Chapter 23

1. Three 12.0-Ω resistors are connected in series to a 50.0-V power source.
   a. What is the equivalent resistance of the circuit?
      \[ R = R_1 + R_2 + R_3 \]
      \[ = 12.0 \, \Omega + 12.0 \, \Omega + 12.0 \, \Omega \]
      \[ = 36.0 \, \Omega \]
   b. What is the current in the circuit?
      \[ R = \frac{V}{I} \]
      \[ I = \frac{V}{R} \]
      \[ = \frac{50.0 \, \text{V}}{36.0 \, \Omega} \]
      \[ = 1.39 \, \text{A} \]
   c. What is the voltage drop across each resistor?
      \[ V = IR \]
      \[ = (1.39 \, \text{A})(12.0 \, \Omega) \]
      \[ = 16.7 \, \text{V} \]

2. Three 15.0-Ω resistors are connected in parallel to a 45.0-V power source.
   a. What is the equivalent resistance of the circuit?
      \[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]
      \[ = \frac{1}{15.0 \, \Omega} + \frac{1}{15.0 \, \Omega} + \frac{1}{15.0 \, \Omega} \]
      \[ = \frac{3}{15} = \frac{1}{5} \]
      \[ R = 5.00 \, \Omega \]
   b. What is the current in the circuit?
      \[ R = \frac{V}{I} \]
      \[ I = \frac{V}{R} \]
      \[ = \frac{45.0 \, \text{V}}{5.00 \, \Omega} \]
      \[ = 9.00 \, \text{A} \]
   c. What is the current through each resistor?
      \[ R = \frac{V}{I} \]
      \[ I = \frac{V}{R} \]
      \[ = \frac{45.0 \, \text{V}}{15.0 \, \Omega} \]
      \[ = 3.00 \, \text{A} \]

3. Two resistors are connected in series to a power source. The voltage drop across the first resistor is 5.40 V and the voltage drop across the second resistor is 9.80 V. The current through the circuit is 1.20 A.
   a. What is the resistance of each of the resistors?
      \[ R_{5.40V} = \frac{V}{I} \]
      \[ = \frac{5.40 \, \text{V}}{1.20 \, \text{A}} \]
      \[ = 4.50 \, \Omega \]
      \[ R_{9.80V} = \frac{V}{I} \]
      \[ = \frac{9.80 \, \text{V}}{1.20 \, \text{A}} \]
      \[ = 8.17 \, \Omega \]
   b. What is the equivalent resistance of the circuit?
      \[ R = R_1 + R_2 \]
      \[ = 4.50 \, \Omega + 8.17 \, \Omega \]
      \[ = 12.7 \, \Omega \]

4. What is the equivalent resistance of the circuit shown below? What is the current in the circuit? What is the voltage drop across the two resistors wired in parallel?
   Find the equivalent resistance of the resistors in parallel.
   \[ \frac{1}{R_{eq1}} = \frac{1}{R_2} + \frac{1}{R_3} \]
   \[ = \frac{1}{12 \, \Omega} + \frac{1}{12 \, \Omega} \]
   \[ R_{eq1} = 6.0 \, \Omega \]
6. A 12-Ω and an 18-Ω resistor are connected to a 48-V power source.
   a. What is the equivalent resistance of the circuit if the resistors are connected in series?
      \[ R = R_1 + R_2 = 12 \, \Omega + 18 \, \Omega = 3.0 \times 10^1 \, \Omega \]
   b. What is the equivalent resistance of the circuit if the resistors are connected in parallel?
      \[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \]
      \[ = \frac{1}{12.0 \, \Omega} + \frac{1}{18.0 \, \Omega} \]
      \[ = \frac{5}{36} \]
      \[ R = 7.2 \, \Omega \]

