so all the current goes through the wire rather than the resistor. The 10 Ω resistor contributes nothing to the circuit. So the total circuit is equivalent to a 2 Ω resistor in series with the 2 Ω equivalent resistance in series with the final 3 Ω resistor. The equivalent resistance of these three series resistors is

$$R_{\text{ab}} = 2\ \Omega + 2\ \Omega + 3\ \Omega = 7\ \Omega$$

Problem 4

Assume that the connecting wires are ideal, but the battery is not. The battery has internal resistance. Also assume that the ammeter does not have any resistance.
Visualize: Please refer to Figure P32.46.
Solve: When the switch is open,

$$\mathcal{E} - Ir - I(5.0\ \Omega) = 0\ \text{V} \Rightarrow \mathcal{E} = (1.636\ \text{A})(r + 5.0\ \Omega)$$

where we applied Kirchhoff's loop law, starting from the lower left corner. When the switch is closed, the current I comes out of the battery and splits at the junction. The current I' = 1.565 A flows through the 5.0 Ω resistor and the rest $(I - I')$ flows through the 10.0 Ω resistor. Because the potential differences across the two resistors are equal,

$$I'(5.0\ \Omega) = (I - I')(10.0\ \Omega) \Rightarrow (1.565\ \text{A})(5.0\ \Omega) = (I - 1.565\ \text{A})(10.0\ \Omega) \Rightarrow I = 2.348\ \text{A}$$

Applying Kirchhoff's loop law to the left loop of the closed circuit,

$$\mathcal{E} - Ir - I'(5.0\ \Omega) = 0\ \text{V} \Rightarrow \mathcal{E} = (2.348\ \text{A})r + (1.565\ \text{A})(5.0\ \Omega) = (2.348\ \text{A})r + 7.825\ \text{V}$$

Combining this equation for $\mathcal{E}$ with the equation obtained from the circuit when the switch was open,

$$(2.348\ \text{A})r + 7.825\ \text{V} = (1.636\ \text{A})r + 8.18\ \text{V} \Rightarrow (0.712\ \text{A})r = 0.355\ \text{V} \Rightarrow r = 0.50\ \Omega$$

We also have $\mathcal{E} = (1.636\ \text{A})(0.50\ \Omega + 5.0\ \Omega) = 9.0\ \text{V}$.

Problem 5

Visualize: Please refer to Figure P32.55.

Solve: **(a)** Only bulb A is in the circuit when the switch is open. The bulb's resistance R is in series with the internal resistance r, giving a total resistance $R_{eq} = R + r$. The current is

$$I_{bat} = \frac{\mathcal{E}}{R + r} = \frac{1.50\text{ V}}{6.50\ \Omega} = 0.231\text{ A}$$

This is the current leaving the battery. But all of this current flows through bulb A, so $I_A = I_{bat} = 0.231$ A.

(b) With the switch closed, bulbs A and B are in parallel with an equivalent resistance $R_{eq} = \frac{1}{2}R = 3.00\ \Omega$. Their equivalent resistance is in series with the battery's internal resistance, so the current flowing *from the battery* is

$$I_{bat} = \frac{\mathcal{E}}{R_{eq} + r} = \frac{1.50\text{ V}}{3.50\ \Omega} = 0.428\text{ A}$$

But only half this current goes through bulb A, with the other half through bulb B, so $I_A = \frac{1}{2}I_{bat} = 0.214$ A.

(c) The change in I_A when the switch is closed is 0.017 A. This is a decrease of 7.4%.

(d) If $r = 0\ \Omega$, the current when the switch is open would be $I_A = I_{bat} = 0.250$ A. With the switch closed, the current would be $I_{bat} = 0.500$ A and the current through bulb A would be $I_A = \frac{1}{2}I_{bat} = 0.250\text{ A}$. The current through A would *not* change when the switch is closed.