39. SSM ***REASONING*** Using Ohm's law (Equation 20.2) we can write an expression for the voltage across the original circuit as $V = I_0 R_0$. When the additional resistor R is inserted in series, assuming that the battery remains the same, the voltage across the new combination is given by $V = I(R + R_0)$. Since V is the same in both cases, we can write $I_0 R_0 = I(R + R_0)$. This expression can be solved for R_0.

SOLUTION Solving for R_0, we have

$$I_0 R_0 - I R_0 = IR \quad \text{or} \quad R_0(I_0 - I) = IR$$

Therefore, we find that

$$R_0 = \frac{IR}{I_0 - I} = \frac{(12.0\ \text{A})(8.00\ \Omega)}{15.0\ \text{A} - 12.0\ \text{A}} = \boxed{32\ \Omega}$$

---

40. ***REASONING*** According to Equation 20.2, the resistance R of the resistor is equal to the voltage V_R across it divided by the current I, or $R = V_R / I$. Since the resistor, the lamp, and the voltage source are in series, the voltage across the resistor is V_R = 120.0 V − V_L, where V_L is the voltage across the lamp. Thus, the resistance is

$$R = \frac{120.0\text{ V} - V_L}{I}$$

Since V_L is known, we need only determine the current in the circuit. Since we know the voltage V_L across the lamp and the power P dissipated by it, we can use Equation 20.6a to find the current: $I = P / V_L$. The resistance can be written as

$$R = \frac{120.0\text{ V} - V_L}{\dfrac{P}{V_L}}$$

SOLUTION Substituting the known values for V_L and P into the equation above, the resistance is

$$R = \frac{120.0\text{ V} - 25\text{ V}}{\dfrac{60.0\text{ W}}{25\text{ V}}} = \boxed{4.0 \times 10^1\ \Omega}$$

---

41. ***REASONING AND SOLUTION*** The equivalent resistance of the circuit is

$$R_s = R_1 + R_2 = 36.0\ \Omega + 18.0\ \Omega = 54.0\ \Omega$$

Ohm's law for the circuit gives $I = V/R_s$ = (15.0 V)/(54.0 Ω) = 0.278 A

a. Ohm's law for R_1 gives V_1 = (0.278 A)(36.0 Ω) = $\boxed{10.0\ \text{V}}$

b. Ohm's law for R_2 gives V_2 = (0.278 A)(18.0 Ω) = $\boxed{5.00\ \text{V}}$

---

48. ***REASONING AND SOLUTION*** The rule for combining parallel resistors is

$$\frac{1}{R_\text{P}} = \frac{1}{R_1} + \frac{1}{R_2}$$

which gives

$$\frac{1}{R_2} = \frac{1}{R_\text{P}} - \frac{1}{R_1} = \frac{1}{115\ \Omega} - \frac{1}{155\ \Omega} \qquad \text{or} \qquad \boxed{R_2 = 446\ \Omega}$$

50. ***REASONING AND SOLUTION*** The power P dissipated in a resistance R is given by Equation 20.6c as $P = V^2/R$. The resistance R_{50} of the 50.0-W filament is

$$R_{50} = \frac{V^2}{P} = \frac{(120.0\ \text{V})^2}{50.0\ \text{W}} = \boxed{288\ \Omega}$$

The resistance R_{100} of the 100.0-W filament is

$$R_{100} = \frac{V^2}{P} = \frac{(120.0\ \text{V})^2}{100.0\ \text{W}} = \boxed{144\ \Omega}$$

---

51. ***REASONING*** The total power is given by Equation 20.15c as $\overline{P} = V_{\text{rms}}^2 / R_{\text{p}}$, where R_{p} is the equivalent parallel resistance of the heater and the lamp. Since the total power and the rms voltage are known, we can use this expression to obtain the equivalent parallel resistance. This equivalent resistance is related to the individual resistances of the heater and the lamp via Equation 20.17, which is $R_{\text{p}}^{-1} = R_{\text{heater}}^{-1} + R_{\text{lamp}}^{-1}$. Since R_{heater} is given, R_{lamp} can be found once R_{p} is known.

