Chapter 23: Series and Parallel Circuits

Practice Problems

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1. There are three 20–Ω resistors connected in series across a 120–V generator.

   a. What is the effective resistance of the circuit?

   $$R = R_1 + R_2 + R_3$$
   $$= 20\ \Omega + 20\ \Omega + 20\ \Omega$$
   $$= 60\ \Omega$$

   b. What is the current in the circuit?

   $I = V/R = (120\ \text{V})/(60\ \Omega) = 2.0\ \text{A}$

2. A 10–Ω resistor, a 15–Ω resistor, and a 5–Ω resistor are connected in series across a 90–V battery.

   a. What is the effective resistance of the circuit?

   $R = 10\ \Omega + 15\ \Omega + 5\ \Omega = 30\ \Omega$

   b. What is the current in the circuit?

   $I = V/R = (90\ \text{V})/(30\ \Omega) = 3.0\ \text{A}$

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3. Consider a 9–V battery in a circuit with three resistors connected in series.

   a. If the resistance of one of the devices increases, how will the series resistance change?

   It will increase.

   b. What will happen to the current?

   $I = V/R$, so it will decrease.

   c. Will there be any change in the battery voltage?

   No. It does not depend on the resistance.

Practice Problems

4. Ten Christmas tree bulbs connected in series have equal resistances. When connected to 120–V outlet, the current through the bulbs is 0.06 A.

   a. What is the effective resistance of the circuit?

   $R = V/I = (120\ \text{V})/(0.06\ \text{A}) = 2000\ \Omega$

   b. What is the resistance of each bulb?

   $2000\ \Omega/10 = 200\ \Omega$

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5. A 20.0–Ω resistor and a 30.0–Ω resistor are connected in series and placed across a 120–V potential difference.

   a. What is the effective resistance of the circuit?

   $R = 20.0\ \Omega + 30.0\ \Omega = 50.0\ \Omega$

   b. What is the current in the circuit?

   $I = V/R = (120\ \text{V})/(50.0\ \Omega) = 2.40\ \text{A}$

   c. What is the voltage drop across each resistor?

   $V = IR$. Across 20.0 Ω–resistor,
   $V = (2.40\ \text{A})(20.0\ \Omega) = 48.0\ \text{V}$.
   Across 30.0 Ω–resistor,
   $V = (2.40\ \text{A})(30.0\ \Omega) = 72.0\ \text{V}$

   d. What is the voltage drop across the two resistors together?

   $V = 48.0\ \text{V} + 72.0\ \text{V} = 120\ \text{V}$

6. Three resistors of 3.0 kΩ ($3.0 \times 10^3\ \Omega$), 5.0 kΩ, and 4.0 kΩ are connected in series across a 12–V battery.

   a. What is the effective resistance?

   $R = 3.0\ \text{k}\Omega + 5.0\ \text{k}\Omega + 4.0\ \text{k}\Omega = 12.0\ \text{k}\Omega$

b. What is the current through the resistors?

$I = V/R = (12\ \text{V})/(12.0\ \text{k}\Omega)$
$= 1.0\ \text{mA} = 1.0 \times 10^{-3}\ \text{A}$

c. What is the voltage drop across each resistor?

$V = IR$,
so $V = 3.0\ \text{V}, 5.0\ \text{V}$, and $4.0\ \text{V}$

d. Find the total voltage drop across the three resistors.

$V = 3.0\ \text{V} + 5.0\ \text{V} + 4.0\ \text{V}$
$= 12.0\ \text{V}$

7. A student makes a voltage divider from a 45-V battery, a 475-kΩ ($475 \times 10^3\ \Omega$) resistor, and a 235-kΩ resistor. The output voltage is measured across the smaller resistor. What is the voltage?

$V_2 = VR_2/(R_1 + R_2)$
$= (45\ \text{V})(235\ \text{k}\Omega)/(475\ \text{k}\Omega + 235\ \text{k}\Omega)$
$= 15\ \text{V}$

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8. A photoresistor is used in a voltage divider as R_2. $V = 9.0\ \text{V}$ and $R_1 = 500\ \Omega$.

a. What is the output voltage, V_2 across R_2, when a bright light strikes the photoresistor and $R_2 = 475\ \Omega$?

$V_2 = VR_2/(R_1 + R_2)$
$= (9.0\ \text{V})(475\ \Omega)/(500\ \Omega + 475\ \Omega)$
$= 4.4\ \text{V}$

b. When the light is dim, $R_2 = 4.0\ \text{k}\Omega$. What is V_2?

$V_2 = VR_2/(R_1 + R_2)$
$= (9.0\ \text{V})(4.0\ \text{k}\Omega)/(0.50\ \text{k}\Omega + 4.0\ \text{k}\Omega)$
$= 8.0\ \text{V}$

c. When the photoresistor is in total darkness, $R_2 = 0.40\ \text{M}\Omega$ ($0.40 \times 10^6\ \Omega$). What is V_2?

$$V_2 = VR_2/(R_1 + R_2) = \frac{(9.0\ \text{V})(4.0 \times 10^5\ \Omega)}{(0.005 \times 10^5\ \Omega + 4.0 \times 10^5\ \Omega)} = 9.0\ \text{V}$$

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9. Three 15-Ω resistors are connected in parallel and placed across a 30-V potential difference.

a. What is the equivalent resistance of the parallel circuit?