7. A voltage divider is made from a 9.0-V battery. Two resistors are connected in series to the battery. If one resistor has a resistance of 24 Ω and the voltage drop across the other resistor must be 4.0 V, what is the resistance of the second resistor?
   Find the current in the circuit.
   Let \( R \) be the unknown resistance.
   Then \( (9.0 \, V) = V_R + V_{24} \)
   \[ = (4.0 \, V) + I(24 \, \Omega) \]
   \[ I = \frac{5.0 \, V}{24 \, \Omega} = 0.21 \, A \]
   Find the resistance of the second resistor.
   \[ R = \frac{V}{I} \]
   \[ = \frac{4.0 \, V}{0.21 \, A} \]
   \[ = 19 \, \Omega \]
8. A circuit is constructed, as shown in the figure below. The voltmeter reads 63.0 V.
   a. Which resistor dissipates the most energy per second?
   \[ R = \frac{V}{I} \]
   \[ I = \frac{V}{R} \]
   \[ = \frac{63.0 \text{ V}}{36 \text{ } \Omega} \]
   \[ = 1.8 \text{ A} \]
   \[ P = I^2R \]
   \[ = (1.8 \text{ A})^2 \times 36 \text{ } \Omega \]
   Thus, the resistor with the highest resistance will dissipate the most energy per second. So, the 54-Ω resistor dissipates the most energy per second.

   b. What is the voltage of the power source?
   \[ R_T = R_1 + R_2 + R_3 \]
   \[ V = IR \]
   \[ = I(R_1 + R_2 + R_3) \]
   \[ = (1.8 \text{ A})(42 \text{ } \Omega + 36 \text{ } \Omega + 54 \text{ } \Omega) \]
   \[ = 240 \text{ V} \]

9. Three identical resistors are connected in parallel across a power source. Their equivalent resistance is 8.00 Ω. What is the resistance of each resistor?
   Let \( R_1 = R_2 = R_3 = R \)
   Then \[ \frac{1}{8} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \]
   \[ = \frac{3}{R} \]
   \[ R = 24.0 \text{ } \Omega \]

10. A 10.0-Ω resistor and a 20.0-Ω resistor are connected in series with a potentiometer and a 9.0-V battery.
    a. What should the potentiometer be set at for a total equivalent resistance of 50.0 Ω in this circuit?
    \[ R_T = R_1 + R_2 + R_P \]
    \[ R_P = R_T - R_1 - R_2 = 50.0 \text{ } \Omega - 10.0 \text{ } \Omega - 20.0 \text{ } \Omega = 20.0 \text{ } \Omega \]
    b. If the potentiometer is set at 32.0 Ω, what would be the current in this circuit?
    \[ R_T = R_1 + R_2 + R_P = 10.0 \text{ } \Omega + 20.0 \text{ } \Omega + 32.0 \text{ } \Omega = 62.0 \text{ } \Omega \]
    \[ I = \frac{V_{source}}{R_T} = \frac{9.0 \text{ V}}{62.0 \text{ } \Omega} = 0.14 \text{ A} \]
    c. If the potentiometer were turned so that the resistance increases, what would happen to the current?
    Since the resistors are connected in series, as \( R_P \) increases, \( R_T \) will increase by the same amount. From Ohm’s law, we see that as resistance and current are inversely proportional so as \( R_T \) increases, the current in the circuit will decrease.

11. A piece of lab equipment must be connected to a standard 6.0-V dry cell. The manual for the equipment says that this device has an internal resistance of 0.10 Ω and cannot handle more than 2.5 A of current.
    a. What value of resistor can you connect in series with this device that would allow it to be connected to the power source?
    From Ohm’s law,
    \[ R_T = \frac{V_{source}}{I} = \frac{6.0 \text{ V}}{2.5 \text{ A}} = 2.4 \text{ } \Omega \]
    \[ R_T = R + R_{internal} \]
    \[ R = R_T - R_{internal} = 2.4 \text{ } \Omega - 0.10 \text{ } \Omega \]
    \[ = 2.3 \text{ } \Omega \]
b. What three resistors of equal value could you use in series instead of the single resistor determined in part a?

