THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Comparing Circuits

How does voltage affect current in series and parallel circuits?

GRADES 9–12

Physical Science

VAN ANDEL EDUCATION INSTITUTE

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INQUIRY-BASED SCIENCE

Physical

Comparing Circuits

Grade Level/ Content	9–12/Physical Science
Lesson Summary	In this lesson, students will explore voltage and resistance in different types of circuits.
Estimated Time	1, 45-minute class period
Materials	wires with clips, batteries, battery holders, small light bulbs or other resisters with known tolerance, multimeter, paper, pencil, calculator, Internet access, Investigation Plan, journal
Secondary Resources	Requirements of a Circuit Circuit Symbols and Diagrams Two Types of Connections Circuit Construction Kit Circuit Builder Interactive Ohm's Law / Calculating Voltage and Resistance Worksheet Ohms Law Wheel Resistors in Circuits
NGSS Connection	**HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
Learning Objectives	• Students will describe how resistors affect voltage and current in series and parallel circuits. • Students will sketch, build, and observe the effects of resistors, conductors, and insulators on series and parallel circuits.

How does voltage affect current in series and parallel circuits?

We depend on energy to power our houses, schools, devices, and other important things in our lives. How often do we think about how that energy moves? Much of this energy moves through circuits. An **electrical circuit** is the path in which an electrical charge from a current source flows. The point where the electrical charge enters a circuit is the "source," and the point where it leaves is the "return" or "ground."

There are two types of circuits: series and parallel. How are these circuits different and how can these differences be demonstrated? Students will build and analyze circuits in series and parallel configurations. They will draw conclusions about current (I), resistance (R), and voltage (V) in the two different types of circuits through the application of Ohm's Law.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Demonstrate for students how to place batteries in holders, and how to attach wires and light bulbs (or other resistors) in a circuit. The materials could come from a circuit kit. Alternatively, if students conduct an online simulation, only the last four materials in the list will be needed. Each group of four students will need the following:

- batteries
- battery holder
- wires with clips (at least 6 per group)
- small light bulbs/resisters of known tolerances
- multimeter to measure voltage
- Internet access
- paper and pencil
- Investigation Plan
- calculator
- journal

Caution: The investigation uses very low amounts of energy available in batteries. Caution students to never attempt an investigation with a power source stronger than household batteries unless otherwise instructed.

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

How does voltage affect current in series and parallel circuits?

OPENNESS TO NEW IDEAS

In addition to considering the components of a circuit, encourage students to consider how the function of the circuit relates to the current flow through its components.

Personal Knowledge

Students capture what they already know about electrical circuits, current, voltage, and resistance.

- Have student groups brainstorm what they know about each of the following terms, including examples from their daily lives: *electricity, electrical circuits, parallel circuit, series circuit, current, voltage, resistance, insulators,* and *conductors*. They may add any terms they feel are relevant.
- Ask groups to write short definitions and examples of each term in a chart, and compare with other groups. Initiate a discussion of each term, as needed.
- If groups are not able to define or give an example, encourage them to mark it with a question mark for revisiting later in the investigation. Have each group post their chart in a prominent place for the group to revisit.
- As students conduct the investigation, remind groups to add details or make edits to their chart.

CONSTRUCTION OF MEANING

Show students a diagram of a simple circuit. Ask them to articulate their understanding of each term labeled on the circuit. As groups continue the investigation, encourage them to revisit their charts and refine definitions as needed.

Secondary Knowledge

Highlight the characteristics of series and parallel series.

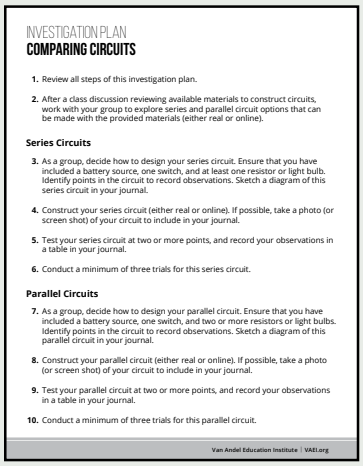
- Use these resources (or your own) to develop students' understanding of circuits, series circuits, and parallel circuits.
  - Requirements of a Circuit
  - Circuit Symbols and Diagrams
  - Two Types of Connections

After reviewing these resources, students should understand what it takes to create a circuit, the differences between series and parallel circuits, and how to diagram simple circuits that include batteries, wires, switches, and resistors/lightbulbs.