$1/R = 1/R_1 + 1/R_2 + 1/R_3$
$= 3/15\ \Omega,\ R = 5.0\ \Omega$

b. What is the current through the entire circuit?

$I = V/R = (30\ \text{V})/(5.0\ \Omega) = 6.0\ \text{A}$

c. What is the current through each branch of the parallel circuit?

$I = V/R = (30\ \text{V})/(15.0\ \Omega) = 2.0\ \text{A}$

10. A 12.0-Ω resistor and a 15.0-Ω resistor are connected in parallel and placed across the terminals of a 15.0-V battery.

a. What is the equivalent resistance of the parallel circuit?

$1/R = 1/15.0\ \Omega + 1/12.0\ \Omega$, so
$R = 6.67\ \Omega$

b. What is the current through the entire circuit?

$I = V/R = (15.0\ \text{V})/(6.67\ \Omega) = 2.25\ \text{A}$

c. What is the current through each branch of the parallel circuit?

$I = V/R = (15.0\ \text{V})/(15.0\ \Omega)$
$= 1.00\ \text{A},\ (15.0\ \text{V})/(12.0\ \Omega)$
$= 1.25\ \text{A}$

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11. A 120.0-Ω resistor, a 60.0-Ω resistor, and a 40.0-Ω resistor are connected in parallel and placed across a potential difference of 12.0 V.

a. What is the equivalent resistance of the parallel circuit?

$1/R = 1/120.0\ \Omega + 1/60.0\ \Omega + 1/40.0\ \Omega$,
$R = 20.0\ \Omega$

b. What is the current through the entire circuit?

$$I = V/R$$
$$= (12.0\ \text{V})/(20.0\ \Omega)$$
$$= 0.600\ \text{A}$$

c. What is the current through each branch of the parallel circuit?

$$I = V/R = (12.0\ \text{V})/(120.0\ \Omega)$$
$$= 0.100\ \text{A},\ (12.0\ \text{V})/(60.0\ \Omega)$$
$$= 0.200\ \text{A},\ (12.0\ \text{V})/(40.0\ \Omega)$$
$$= 0.300\ \text{A}$$

12. Suppose the 12.0-Ω resistor in Practice Problem 10 is replaced by a 10.0-Ω resistor.

a. Does the equivalent resistance become smaller, larger, or remain the same?

Smaller.

b. Does the amount of current through the entire circuit change? in what way?

Gets larger.

c. Does the amount of current through the 15.0-Ω resistor change? in what way?

No. It remains the same. Currents are independent.

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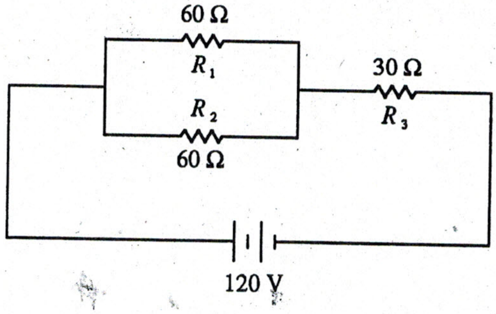
13. Two 60-Ω resistors are connected in parallel. This parallel arrangement is connected in series with a 30-Ω resistor. The combination is then placed across a 120-V potential difference.

a. Draw a diagram of the circuit.



Practice Problems

b. What is the equivalent resistance of the parallel portion of the circuit?

$$\frac{1}{R} = \frac{1}{60\ \Omega} + \frac{1}{60\ \Omega} = \frac{2}{60\ \Omega}$$

$$R = \frac{60\ \Omega}{2} = 30\ \Omega$$

c. What single resistance could replace the three original resistors?

$$R_{\text{eff}} = 30\ \Omega + 30\ \Omega = 60\ \Omega$$

d. What is the current in the circuit?

$$I = \frac{V}{R} = \frac{120\ \text{V}}{60\ \Omega} = 2.0\ \text{A}$$

e. What is the voltage drop across the 30-Ω resistor?

$$V_3 = IR_3 = (2.0)(30\ \Omega) = 60\ \text{V}$$

f. What is the voltage drop across the parallel portion of the circuit?