From part a, \( R_T = 2.4 \, \Omega \)

\[
R_T = 3R + R_{\text{internal}}
\]

\[
R = \frac{R_T - R_{\text{internal}}}{3}
\]

\[
= \frac{2.4 \, \Omega - 0.10 \, \Omega}{3}
\]

\[
= 0.77 \, \Omega
\]

12. Two resistors are connected in parallel to a 3.0-V power source. The first resistor is marked as 150 \( \Omega \) but the second resistor is unmarked and unknown. Using an ammeter, you measure the current passing through the unknown resistor as 45.0 mA.

a. What is the value of the second resistor?

\[
R_2 = \frac{V}{I_2} = \frac{3.0 \, V}{45.0 \times 10^{-3} \, A} = 67 \, \Omega
\]

b. What is the current passing through the 150-\( \Omega \) resistor?

\[
I_1 = \frac{V}{R_2} = \frac{3.0 \, V}{150 \, \Omega} = 0.020 \, A = 20 \, mA
\]

c. What is the total current passing through this power source?

\[
\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}
\]

\[
R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{(150 \, \Omega)(67 \, \Omega)}{150 \, \Omega + 67 \, \Omega}
\]

\[
= 46 \, \Omega
\]

\[
I_T = \frac{V}{R_T} = \frac{3.0 \, V}{46 \, \Omega} = 0.065 \, A
\]

\[
= 65 \, mA
\]

or

\[
I_T = I_1 + I_2
\]

\[
= 45 \, mA + 20 \, mA = 65 \, mA
\]

13. A circuit is constructed, as shown in the figure below:

What is the value of \( R_3 \)?

![Circuit Diagram]

\[ R_1 = 15 \]

\[ R_2 = 30.0 \, \Omega \]

\[ R_3 \]

\[ R_4 = 40.0 \, \Omega \]

\[ 7.5 \, V \]

\[ 0.20 \, A \]
14. What is the equivalent resistance of the resistors in the circuit as shown in the figure below?

\[
R_T = \frac{V}{I} = \frac{7.5 \text{ V}}{0.20 \text{ A}} = 37 \Omega
\]

\[
\frac{1}{R_{12}} = \frac{1}{R_1} + \frac{1}{R_2}
\]

\[
R_{12} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(15 \Omega)(30.0 \Omega)}{15 \Omega + 30.0 \Omega} = 1.0 \times 10^1 \Omega
\]

\[
R_T = R_{12} + R_{34}
\]

\[
R_{34} = R_T - R_{12} = 37 \Omega - 10.0 \Omega = 27 \Omega
\]

\[
\frac{1}{R_{34}} = \frac{1}{R_3} + \frac{1}{R_4}
\]

\[
R_3 = \frac{R_{34} R_4}{R_4 - R_{34}} = \frac{(27 \Omega)(40.0 \Omega)}{40.0 \Omega - 27 \Omega} = 9.0 \times 10^1 \Omega
\]

\[
R_A = 100 \Omega
\]

\[
\frac{1}{R_B} = \frac{1}{R_{70}} + \frac{1}{R_{70}} = \frac{2}{R_{70}}
\]

\[
R_B = \frac{R_{70}}{2} = \frac{70.0 \Omega}{2} = 35.0 \Omega
\]

\[
\frac{1}{R_C} = \frac{1}{R_{40}} + \frac{1}{R_{40}} + \frac{1}{R_{40}} = \frac{3}{R_{40}}
\]

\[
R_C = \frac{R_{40}}{3} = \frac{40.0 \Omega}{3} = 13.0 \Omega
\]

\[
R_T = R_A + R_B + R_C
\]

\[
= 100.0 \Omega + 35.0 \Omega + 13.0 \Omega
\]

\[
= 148 \Omega
\]
Chapter 24

1. A 1.20-cm wire carrying a current of 0.80 A is perpendicular to a 2.40-T magnetic field. What is the magnitude of the force on the wire?

\[ F = ILB \]
\[ = (0.80 \text{ A})(0.0120 \text{ m})(2.40 \text{ T}) \]
\[ = 0.023 \text{ N} \]

2. A 24.0-cm length of wire carries a current and is perpendicular to a 0.75-T magnetic field. If the force on the wire is 1.80 N, what is the current in the wire?

\[ F = ILB \]
\[ I = \frac{F}{LB} \]
\[ = \frac{1.80 \text{ N}}{(0.240 \text{ m})(0.75 \text{ T})} \]
\[ = 1.0 \times 10^1 \text{ A} \]

3. A 0.50-cm length of wire carries a current and is perpendicular to a magnetic field, as shown below.

a. What is the direction of the force on the wire?