Investigation Plan

Students collect materials and prepare to conduct trials to measure how electric current moves in two different types of circuits.

- Divide the class into teams of 4 (or 2 if utilizing online simulations).
- Ask teams to follow the Investigation Plan.
- Provide each team with the materials necessary to build circuits, and review their correct usage.
- Discuss how students could test and analyze voltage, resistance, conductors, insulators, and other properties at various points in the circuit.
- If students are utilizing an online simulator, provide them with a quick overview of how to proceed. Good examples of online circuit simulators include the Circuit Construction Kit or Circuit Builder Interactive.



INVESTIGATION PLAN
COMPARING CIRCUITS

1. Review all steps of this investigation plan.
2. After a class discussion reviewing available materials to construct circuits, work with your group to explore series and parallel circuit options that can be made with the provided materials (either real or online).

Series Circuits

3. As a group, decide how to design your series circuit. Ensure that you have included a battery source, one switch, and at least one resistor or light bulb. Identify points in the circuit to record observations. Sketch a diagram of this series circuit in your journal.
4. Construct your series circuit (either real or online). If possible, take a photo (or screen shot) of your circuit to include in your journal.
5. Test your series circuit at two or more points, and record your observations in a table in your journal.
6. Conduct a minimum of three trials for this series circuit.

Parallel Circuits

7. As a group, decide how to design your parallel circuit. Ensure that you have included a battery source, one switch, and two or more resistors or light bulbs. Identify points in the circuit to record observations. Sketch a diagram of this parallel circuit in your journal.
8. Construct your parallel circuit (either real or online). If possible, take a photo (or screen shot) of your circuit to include in your journal.
9. Test your parallel circuit at two or more points, and record your observations in a table in your journal.
10. Conduct a minimum of three trials for this parallel circuit.

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Investigation Plan

CRITICAL THINKING

Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they can be in their results.

Observation

Students conduct trials to measure electric current in two different types of circuits.

- Students will use the materials to sketch, build, and test series and parallel electrical circuits at designated points in the circuit.
- Students conduct a minimum of three trials for each circuit arrangement. Remind them to note instances where they did not complete a circuit.
- Encourage students to take a photo or screen capture (if using an online simulator) of each type and provide a written explanation of what is happening in their journal.

DISCOURSE

Ensure that all students are participating in the investigation. Ask students to share the status of their circuit investigations, problems encountered, and possible solutions with their peers.

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

- Have students analyze their data. They may wish to use the Data Analysis prompt as a guide.
- Have students **evaluate** their data for trustworthiness.
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning.
- Have students **interpret** what the identified patterns or trends mean.
- As students organize the data and identify patterns, they may draw revised diagrams to represent any new or refined understandings. Encourage them to also return to their Personal Knowledge charts to make revisions as necessary.
- Ensure that student groups have enough data and observations to use as evidence to support a claim.

Secondary Knowledge

Students use secondary sources to understand how energy travels in a circuit, and how different setups and resistors affect voltage.

- Use these resources (or your own) to develop students' understanding of circuits, voltage, and resistance.
  - Ohm's Law / Calculating Voltage and Resistance Worksheet
  - Ohms Law Wheel
  - Resistors in Circuits
- Review Ohm's Law as a class by discussing each part of the formula with I standing for current, V for voltage, and R for resistance (V = IR). Ohm's Law states that the current through a conductor between two points is directly proportional to the voltage across the two points. The resistance in this relationship is constant, independent of the current.
- Continue by reviewing formulas for calculating resistance in different types of circuits with the following examples:

Resistance in Series Circuits:

Voltage = 12V; R_1 = 20 Ohm; R_2 = 30 Ohm; R_3 = 50 Ohm

"R_t" means total resistance of the circuit. R_1, R_2, and R_3 correspond to each resistor, which in the students' investigations can be resistors or light bulbs.

Apply the resistance formula for a series circuit to this example. Explain to students that resistances in series circuits add up and are written as R_t, for example:

$$R_t = R_1 + R_2 + R_3$$

Here is the formula applied to the example: $R_t = 20\ \Omega + 30\ \Omega + 50\ \Omega$

$$R_t = 100\ \Omega$$

Resistance in Parallel Circuits:

Voltage = 12V; R_1 = 20 Ohm; R_2 = 100 Ohm; R_3 = 50 Ohm

Continued

Apply the resistance formula for a parallel circuit to this example. Explain to students that resistances in parallel circuits combine according to the sum-of-inverses rule.