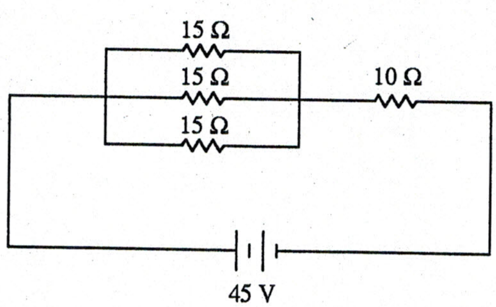
$$V = IR = (2.0\ \text{A})(30\ \Omega) = 60\ \text{V}$$

g. What is the current in each branch of the parallel portion of the circuit?

$$I = \frac{V}{R_1} = \frac{V}{R_2} = \frac{60\ \text{V}}{60\ \Omega} = 1.0\ \text{A}$$

14. Three 15-Ω resistors are connected in parallel. This arrangement is connected in series with a 10-Ω resistor. The entire combination is then placed across a 45-V difference in potential.

a. Draw a diagram of the circuit.



b. What is the equivalent resistance of the parallel portion of the circuit?

$$\frac{1}{R} = \frac{1}{15\ \Omega} + \frac{1}{15\ \Omega} + \frac{1}{15\ \Omega} = \frac{3}{15\ \Omega}$$

$$R = \frac{15\ \Omega}{3} = 5.0\ \Omega$$

c. What is the equivalent resistance of the entire circuit?

$$R_{eff} = 5\ \Omega + 10\ \Omega = 15\ \Omega$$

d. What is the current in the entire circuit?

$$I = \frac{V}{R_{eff}} = \frac{45\ V}{15\ \Omega} = 3.0\ A$$

e. What is the voltage drop across the 10-Ω resistor?

$$V = IR = (3.0\ A)(10\ \Omega) = 30\ V$$

15. Suppose you are given three 68-Ω resistors. You can use them in a series, parallel, or series-parallel circuit. Find the three different resistances you can produce in the circuit.

Series: $68\ \Omega + 68\ \Omega + 68\ \Omega = 204\ \Omega$,
Parallel: $68\ \Omega/3 = 23\ \Omega$,
Series Parallel: $68\ \Omega + 68\ \Omega/2 = 102\ \Omega$

Chapter Review Problems

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1. A 20.0-Ω lamp and a 5.0-Ω lamp are connected in series and placed across a difference in potential of 50 V.

a. What is the effective resistance of the circuit?

$$20.0\ \Omega + 5.0\ \Omega = 25.0\ \Omega$$

b. What is the current in the circuit?

$$I = \frac{V}{R} = \frac{50\ V}{25.0\ \Omega} = 2.0\ A$$

c. What is the voltage drop across each lamp?

$$V = IR = (2.0\ A)(20.0\ \Omega) = 40\ V$$
$$V = IR = (2.0\ A)(5.0\ \Omega) = 10\ V$$

d. What is the power dissipated in each lamp?

$$P = IV = (2.0\ A)(40\ V) = 80\ W$$
$$P = IV = (2.0\ A)(10\ V) = 20\ W$$

2. Three identical lamps are connected in series to a 6.0-V battery. What is the voltage drop across each lamp?

Since each lamp is identical to the others, they will each have the same voltage drop of

$$\frac{6.0\ V}{3} = 2.0\ V.$$

3. The load across a 12-V battery consists of a series combination of three resistors of 15 Ω, 21 Ω, and 24 Ω.

a. What is the total resistance of the load?

$$R = R_1 + R_2 + R_3 = 15\ \Omega + 21\ \Omega + 24\ \Omega = 60\ \Omega$$

b. What is the current in the circuit?

$$I = \frac{V}{R} = \frac{12\ V}{60\ \Omega} = 0.20\ A$$

4. The load across a battery consists of two resistors connected in series with values of 15 Ω and 45 Ω.

a. What is the total resistance of the load?

$$R = R_1 + R_2 = 15\ \Omega + 45\ \Omega = 60\ \Omega$$

b. What is the voltage of the battery if the current in the circuit is 0.10 A?

$$V = IR = (60\ \Omega)(0.10\ A) = 6.0\ V$$

5. A lamp having a resistance of 10 Ω is connected across a 15-V battery.

a. What is the current through the lamp?

$$V = IR, \text{ so } I = \frac{V}{R} = \frac{15\ V}{10\ \Omega} = 1.5\ A$$

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b. What resistance must be connected in series with the lamp to reduce the current to 0.50 A?

The total resistance is given by $V = IR$, so

$$R = \frac{V}{I} = \frac{15\ \text{V}}{0.50\ \text{A}} = 30\ \Omega$$

And $R = R_1 + R_2$, so

$R_2 = R - R_1 = 30\ \Omega - 10\ \Omega = 20\ \Omega$

6. A string of eighteen identical Christmas tree lights are connected in series to a 120–V source. The string dissipates 64 W.

a. What is the equivalent resistance of the light string?

$$P = IV, \text{ so } I = \frac{P}{V} = \frac{64\ \text{W}}{120\ \text{V}} = 0.53\ \text{A and}$$

$$V = IR, \text{ so } R = \frac{V}{I} = \frac{120\ \text{V}}{0.53\ \text{A}} = 2.3 \times 10^2\ \Omega$$

b. What is the resistance of a single light?

R is sum of resistances of 18 lamps, so each resistance is $(230\ \Omega)/18 = 13\ \Omega$.

c. What power is dissipated by each lamp?

$(64\ \text{W})/18 = 3.6\ \text{W}$

7. One of the bulbs in the previous problem burns out. The lamp has a wire that shorts out the lamp filament when it burns out. This drops the resistance of the lamp to zero.

a. What is the resistance of the light string now?

