

PHYS11 CH:19.1-19.4

Ohm's Law, Series & Parallel Circuits, and Electric Power

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Outline

- 1 Learning Objectives
- 2 Ohm's Law
- 3 Series Circuits
- 4 Parallel Circuits
- 5 Electric Power
- 6 Examples
- 7 Summary

Learning Objectives

By the end of this lesson, you will be able to:

- State and apply Ohm's law to simple circuits
- Distinguish between series and parallel circuit configurations
- Calculate equivalent resistance for resistors in series and parallel
- Analyze current flow and voltage drops in different circuit configurations
- Compute electric power dissipation in resistive elements

Current and Resistance

Electric Current

Electric current is the rate of charge flow:

$$I = \frac{\Delta Q}{\Delta t} \quad (1)$$

where:

- I is the current (measured in amperes, A)
- ΔQ is the charge that passes (measured in coulombs, C)
- Δt is the time interval (measured in seconds, s)

Definition of Ampere

$$1 \text{ A} = 1 \text{ C/s} \quad (2)$$

Ohm's Law

Ohm's Law Statement

For ohmic materials, the voltage drop along a path is proportional to the current that runs through the path, with resistance as the constant of proportionality.

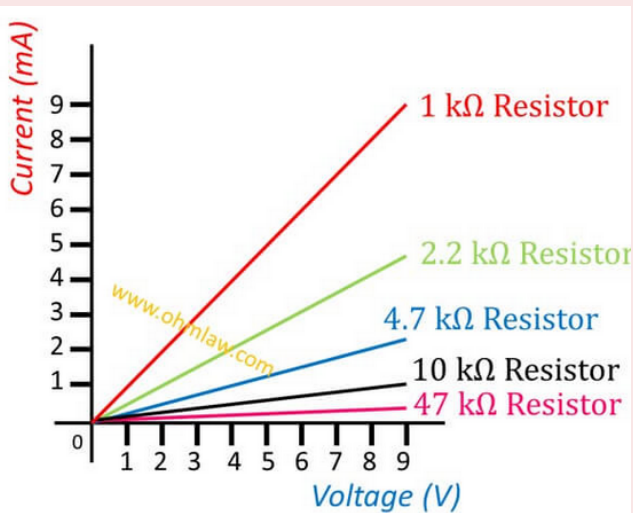
Mathematical Form

$$V = IR \quad (3)$$

where:

- V is the voltage drop (measured in volts, V)
- I is the current (measured in amperes, A)
- R is the resistance (measured in ohms, Ω)

Ohm's Law



Direct vs. Alternating Current

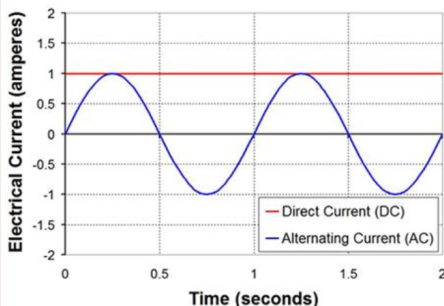
Direct Current (DC)

- Constant over time
- Flows in one direction
- Example: Batteries

Alternating Current (AC)

- Alternates back and forth over time
- Changes direction periodically
- Example: Household electricity

Current Types Visualization



Series Circuits: Characteristics

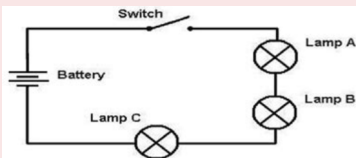
Definition

Resistors in series are connected head to tail, forming a single path for current flow.

Key Properties

- Same current flows through all resistors
- Voltage drop can be different across each resistor
- Voltage is the same at every point in a given wire
- Total voltage equals sum of individual voltage drops

Series Circuit



Series Circuits: Equivalent Resistance

Equivalent Resistance Formula

For N resistors connected in series:

$$R_{\text{equiv}} = R_1 + R_2 + \cdots + R_N \quad (4)$$

Interpretation

- The equivalent resistance is always greater than any individual resistance
- Adding resistors in series increases the total resistance
- Current is limited by the sum of all resistances

Parallel Circuits: Characteristics

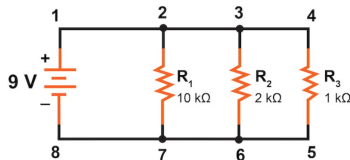
Definition

Resistors in parallel provide multiple paths for current flow, with one end of each resistor connected to a common point.

Key Properties

- Same voltage across all resistors
- Current through each resistor can differ
- Total current equals sum of individual currents
- More paths available for current flow

Parallel Circuit



Parallel Circuits: Equivalent Resistance

Equivalent Resistance Formula

For N resistors connected in parallel:

$$\frac{1}{R_{\text{equiv}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N} \quad (5)$$

Special Case: Identical Resistors

For N identical resistors each with resistance R connected in parallel:

$$R_{\text{equiv}} = \frac{R}{N} \quad (6)$$

Interpretation

- The equivalent resistance is always less than the smallest individual resistance
- Adding resistors in parallel decreases the total resistance

Electric Power: Basic Concept

Definition

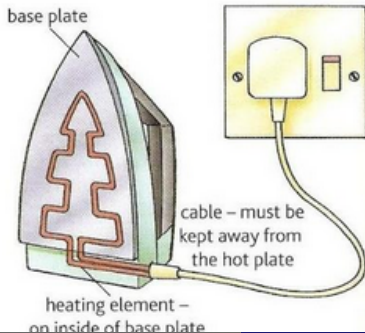
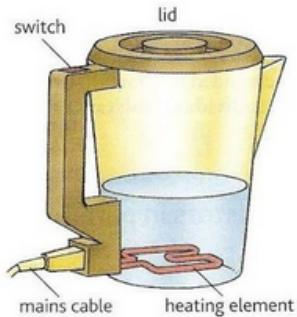
Electric power is the rate at which energy is transferred or converted in an electric circuit.