SOLUTION According to Equation 20.15c, the equivalent parallel resistance is

$$R_{\text{p}} = \frac{V_{\text{rms}}^2}{\overline{P}}$$

Using this result in Equation 20.17 gives

$$\frac{1}{R_{\text{p}}} = \frac{1}{V_{\text{rms}}^2 / \overline{P}} = \frac{1}{R_{\text{heater}}} + \frac{1}{R_{\text{lamp}}}$$

Rearranging this expression shows that

$$\frac{1}{R_{\text{lamp}}} = \frac{\overline{P}}{V_{\text{rms}}^2} - \frac{1}{R_{\text{heater}}} = \frac{111\text{ W}}{(120\text{ V})^2} - \frac{1}{4.0\times10^2\ \Omega} = 5.2\times10^{-3}\ \Omega^{-1}$$

Therefore,

$$R_{\text{lamp}} = \frac{1}{5.2\times10^{-3}\ \Omega^{-1}} = \boxed{190\ \Omega}$$

---

52. ***REASONING*** When the switch is open, no current goes to the resistor R_2. Current exists only in R_1, so it is the equivalent resistance. When the switch is closed, current is sent to both resistors. Since they are wired in parallel, we can use Equation 20.17 to find the equivalent resistance. Whether the switch is open or closed, the power P delivered to the circuit can be found from the relation $P = V^2/R$ (Equation 20.6c), where V is the battery voltage and R is the equivalent resistance.

SOLUTION
a. When the switch is open, there is current only in resistor R_1. Thus, the equivalent resistance is $R_1 = \boxed{65.0\ \Omega}$.

b. When the switch is closed, there is current in both resistors and, furthermore, they are wired in parallel. The equivalent resistance is

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{65.0\ \Omega} + \frac{1}{96.0\ \Omega} \quad \text{or} \quad R_P = \boxed{38.8\ \Omega} \qquad (20.17)$$

c. When the switch is open, the power delivered to the circuit by the battery is given by $P = V^2/R_1$, since the only resistance in the circuit is R_1. Thus, the power is

$$P = \frac{V^2}{R_1} = \frac{(9.00\ \text{V})^2}{65.0\ \Omega} = \boxed{1.25\ \text{W}} \qquad (20.6)$$

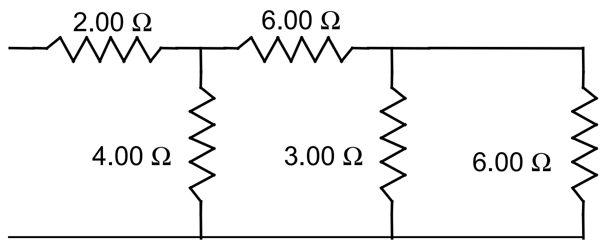
d. When the switch is closed, the power delivered to the circuit is $P = V^2/R_P$, where R_P is the equivalent resistance of the two resistors wired in parallel:

$$P = \frac{V^2}{R_P} = \frac{(9.00\ \text{V})^2}{38.8\ \Omega} = \boxed{2.09\ \text{W}} \qquad (20.6)$$

---

58. ***REASONING*** We will approach this problem in parts. The resistors that are in series will be combined according to Equation 20.16, and the resistors that are in parallel will be combined according to Equation 20.17.

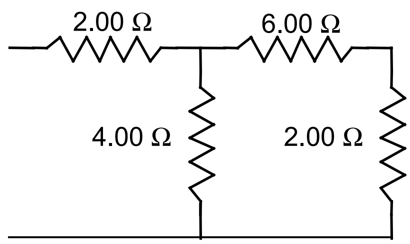
SOLUTION The 1.00 Ω, 2.00 Ω and 3.00 Ω resistors are in series with an equivalent resistance of $R_S = 6.00\ \Omega$.