There are now 17 lamps in series instead of 18 lamps. The resistance is

$$\frac{17}{18}(2.3 \times 10^2\ \Omega) = 2.2 \times 10^2\ \Omega$$

b. Find the power dissipated by the string.

$$I = \frac{V}{R} = \frac{120\ \text{V}}{2.2 \times 10^2\ \Omega} = 0.55\ \text{A and}$$

$$P = IV = (0.55\ \text{A})(120\ \text{V}) = 66\ \text{W}$$

c. Did the power go up or down when a bulb burned out?

It increased!

8. A 75.0–W bulb is connected to a 120–V source.

a. What is the current through the bulb?

$$P = IV, \text{ so } I = \frac{P}{V} = \frac{75.0\ \text{W}}{120\ \text{V}} = 0.625\ \text{A}$$

b. What is the resistance of the bulb?

$$V = IR, \text{ so } R = \frac{V}{I} = \frac{120\ \text{V}}{0.625\ \text{A}} = 192\ \Omega$$

c. A lamp dimmer puts a resistance in series with the bulb. What resistance would be needed to reduce the current to 0.300 A?

$$V = IR, \text{ so } R = \frac{V}{I} = \frac{120\ \text{V}}{0.300\ \text{A}} = 400\ \Omega \text{ and}$$

$R = R_1 + R_2$, so

$R_2 = R - R_1 = 400\ \Omega - 192\ \Omega = 208\ \Omega$

9. In the previous problem, you found the resistance of a lamp and a dimmer resistor.

a. Assuming the resistances are constant, find the voltage drops across the lamp and the resistor.

$V = IR = (0.300\ \text{A})(192\ \text{V}) = 57.6\ \text{V}$

$V = IR = (0.300\ \text{A})(208\ \text{V}) = 62.4\ \text{V}$

b. Find the power dissipated by the lamp.

$P = IV = (0.300\ \text{A})(57.6\ \text{V}) = 17.3\ \text{W}$

c. Find the power dissipated by the dimmer resistor.

$P = IV = (0.300\ \text{A})(62.4\ \text{V}) = 18.7\ \text{W}$

10. Amy needs 5.0 V for some integrated circuit experiments. She uses a 6.0–V battery and two resistors to make a voltage divider. One resistor is 330 Ω. She decides to make the other resistor smaller. What value should it have?

$V_2 = \dfrac{VR_2}{R_1 + R_2}$. Since V_2 is more than half V, the voltage across R_2 is larger than that across R_1, so $R_2 > R_1$.

$$R_1 = \frac{VR_2}{V_2} - R_2 = \frac{(6.0\ \text{V})(330\ \Omega)}{5.0\ \text{V}} - 330\ \Omega$$

$$= 66\ \Omega$$

Chapter Review Problems

11. Pete is designing a voltage divider using a 12.0–V battery and a 100–Ω resistor as R_2. What resistor should be used as R_1 if the output voltage across R_2 is to be 4.00 V?

$$V_2 = \frac{VR_2}{R_1 + R_2}, \text{ or } R_1 + R_2 = \frac{VR_2}{R_2}, \text{ so}$$

$$R_1 = \frac{VR_2}{V_2} - R_2 = \frac{(12.0\ \text{V})(100\ \Omega)}{4.00\ \text{V}} - 100\ \Omega$$

$$= 200\ \Omega$$

12. A typical television dissipates 275 W when connected to a 120–V outlet.

a. Find the resistance of the television.

$$P = IV \text{ and } I = \frac{V}{R}, \text{ so } P = \frac{V^2}{R}, \text{ or}$$

$$R = \frac{V^2}{P} = \frac{(120\ \text{V})^2}{275\ \text{W}} = 52.4\ \Omega$$

b. The television and connecting wires, with a resistance of 2.5 Ω, form a series circuit that works like a voltage divider. Find the voltage drop across the television.

$$V_1 = \frac{VR_1}{R_1 + R_2} = \frac{(120\ \text{V})(52.4\ \Omega)}{52.4\ \Omega + 2.5\ \Omega}$$

$$= 115\ \text{V}$$

c. A 12–Ω hair dryer is now plugged into the same outlet. Find the equivalent resistance of the two appliances.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{52.4\ \Omega} + \frac{1}{12\ \Omega} = 9.8\ \Omega$$

d. Find the voltage drop across the television and hair dryer combination. The lower voltage explains why the television picture sometimes shrinks when another appliance is turned on.

$$V_1 = \frac{VR_1}{R_1 + R_2} = \frac{(120\ \text{V})(9.8\ \Omega)}{9.8\ \Omega + 2.5\ \Omega} = 96\ \text{V}$$

13. Three identical lamps are connected in parallel to each other and then connected to a 6.0–V battery. What is the voltage drop across each lamp?

In parallel circuits, the voltage drop across each branch are the same, in this case 6.0 V.