Key Points

- Electric power is dissipated in resistances of a circuit
- Capacitors do not dissipate electric power
- Power dissipation often manifests as heat
- Measured in watts (W), where $1 \text{ W} = 1 \text{ J/s}$

The heating effect of an electric current

- When an electric current flows through an electrical conductor the resistance of the conductor causes the conductor to be heated.
- This effect is used in the heating elements of various devices like those shown below:



Heating effect of resistance
Phet

Electric Power: Mathematical Expressions

Basic Power Formula

Power is proportional to voltage and current:

$$P = IV \quad (7)$$

Alternative Expressions (Using Ohm's Law)

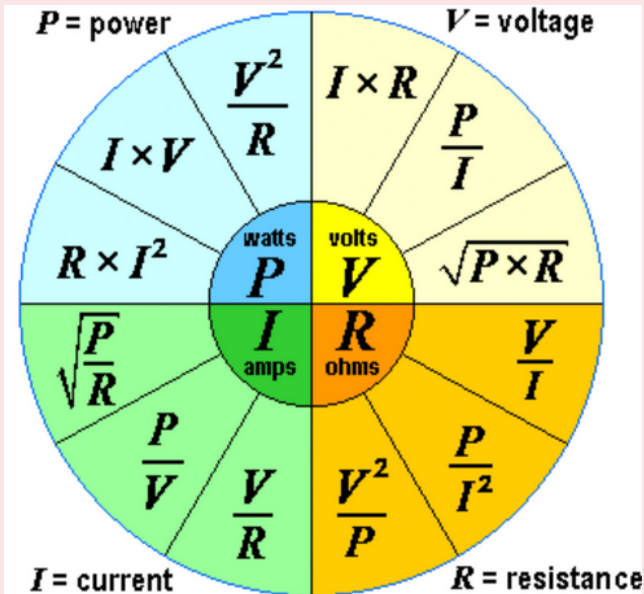
Without current term:

$$P = \frac{V^2}{R} \quad (8)$$

Without voltage term:

$$P = I^2 R \quad (9)$$

Equivalent Expressions



I Do: Ohm's Law Example

Problem

A resistor with resistance $R = 10\ \Omega$ is connected to a voltage source of $V = 12\text{ V}$. Calculate the current flowing through the resistor.

I Do: Ohm's Law Example

Problem

A resistor with resistance $R = 10\ \Omega$ is connected to a voltage source of $V = 12\text{ V}$. Calculate the current flowing through the resistor.

Solution

Using Ohm's law: $V = IR$

Rearranging to solve for current: $I = \frac{V}{R}$

Substituting the values:

$$I = \frac{12\text{ V}}{10\ \Omega} \quad (10)$$

$$= 1.2\text{ A} \quad (11)$$

Therefore, the current flowing through the resistor is 1.2 A.

We Do: Series Circuit Analysis

Problem

Three resistors are connected in series: $R_1 = 5\ \Omega$, $R_2 = 10\ \Omega$, $R_3 = 15\ \Omega$.
If connected to a 30 V source:

- 1 Calculate the equivalent resistance
- 2 Find the current through the circuit
- 3 Calculate the voltage drop across each resistor

Partial Solution

1. Equivalent resistance:

$$R_{\text{equiv}} = R_1 + R_2 + R_3 \quad (12)$$

$$= 5\ \Omega + 10\ \Omega + 15\ \Omega \quad (13)$$

$$= 30\ \Omega \quad (14)$$

We Do: Series Circuit Analysis (continued)

Complete the Solution

2. Circuit current:

$$I = \frac{V}{R_{\text{equiv}}} \quad (15)$$

$$= \frac{30 \text{ V}}{30 \Omega} \quad (16)$$

$$= 1 \text{ A} \quad (17)$$

3. Voltage drops across each resistor:

$$\text{For } R_1: V_1 = I \times R_1 = 1 \text{ A} \times 5 \Omega = ?$$

$$\text{For } R_2: V_2 = I \times R_2 = 1 \text{ A} \times 10 \Omega = ?$$

$$\text{For } R_3: V_3 = I \times R_3 = 1 \text{ A} \times 15 \Omega = ?$$

Let's work through these calculations together.

You Do: Parallel Circuit Problem

Problem

Three resistors are connected in parallel: $R_1 = 6\ \Omega$, $R_2 = 12\ \Omega$, $R_3 = 4\ \Omega$.
If connected to a 24 V source:

- 1 Calculate the equivalent resistance
- 2 Find the total current from the source
- 3 Calculate the current through each resistor

Work on this problem independently, and we'll review the solution together afterward.

Key Concepts Summary

Ohm's Law

- $V = IR$
- Linear relationship for ohmic materials

Series Circuits

- Same current through all resistors
- $R_{\text{equiv}} = R_1 + R_2 + \cdots + R_N$

Parallel Circuits

- Same voltage across all resistors
- $\frac{1}{R_{\text{equiv}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$

Electric Power

- $P = IV = I^2 R = \frac{V^2}{R}$

Practice Questions

Consider This

- 1 How does adding more resistors in series affect the total current in a circuit?
- 2 Why is the equivalent resistance in a parallel circuit always less than the smallest individual resistor?
- 3 In what ways can you reduce power consumption in an electrical circuit?
- 4 How does current distribute in a parallel circuit? Why?

Next Steps

We will explore more complex circuit configurations and apply these principles to practical problems in our next lesson.