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Chapter 35 Electric Circuits

# Summary

**THE BIG IDEA** **Any path along which electrons can flow is a circuit.**

## 35.1 A Battery and a Bulb

**In a flashlight, when the switch is turned on to complete an electric circuit, the mobile conduction electrons already in the wires and the filament begin to drift through the circuit.**

- There must be a complete path, or **circuit,** for a bulb in a simple circuit to light.
- In a simple circuit, electrons flow from the negative part of a battery through a wire or foil to the side (or bottom) of a bulb, through a filament inside the bulb, and out the bottom (or side) and through the other piece of wire or foil to the positive part of the battery. The current then passes through the interior of the battery to complete the circuit.

## 35.2 Electric Circuits

**For a continuous flow of electrons, there must be a complete circuit with no gaps.**

- A gap is usually provided by an electric switch that can be opened or closed to either cut off or allow electron flow.
- When connected **in series,** the devices in a circuit form a single pathway for electron flow between the terminals of the battery, generator, or wall socket. When connected **in parallel,** the devices form branches, each of which is a separate path for the flow of electrons.

## 35.3 Series Circuits

**If one device fails in a series circuit, current in the whole circuit ceases and none of the devices will work.**

- In a **series circuit,** devices are arranged so that charge flows through each in turn.
- The current passing through each device in a series circuit is the same.
- In a series circuit, the total resistance to current is the sum of the individual resistances along the circuit path.
- The current in a series circuit is numerically equal to the voltage supplied by the source divided by the total resistance. This is Ohm's law. Ohm's law also applies separately to each device.
- The *voltage drop,* or potential difference, across each device connected in series depends directly on its resistance. The total voltage across a series circuit divides among the individual devices.

## 35.4 Parallel Circuits

**In a parallel circuit, each device operates independent of the other devices. A break in any one path does not interrupt the flow of charge in the other paths.**

- In a **parallel circuit,** each electric device is connected to the same two points of the circuit. The voltage is therefore the same across each device connected in parallel.
- The total current in a parallel circuit divides among the branches. Ohm's law applies separately to each branch.
- The overall resistance of a parallel circuit is less than the resistance of any one of its branches.

## 35.5 Schematic Diagrams

**In a schematic diagram, resistance is shown by a zigzag line, and ideal resistance-free wires are shown with solid straight lines. A battery is represented with a set of short and long parallel lines.**

- Electric circuits are frequently described by simple diagrams, called **schematic diagrams,** using special symbols to represent certain circuit elements.

## 35.6 Combining Resistors in a Compound Circuit

**The equivalent resistance of resistors connected in series is the sum of their values. The equivalent resistance for a pair of equal resistors in parallel is half the value of either resistor.**

- The *equivalent resistance* of a circuit with several resistors is the value of a single resistor that would comprise the same load to the battery or power source.
- The equivalent resistance for a pair of 1-ohm resistors in series is 2 ohms.
- The equivalent resistance for a pair of 1-ohm resistors in parallel is 0.5 ohm.

## 35.7 Parallel Circuits and Overloading

**To prevent overloading in circuits, fuses or circuit breakers are connected in series along the supply line.**

- Electric current is usually fed into a home by wires called lines, which supply 110–120 V. This voltage is applied to devices that are connected in parallel by plugs to these lines.
- As more devices are connected to the lines, more pathways are provided for current. The combined resistance of the circuit is thereby lowered, and a greater amount of current occurs in the lines. Lines that carry more than a safe amount of current are said to be *overloaded.*
- When insulation that separates the wires in a circuit wears away and allows the wires to touch, the path of the circuit is shortened. This is called a short circuit, and it can draw a dangerously large current.

# Exercises

## 35.1 A Battery and a Bulb (pages 703–704)

1. A _____ is a complete path along which charge can flow.
2. Circle the letter of each statement that is true about a completed electric circuit consisting of a battery, a lightbulb, and two wires.
   a. Electrons flow from the positive terminal of the battery to the negative terminal.
   b. The battery acts like a pump, causing current to flow through the circuit.
   c. The conduction electrons tend to pile up inside the bulb.
   d. The conduction electrons that drift through the circuit originate from the wires and the bulb filament.

## 35.2 Electric Circuits (page 704)

3. A gap in a circuit is usually provided by an electric _____.

*Match each switch position with the correct effect on the circuit.*

| Switch Position | Effect |
|---|---|
| _____ 4. open | a. cuts off electron flow |
| _____ 5. closed | b. allows electron flow |

6. When connected in _____, devices in a circuit form a single pathway for electron flow.
7. When connected in _____, devices in a circuit form branches, each of which is a separate path for the flow of electrons.

## 35.3 Series Circuits (pages 705–706)

8. Suppose you have a completed circuit with three lamps connected in series. Circle the letter of the statement that correctly describes what happens if the filament of the middle lamp burns out.
   a. Current ceases, and the remaining two lamps will also go out.
   b. Both of the remaining lamps will stay lit.
   c. Only one of the remaining lamps will stay lit.
   d. The amount of current flowing through the circuit drops by one third.
9. The total resistance to current in a series circuit is the _____ of the individual resistances along the circuit path.
10. The voltage drop across each device in a series circuit depends directly on its _____.
11. Describe the main disadvantage of a series circuit.