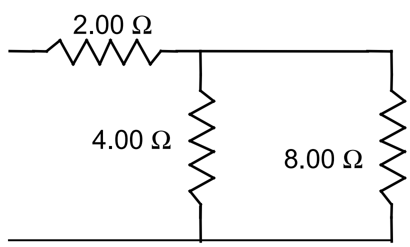
This equivalent resistor of 6.00 Ω is in parallel with the 3.00-Ω resistor, so

$$\frac{1}{R_P} = \frac{1}{6.00\ \Omega} + \frac{1}{3.00\ \Omega}$$

$$R_P = 2.00\ \Omega$$



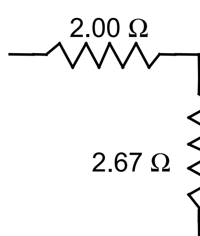
This new equivalent resistor of 2.00 Ω is in series with the 6.00-Ω resistor, so $R_S' = 8.00\ \Omega$.



R_S' is in parallel with the 4.00-Ω resistor, so

$$\frac{1}{R_P'} = \frac{1}{8.00\ \Omega} + \frac{1}{4.00\ \Omega}$$

$$R_P' = 2.67\ \Omega$$



Finally, R_P' is in series with the 2.00-Ω, so the total equivalent resistance is $\boxed{4.67\ \Omega}$.

67. **SSM** ***REASONING*** The terminal voltage of the battery is given by $V_{\text{terminal}} = \text{Emf} - Ir$, where r is the internal resistance of the battery. Since the terminal voltage is observed to be one-half of the emf of the battery, we have $V_{\text{terminal}} = \text{Emf}/2$ and $I = \text{Emf}/(2r)$. From Ohm's law, the equivalent resistance of the circuit is $R = \text{emf}/I = 2r$. We can also find the equivalent resistance of the circuit by considering that the identical bulbs are in parallel across the battery terminals, so that the equivalent resistance of the N bulbs is found from

$$\frac{1}{R_{\text{p}}} = \frac{N}{R_{\text{bulb}}} \qquad \text{or} \qquad R_{\text{p}} = \frac{R_{\text{bulb}}}{N}$$

This equivalent resistance is in series with the battery, so we find that the equivalent resistance of the circuit is

$$R = 2r = \frac{R_{\text{bulb}}}{N} + r$$

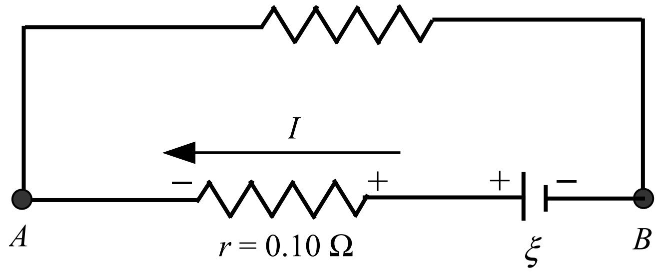
This expression can be solved for N.

SOLUTION Solving the above expression for N, we have

$$N = \frac{R_{\text{bulb}}}{2r - r} = \frac{R_{\text{bulb}}}{r} = \frac{15\ \Omega}{0.50\ \Omega} = \boxed{30}$$

---

70. ***REASONING*** The drawing shows the battery (emf = ξ), its internal resistance *r*, and the light bulb (represented as a resistor). The voltage between the terminals of the battery is the voltage V_{AB} between the points *A* and *B* in the drawing. This voltage is not equal to the emf of the battery, because part of the emf is needed to make the current *I* go through the internal resistance. Ohm's law states that this part of the emf is Ir. The current can be determined from the relation $P = IV_{AB}$, since the power *P* delivered to the light bulb and the voltage V_{AB} across it are known.



SOLUTION The terminal voltage V_{AB} is equal to the emf ξ of the battery minus the voltage across the internal resistance *r,* which is Ir (Equation 20.2): $V_{AB} = \xi - Ir$. Solving this equation for the emf gives

$$\xi = V_{AB} + Ir \qquad (1)$$

The current also goes through the light bulb, and it is related to the power *P* delivered to the bulb and the voltage V_{AB} according to $I = P/V_{AB}$ (Equation 20.6a). Substituting this expression for the current into Equation (1) gives

$$\xi = V_{AB} + Ir = V_{AB} + \left(\frac{P}{V_{AB}}\right) r$$

$$= 11.8\text{ V} + \left(\frac{24\text{ W}}{11.8\text{ V}}\right)(0.10\ \Omega) = \boxed{12.0\text{ V}}$$