An inverse is written as 1 over R_t, for example: $1/R_t = 1/R_1 + 1/R_2 + 1/R_3$

Here is the formula applied to the example:

$$1/R_t = 1/20\ \Omega + 1/100\ \Omega + 1/50\ \Omega$$
$$1/R_t = 5/100\ \Omega + 1/100\ \Omega + 2/100\ \Omega$$
$$1/R_t = 8/100\ \Omega$$
$$R_t = 100\ \Omega /8$$
$$R_t = 12.5\ \Omega$$

- It may be helpful to share an Ohm's Law wheel for students to use as a reference and to gain a better understanding of the relationship between voltage, resistance, and current (and, consequently, power). Sharing one of the many fun illustrations of "Ohm," "Volt," and "Amp" as caricatures, or creating one of your own, may also assist students in keeping the relationships between these components clear.
- After reviewing these resources and examples, students should understand how to calculate resistance in either type of circuit.

RICH LANGUAGE

Engage students in a class discussion of how electric current flows, meets and overcomes resistance, and so on. Some students, including English Language Learners, may need extra support to describe the causal relationships found in circuits using this vocabulary.

Explanation

Students write a claim and provide evidence and reasoning to support it for each circuit type tested.

- Have students use what they've discovered to answer their investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their explanation in their journal.
- Have students develop a **Claim** to answer the question: How does voltage affect current in series and parallel circuits?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.
- Answers will vary depending on the observations of each student group's investigations. For example, students should make some or all the following claims supported by evidence:

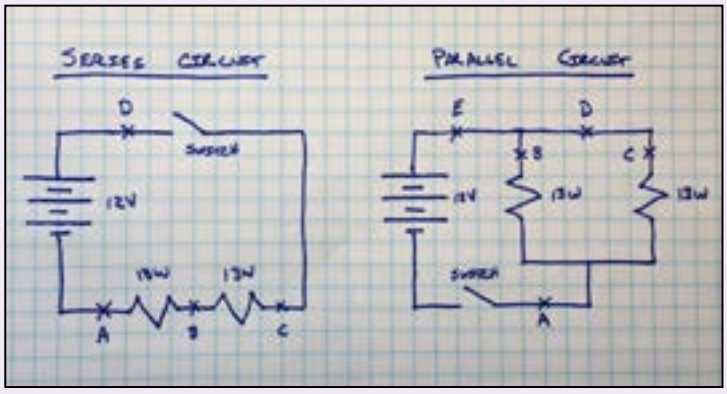
Claim

In series circuits, the current remains constant. In parallel circuits, the voltage remains constant.

Evidence

We built and measured the voltage at defined points in our series and parallel circuits. The flow of energy did not start until we closed the switch. We saw that energy was flowing because the light bulbs started working and we were able to measure a voltage with the multimeter.

Continued



Circuit Diagrams

Reasoning

Investigation: We conducted four trials for each of the circuits we built and calculated the resistance for each circuit type. Our findings were consistent with other groups in our class.

Science: In our additional research, we learned that the total resistance in a series circuit is the sum of the resistances in the circuit. We also learned that in parallel circuits, the total resistance is the inverse of each resistance in the circuit.

- Once the explanation is written, have students discuss their results using a Present and Defend.

DISCOURSE

Have students conduct a Present and Defend to develop presentation skills as well as audience participation. Research teams present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning.

Evaluation

Students reflect on the investigation.

- Ask students what surprised them in comparing series and parallel circuits.
- Ask students what they learned about Ohm's law during the testing of both circuit types.

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of modeling by applying their learning in multiple contexts.

- Have students apply their learning by analyzing, sketching, and calculating characteristics for other circuits.
- Have students think of practical uses for the flow of energy in their homes or school to power appliances and devices.
- Have students theorize what types of circuits are the most efficient. Encourage them to think about how energy can better be utilized.

CRITICAL THINKING

Have students compare their Personal Knowledge charts made before the investigation with the **claim, evidence,** and **reasoning** they produced in the investigation. Has their understanding of circuits and the flow of current changed? Have them update their charts.

Assessment

Evaluate each group's explanation of how well students:

- describe how resistors effect voltage and current in series and parallel circuits.
- sketch, build, and observe the effects of resistors, conductors, and insulators on series and parallel circuits.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

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Parallel Circuits

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8. Construct your parallel circuit (either real or online). If possible, take a photo (or screen shot) of your circuit to include in your journal.

9. Test your parallel circuit at two or more points, and record your observations in a table in your journal.

10. Conduct a minimum of three trials for this parallel circuit.