14. A 16.0–Ω and a 20.0–Ω resistor are connected in parallel. A difference in potential of 40.0 V is applied to the combination.

a. Compute the equivalent resistance of the parallel circuit.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{16.0\ \Omega} + \frac{1}{20.0\ \Omega}$$

$$R = \frac{1}{0.1125\ \Omega} = 8.89\ \Omega$$

b. What is the current in the circuit?

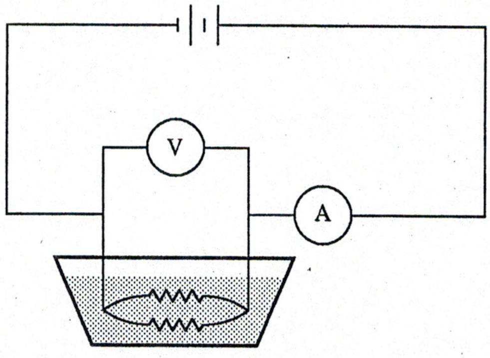
$$I = \frac{V}{R} = \frac{40.0\ \text{V}}{8.89\ \Omega} = 4.50\ \text{A}$$

c. How large is the current through the 16.0–Ω resistor?

$$I_1 = \frac{V}{R_1} = \frac{40.0\ \text{V}}{16.0\ \Omega} = 2.50\ \text{A}$$

15. During a laboratory exercise, you are supplied with the following apparatus: a battery of potential difference V, two heating elements of low resistance that can be placed in water, an ammeter of negligible resistance, a voltmeter of extremely high resistance, wires of negligible resistance, a beaker that is well-insulated and has negligible heat capacity, 100.0 g of water at 25°C.

a. By means of a diagram using standard symbols, show how these components should be connected to heat the water as rapidly as possible.



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b. If the voltmeter reading holds steady at 50.0 V and the ammeter reading holds steady at 5.0 A, estimate the time in seconds required to completely vaporize the water in the beaker. Use 4200 J/kg·C° as the specific heat of water and 2.30×10^6 J/kg as the heat of vaporization of water.

$$\Delta Q = mc\Delta T = (100.0\ \text{g})(4.2\ \text{J/g}\cdot\text{C}^\circ)(75\ \text{C}^\circ) = 32\ 000\ \text{J}$$

$$\Delta Q = mL_v = (100.0\ \text{g})(2300\ \text{J/g}) = 230\ 000\ \text{J}$$

$$\Delta Q_{total} = 32\ 000\ \text{J} + 230\ 000\ \text{J} = 260\ 000\ \text{J}$$

Energy is provided at the rate of
$P = IV = (5.0\ \text{A})(50.0\ \text{V}) = 250\ \text{J/s}$

The time required is $t = \frac{260\ 000\ \text{J}}{250\ \text{J/s}}$

$$= 1.0 \times 10^3\ \text{s}$$

16. A circuit contains six 240-Ω lamps, 60-W bulbs, and a 10.0-Ω heater connected in parallel. The voltage across the circuit is 120 V. What is the current in the circuit

a. when four lamps are turned on?

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{240\ \Omega} + \frac{1}{240\ \Omega} + \frac{1}{240\ \Omega} + \frac{1}{240\ \Omega}$$

$$= \frac{4}{240\ \Omega},\ \text{so}$$

$$R = \frac{240\ \Omega}{4} = 60\ \Omega$$

$$I = \frac{V}{R} = \frac{120\ \text{V}}{60\ \Omega} = 2.0\ \text{A}$$

b. when all six lamps are turned on?

$$\frac{1}{R} = \frac{6}{240\ \Omega}$$

$$R = \frac{240\ \Omega}{6} = 40\ \Omega$$

$$I = \frac{V}{R} = \frac{120\ \text{V}}{40\ \Omega} = 3.0\ \text{A}$$

c. if all six lamps and the heater are operating?

$$\frac{1}{R} = \frac{1}{40\ \Omega} + \frac{1}{10.0\ \Omega} = \frac{5}{40\ \Omega}$$

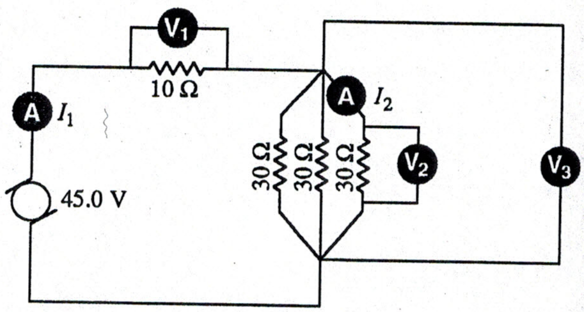
$$R = \frac{40\ \Omega}{5} = 8.0\ \Omega$$

$$I = \frac{V}{R} = \frac{120\ \text{V}}{8.0\ \Omega} = 15\ \text{A}$$

d. If the circuit has a fuse rated at 12 A, will it melt if everything is on?

Yes. The 15-A current will melt the 12-A fuse.