_____

_____

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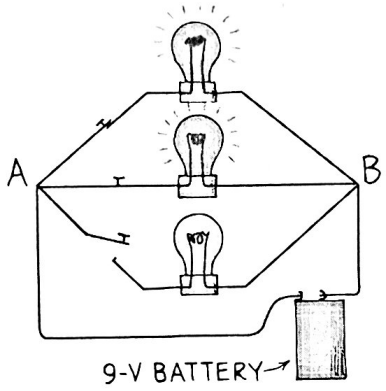
## 35.4 Parallel Circuits (pages 707–708)

*Use the figure below to answer Questions 12–17.*




**12.** Circle the letter of the correct answer. How many *possible* pathways for current are there between points A and B?

a. 1

b. 3

c. 4

d. 5

**13.** Is the following sentence true or false? In a parallel circuit like the one shown, each device operates independent of the other devices.

_____

**14.** Circle the letter of the correct answer. What is the voltage across each lit bulb in the circuit shown?

a. 3 volts

b. 4.5 volts

c. 6 volts

d. 9 volts

**15.** Suppose $I$ is the total current in the circuit. Circle the letter of the amount of current through each lit bulb.

a. $\frac{I}{2}$

b. $\frac{I}{3}$

c. $2I$

d. $3I$

**16.** If the switch next to the unlit bulb were closed, the total current through the battery would _____.

**17.** Is the following sentence true or false? The overall resistance of the circuit is less than the resistance of any one of the branches.

_____

## 35.5 Schematic Diagrams (page 709)

18. What is a schematic diagram?

_____

_____

_____

19. Describe how the positive and negative terminals of a battery are indicated on a schematic diagram.

_____

_____

*Match each circuit element with the description of its symbol in a schematic diagram.*

| Circuit Element | Symbol |
|---|---|
| _____ 20. resistance | a. zigzag line |
| _____ 21. connecting wire | b. broken line with one end tilted up at an angle |
| _____ 22. battery | c. set of short and long parallel lines |
| _____ 23. open switch | d. solid straight line |

## 35.6 Combining Resistors in a Compound Circuit (pages 710–711)

24. Define equivalent resistance.

_____

_____

_____

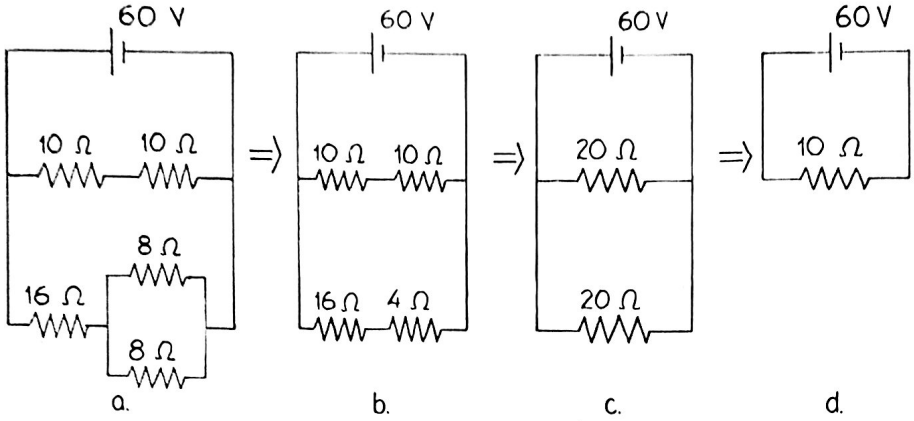
25. The equivalent resistance of resistors in series is _____

_____.

26. The equivalent resistance of two resistors in parallel is _____

_____.

*The diagrams below show how a complex schematic diagram can be simplified by using equivalent resistances. Use these diagrams to answer Questions 27–29.*




27. Describe how diagram (a) was simplified to make diagram (b).

_____

_____

_____

28. Describe how diagram (b) was simplified to make diagram (c).

_____

_____

_____

29. Describe how diagram (c) was simplified to make diagram (d).

_____

_____

_____

## 35.7 Parallel Circuits and Overloading (pages 711–712)

30. Is the following sentence true or false? The more devices you connect in parallel to your household supply line, the more you increase the total line current. _____

31. What is the purpose of connecting a fuse or circuit breaker in series along the supply line?

_____

_____

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# Ohm's Law and Parallel Circuits

The equivalent resistance for resistors in parallel can be found using the following equation.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$

Calculate the current in a 48-V battery that powers three 15-Ω resistors connected in parallel.

**1. Read and Understand**

*What information are you given?*

voltage = $V$ = 48 V

individual resistances: $R_1 = R_2 = R_3 = 15\ \Omega$

**2. Plan and Solve**

*What unknown are you trying to calculate?*

current = $I$ = ?

*What equation can you use to find the unknown?*

Ohm's law: $V = IR$

For a parallel circuit, $V = IR_{eq}$, where $R_{eq}$ is the equivalent resistance.

Rearranging the equation gives you $I = \frac{V}{R_{eq}}$.

First, find the equivalent resistance $R_{eq}$.

$$\frac{1}{R_{eq}} = \frac{1}{15\ \Omega} + \frac{1}{15\ \Omega} + \frac{1}{15\ \Omega} = \frac{1}{5\ \Omega}$$

$R_{eq} = 5\ \Omega$

Then substitute for $V$ and $R_{eq}$ to solve for $I$.

$$I = \frac{48\ \text{V}}{5\ \Omega} = 9.6\ \text{A}$$

**3. Look Back and Check**

*Is your answer reasonable?*

Yes, a current of 9.6 A is reasonable, and the units are $\frac{\text{V}}{\Omega}$, or A, which is reasonable.

## Math Practice

*On a separate sheet of paper, solve the following problems.*

1. Calculate the current in a 9-V battery that powers three 6-Ω resistors in parallel.

2. Calculate the voltage impressed across a circuit in which three 1.5-Ω resistors in parallel draw a current of 12 A.

3. Calculate the current in 12-V battery that powers four 10-Ω resistors in parallel.