According to the third right-hand rule, in which the fingers of the right hand point in the direction of the magnetic field and the thumb points in the direction of the conventional current, the direction of the force on the wire is out of the page or in the negative z direction.

b. What is the magnitude of the force on the wire?

\[ F = ILB \]
\[ = (2.6 \text{ A})(0.0050 \text{ m})(0.75 \text{ T}) \]
\[ = 0.0098 \text{ N} \]
Chapter 24 continued

4. A 4.50-cm length of wire carries a 2.1-A current and is perpendicular to a magnetic field. If the wire experiences a force of 3.8 N from the magnetic field, what is the magnitude of the magnetic field?

\[ F = ILB \]
\[ B = \frac{F}{IL} \]
\[ = \frac{3.8 \text{ N}}{(2.1 \text{ A})(0.0450 \text{ m})} \]
\[ = 40 \text{ T} \]

5. A length of wire carrying a current of 2.0 A is perpendicular to a 6.5-T magnetic field. What is the length of the wire if it experiences a force of 2.99 N?

\[ F = ILB \]
\[ L = \frac{F}{IB} \]
\[ = \frac{2.99 \text{ N}}{(2.0 \text{ A})(6.5 \text{ T})} \]
\[ = 0.23 \text{ m} \]

6. An electron beam is perpendicular to a 0.020-T magnetic field. What is the force experienced by one electron if the beam has a velocity of 9.8 \times 10^3 \text{ m/s}?

\[ F = qvB \]
\[ = (1.60 \times 10^{-19} \text{ C})(9.8 \times 10^3 \text{ m/s})(0.020 \text{ T}) \]
\[ = 3.1 \times 10^{-17} \text{ N} \]

7. A proton experiences a force of 6.9 \times 10^{-15} \text{ N} when it travels at a right angle to a 1.35-T magnetic field. What is the velocity of the proton?

\[ F = qvB \]
\[ v = \frac{F}{qB} \]
\[ = \frac{6.9 \times 10^{-15} \text{ N}}{(1.60 \times 10^{-19} \text{ C})(1.35 \text{ T})} \]
\[ = 3.2 \times 10^4 \text{ m/s} \]

8. A doubly ionized particle travels through a magnetic field, as shown in the figure below. What is the force experienced by the particle?

\[ F = qvB \]
\[ = (3.2 \times 10^{-19} \text{ C})(4.1 \times 10^4 \text{ m/s})(1.50 \text{ T}) \]
\[ = 2.0 \times 10^{-14} \text{ N} \]

\[ B = 1.50 \text{ T} \]
\[ v = 4.1 \times 10^4 \text{ m/s} \]

9. A positively charged particle travels at a right angle through a 3.00-T magnetic field with a velocity of 4.50 \times 10^5 \text{ m/s}. If the particle experiences a force of 4.32 \times 10^{-13} \text{ N} as it travels through the magnetic field, what is the charge on the particle?

\[ F = qvB \]
\[ q = \frac{F}{vB} \]
\[ = \frac{4.32 \times 10^{-13} \text{ N}}{(4.50 \times 10^5 \text{ m/s})(3.00 \text{ T})} \]
\[ = 3.20 \times 10^{-19} \text{ C} \]

10. An electron traveling 8.6 \times 10^7 \text{ m/s} at a right angle to a magnetic field experiences a force of 2.9 \times 10^{-11} \text{ N}. What is the strength of the magnetic field?

\[ F = qvB \]
\[ B = \frac{F}{qv} \]
\[ = \frac{2.9 \times 10^{-11} \text{ N}}{(1.60 \times 10^{-19} \text{ C})(8.6 \times 10^7 \text{ m/s})} \]
\[ = 2.1 \text{ T} \]