17. Determine the reading of each ammeter and each voltmeter in Figure 23-18.



The three resistors in parallel have a total resistance of

$$\frac{1}{R_E} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{30.0\ \Omega} + \frac{1}{30.0\ \Omega} + \frac{1}{30.0\ \Omega},\ \text{so}$$

$R_E = 10.0\ \Omega$.
The total resistance of the circuit is
$R_T = R_1 + R_E = 10.0\ \Omega + 10.0\ \Omega = 20.0\ \Omega$

$$I_1 = \frac{V}{R_T} = \frac{45.0\ \text{V}}{20.0\ \Omega} = 2.25\ \text{A}$$

$V_1 = IR_1 = (2.25\ \text{A})(10.0\ \Omega) = 22.5\ \text{V}$
Because the ammeter has an internal resistance of almost zero,
$V_2 = V_3 = 45.0\ \text{V} - V_1 = 45.0\ \text{V} - 22.5\ \text{V} = 22.5\ \text{V}$

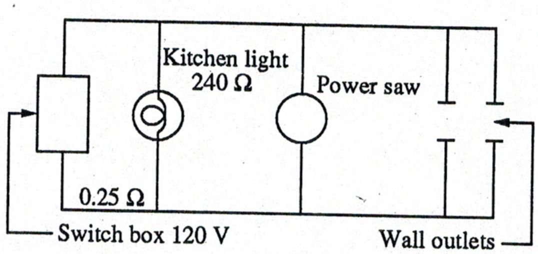
$$I_2 = \frac{V_2}{R_2} = \frac{22.5\ \text{V}}{30.0\ \Omega} = 0.750\ \text{A}$$

18. Determine the power used by each resistance shown in Figure 23–18.

Some information is from the previous problem. See figure from Problem 17.

In the 10–Ω resistor,
$P_1 = I_1V_1 = (2.25\ \text{A})(22.5\ \text{V}) = 50.6\ \text{W}$
In each of the 30–Ω resistors the power will be equal to
$P = IV = (0.750\ \text{A})(22.5\ \text{V}) = 16.9\ \text{W}$.

19. A typical home circuit is diagrammed in Figure 23–19. Note that the lead lines to the kitchen lamp each have very low resistances of 0.25 Ω. The lamp has a resistance of 240.0 Ω. Although the circuit is a parallel circuit, the lead lines are in series with each of the components of the circuit.



a. Compute the effective resistance of the circuit consisting of just the light and the lead lines to and from the light.

$R = 0.25\ \Omega + 0.25\ \Omega + 240\ \Omega = 240\ \Omega$

b. Find the current to the bulb.

$I = \frac{V}{R} = \frac{120\ \text{V}}{240\ \Omega} = 0.50\ \text{A}$

c. Find the power rating of the bulb.

$P = IV = (0.50\ \text{A})(120\ \text{V}) = 60\ \text{W}$

d. Since the current in the bulb is 0.50 A, the current in the lead lines must also be 0.50 A. Calculate the voltage drop due to the two leads.

$V = IR = (0.50\ \text{A})(0.50\ \Omega) = 0.25\ \text{V}$

Chapter Review Problems

20. A power saw is operated by an electric motor. When the electric motor is first turned on, it has a very low resistance. Suppose that the kitchen light discussed in the previous problem is on and a power saw is suddenly turned on. The saw plus the lead lines have an initial total resistance of 6.0 Ω.

a. Compute the effective resistance of the light–saw parallel circuit.

$\frac{1}{R} = \frac{1}{240\ \Omega} + \frac{1}{6.0\ \Omega}$

$R = 5.9\ \Omega$
$R_{eff} = 5.9\ \Omega + 0.25\ \Omega + 0.25\ \Omega = 6.4\ \Omega$

b. What current flows to the light?

$I = \frac{V}{R} = \frac{120\ \text{V}}{6.4\ \Omega} = 19\ \text{A}$

c. What is the total voltage drop across the two leads to the light?

$V = IR = (19\ \text{A})(0.50\ \Omega) = 9.5\ \text{V}$

d. What voltage remains to operate the light? Will this voltage cause the light to dim temporarily?

$V = 120\ \text{V} - 9.5\ \text{V} = 110\ \text{V}$
Yes, this will cause a momentary dimming.

Supplementary Problems (Appendix B)

1. The load across a 50.0–V battery consists of a series combination of two lamps with resistances of 125 Ω and 225 Ω.

a. Find the total resistance of the circuit.

$R_T = R_1 + R_2 = 125\ \Omega + 225\ \Omega = 350\ \Omega$

b. Find the current in the circuit.

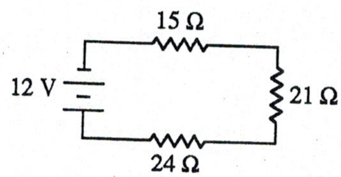
$V = IR$, so $I = \frac{V}{R} = \frac{50.0\ \text{V}}{350\ \Omega} = 0.143\ \text{A}$

c. Find the potential difference across the 125–Ω lamp.

$V = IR = (0.143\ \text{A})(125\ \Omega) = 17.9\ \text{V}$

2. The load across a 12–V battery consists of a series combination of three resistances that are 15 Ω, 21 Ω, and 24 Ω respectively.

a. Draw the circuit diagram.



b. What is the total resistance of the load?

$R_T = R_1 + R_2 + R_3 = 15\ \Omega + 21\ \Omega + 24\ \Omega = 60\ \Omega$

c. What is the magnitude of the circuit current?

$V = IR$, so $I = \frac{V}{R} = \frac{12\ \text{V}}{60\ \Omega} = 0.20\ \text{A}$

3. The load across a 12–V battery consists of a series combination of three resistances R_1, R_2, and R_3. R_1 is 210 Ω, R_2 is 350 Ω and R_3 is 120 Ω.

a. Find the equivalent resistance of the circuit.

$$R_T = R_1 + R_2 + R_3 = 210\ \Omega + 350\ \Omega + 120\ \Omega = 680\ \Omega$$

b. Find the current in the circuit.

$V = IR$, so

$I = \frac{V}{R} = \frac{12\ \text{V}}{680\ \Omega} = 1.8 \times 10^{-2}\ \text{A} = 18\ \text{mA}$

c. Find the potential difference across R_3.

$V = IR = (1.8 \times 10^{-2}\ \text{A})(120\ \Omega) = 2.2\ \text{V}$

4. The load across a 40–V battery consists of a series combination of three resistances, R_1, R_2, and R_3. R_1 is 240 Ω, and R_3 is 120 Ω. The potential difference across R_1 is 24 V.

a. Find the current in the circuit.

$V = IR$, so $I = \frac{V_1}{R_1} = \frac{24\ \text{V}}{240\ \Omega} = 0.10\ \text{A}$

b. Find the equivalent resistance of the circuit.

$V = IR$, so $R = \frac{V}{I} = \frac{40\ \text{V}}{0.10\ \text{A}} = 400\ \Omega$

c. Find the resistance of R_2.

$$R_T = R_1 + R_2 + R_3, \text{ so}$$
$$R_2 = R_T - R_1 - R_3 = 400\ \Omega - 240\ \Omega - 120\ \Omega = 40\ \Omega$$

5. Pete is designing a voltage divider using a 12.0–V battery and a 100–Ω resistor as R_2. What resistor should be used as R_1 if the output voltage is 4.75 V?

$V_2 = \frac{VR_2}{R_1 + R_2}$, so $(R_1 + R_2)V_2 = VR_2$ and

$R_1V_2 = VR_2 - V_2R_2$, so

$$R_1 = \left[\frac{V - V_2}{V_2}\right]R_2 = \left[\frac{12.0 - 4.75}{4.75}\right]100\ \Omega = 153\ \Omega$$

6. Two resistances, one 12 Ω and the other 18 Ω, are connected in parallel. What is the equivalent resistance of the parallel combination?

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{12\ \Omega} + \frac{1}{18\ \Omega}$, so $R = 7.2\ \Omega$

7. Three resistances of 12 Ω each are connected in parallel. What is the equivalent resistance?

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{12\ \Omega} + \frac{1}{12\ \Omega} + \frac{1}{12\ \Omega} = \frac{3}{12\ \Omega} = \frac{1}{4.0\ \Omega}, \text{ so } R = 4.0\ \Omega$$

8. Two resistances, one 62 Ω and the other 88 Ω, are connected in parallel. The resistors are then connected to a 12 V battery.

a. What is the equivalent resistance of the parallel combination?

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{62\ \Omega} + \frac{1}{88\ \Omega},$$

so $R = 36\ \Omega$

b. What is the current through each resistor?

$$V = IR, \text{ so } I = \frac{V}{R} = \frac{12\ \text{V}}{62\ \Omega} = 0.19\ \text{A}$$

$$I = \frac{V}{R} = \frac{12\ \text{V}}{88\ \Omega} = 0.14\ \text{A}$$

9. A 35 Ω, 55 Ω and 85 Ω resistor are connected in parallel. The resistors are then connected to a 35 V battery.

a. What is the equivalent resistance of the parallel combination?

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{35\ \Omega} + \frac{1}{55\ \Omega} + \frac{1}{85\ \Omega}, \text{ so}$$

$R = 17\ \Omega$

b. What is the current through each resistor?

$$V = IR, \text{ so } I_1 = \frac{V}{R_1} = \frac{35\ \text{V}}{35\ \Omega} = 1.0\ \text{A}$$

$$I_2 = \frac{V}{R_2} = \frac{35\ \text{V}}{55\ \Omega} = 0.64\ \text{A}$$

$$I_3 = \frac{V}{R_3} = \frac{35\ \text{V}}{85\ \Omega} = 0.41\ \text{A}$$

10. A 110 V household circuit that contains a 1800 W microwave, a 1000 W toaster, and a 800 W coffee maker is connected to a 20 A fuse. Will the fuse melt if the microwave and the coffee maker are both on?

$P = IV$, so

$$I = \frac{P}{V} = \frac{1800\ \text{W}}{110\ \text{V}} = 16.4\ \text{A} \quad \text{(microwave)}$$

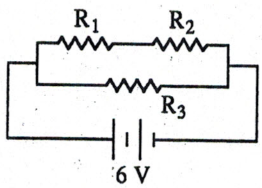
$$I = \frac{P}{V} = \frac{800\ \text{W}}{110\ \text{V}} = 7.27\ \text{A} \quad \text{(coffee maker)}$$

Total current of 23.7 A is greater than 20 A so the fuse will melt.

Supplemental Problems

11. Resistors R_1, R_2, and R_3 have resistances of 15.0 Ω, 9.0 Ω, and 8.0 Ω respectively. R_1 and R_2 are connected in series and their combination is in parallel with R_3 to form a load across a 6.0 Volt battery.

a. Draw the circuit diagram.



b. What is the total resistance of the load?

$R_1 + R_2 = 15.0\ \Omega + 9.0\ \Omega = 24.0\ \Omega$

$$\frac{1}{R_T} = \frac{1}{R_{12}} + \frac{1}{R_3} = \frac{1}{24.0\ \Omega} + \frac{1}{8.0\ \Omega}, \text{ so}$$

$R_T = 6.0\ \Omega$

c. What is the magnitude of the circuit current?

$$V = IR, \text{ so } I = \frac{V}{R} = \frac{6.0\ \text{V}}{6.0\ \Omega} = 1.0\ \text{A}$$

d. What is the current in R_3?

$$V = IR, \text{ so } I_3 = \frac{V}{R_3} = \frac{6.0\ \text{V}}{8.0\ \Omega} = 0.75\ \text{A}$$

e. What is the potential difference across R_2?

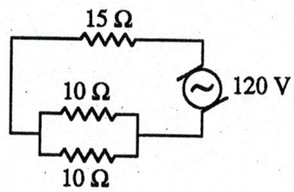
$I_T = I_2 + I_3$, so

$I_2 = I_T - I_3 = 1.0\ \text{A} - 0.75\ \text{A} = 0.25\ \text{A}$ and

$V_2 = I_2R_2 = (0.25\ \text{A})(9.0\ \Omega) = 2.3\ \text{V}$

12. A 15.0 Ω resistor is connected in series to a 120 Volt generator and two 10.0 Ω resistors that are connected in parallel to each other.

a. Draw the circuit diagram.



b. What is the total resistance of the load?

$$\frac{1}{R_{12}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10.0\ \Omega} + \frac{1}{10.0\ \Omega} = \frac{1}{5.0\ \Omega},$$

so $R_{12} = 5.0\ \Omega$

$R_T = R_3 + R_{12} = 15.0\ \Omega + 5.0\ \Omega = 20.0\ \Omega$

c. What is the magnitude of the circuit current?

$V = IR$, so $I = \frac{V}{R} = \frac{120\ \text{V}}{20.0\ \Omega} = 6.00\ \text{A}$

d. What is the current in one of the 10.0 Ω resistors?

The current would divide equally, so 3.00 A.

e. What is the potential difference across 15.0 Ω resistor?

$V = IR = (6.00\ \text{A})(15.0\ \Omega) = 90.0\ \text{V}$

13. How would you change the resistance of a voltmeter to allow the voltmeter to measure a larger potential difference?

Increase the resistance.

14. How would you change the shunt in an ammeter to allow the ammeter to measure a larger current?

Decrease the resistance of the shunt.

Supplemental Problems

15. An ohmmeter is made by connecting a 6.0 V battery in series with an adjustable resistor and an ideal ammeter. The ammeter deflects full–scale with a current of 1.0 mA. The two leads are touched together and the resistance is adjusted so 1.0 mA current flows.

a. What is the resistance of the adjustable resistor?

$V = IR$, so

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{1.0 \times 10^{-3}\ \text{A}} = 6.0 \times 10^3\ \Omega$$

b. The leads are now connected to an unknown resistance. What external resistance would produce a reading of 0.50 mA, half full–scale?

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.50 \times 10^{-3}\ \text{A}} = 1.2 \times 10^4\ \Omega \text{ and}$$

$R_T = R_I + R_e$, so

$R_e = R_T - R_I = 1.2 \times 10^4\ \Omega - 6.0 \times 10^3\ \Omega = 6 \times 10^3\ \Omega$

c. What external resistance would produce a reading of 0.25 mA, quarter–scale?

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.25 \times 10^{-3}\ \text{A}} = 2.4 \times 10^4\ \Omega \text{ and}$$

$R_e = R_T - R_I = 2.4 \times 10^4\ \Omega - 6.0 \times 10^3\ \Omega = 1.8 \times 10^4\ \Omega$

d. What external resistance would produce a reading of 0.75 mA, three–quarter full–scale?

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.75 \times 10^{-3}\ \text{A}} = 8.0 \times 10^3\ \Omega \text{ and}$$

$R_e = R_T - R_I = 8.0 \times 10^3\ \Omega - 6.0 \times 10^3\ \Omega = 2.0 \times 10^3\ \Omega$