Grade 9-12 STEM Challenge

Wire It Up

Inspired by Nick, a Maintenance Technician in the Indiana Uplands.

Published by Regional Opportunity Initiatives

GRADE 9-12 STEM CHALLENGE

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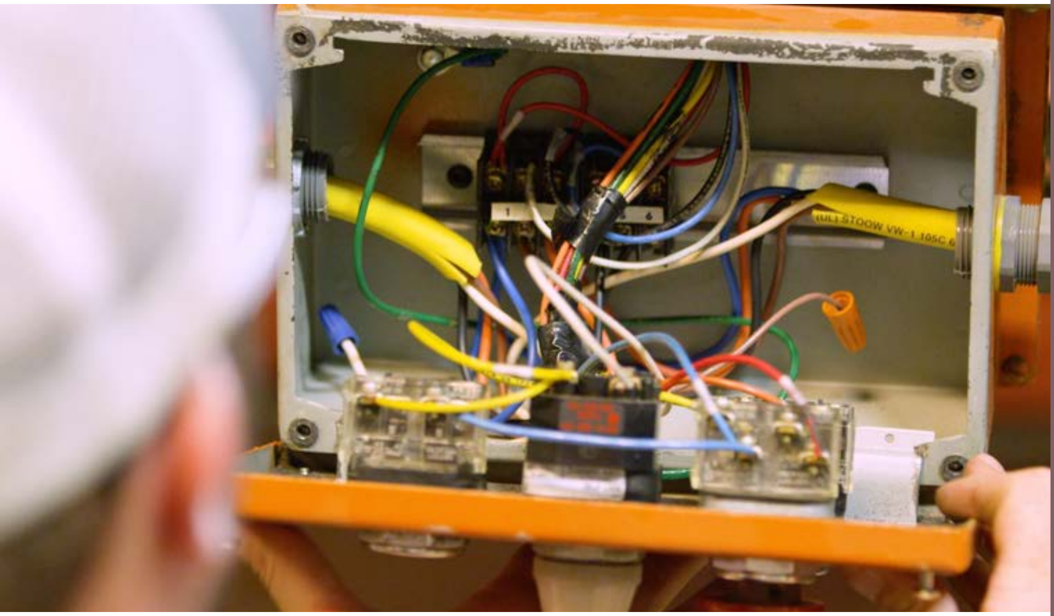
Inspired by Nick, a maintenance technician in the Indiana Uplands.

Students will use Ohm's law to troubleshoot problems in a circuit.



CAREER CONNECTION AND LESSON OVERVIEW

Nick is a Maintenance Technician with MasterBrand Cabinets in Ferdinand, Indiana. Nick's job is not only to repair machinery when it breaks down but also to routinely inspect and maintain the equipment before there is a problem. Most of this machinery is engineered with durability in mind. There is also redundancy, or "back-up" systems, built in for things like safety—you wouldn't want the machinery to keep running if the safety systems failed!

Being able to understand circuits and diagnose problems in electrical systems is a significant part of a maintenance technician's day. In this set of activities, students will build series and parallel circuits and investigate resistance. Once they understand circuits, students can then use their knowledge to troubleshoot a damaged electrical system.

LESSON TIMELINE

DAY 1

- Show the inspiration video, "Nick - Maintenance Technician" (10 minutes)
- Introduce the challenge (10 minutes)
- Circuit exploration (20 minutes)
- Resistance investigations (10 minutes)
- Discussion (10 minutes)

DAY 2

- Resistance investigations (if incomplete on day 2)
- Discussion (15 minutes)

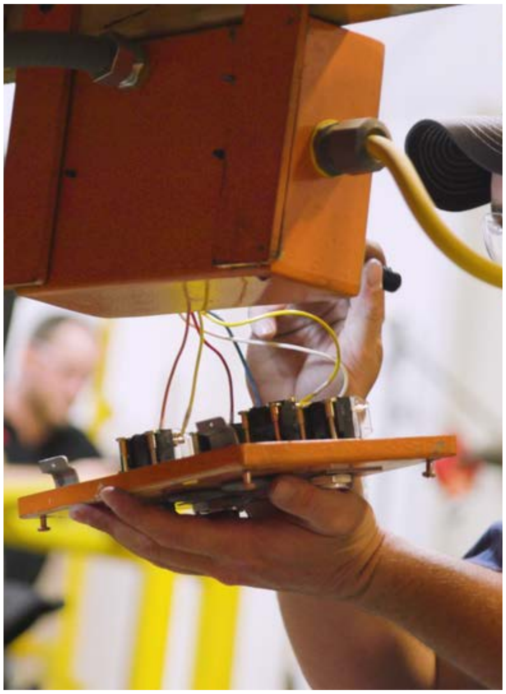
Recommended Supplies

General supplies (per group of 3-4):

- 6 pieces of "bell wire" (15 cm) each with the ends stripped
- Battery holder (should hold at least two D batteries)
- 2 to 3 D batteries
- Lightbulb socket to fit 1.5 volt bulbs
- Three or more 1.5 volt bulbs
- Access to a multimeter capable of reading current, voltage, and resistance
- Switch (optional)
- Damaged components such as burned-out bulbs, dead batteries, damaged wires, etc. (optional)
- Alternative materials
  - Incandescent holiday lights, with wires cut, can be used instead of sockets and bulbs
  - Lantern batteries or 9V batteries may be substituted
  - Aluminum foil can be used in place of wires.

For each student:

- Student Data Sheet
- Wire cutters



IN THIS CHALLENGE, STUDENTS WILL:

- Build simple circuits to understand the difference between parallel and series circuit design and function.
- Learn that different circuit designs result in different electrical behaviors.
- Understand how maintenance technicians use their knowledge of electrical circuits to troubleshoot equipment.

Standards

Science & Engineering Process Standards

SEPS.1 Posing questions and defining problems
SEPS.2 Developing and using models and tools
SEPS.3 Constructing and performing investigations
SEPS.4 Analyzing and interpreting data
SEPS.6 Constructing explanations and designing solutions
SEPS.7 Engaging in argument from evidence
SEPS.8 Obtaining, evaluating, and communicating information

Preparing for College and Careers

PCC-2.1 Determine roles, functions, education, and training requirements of various career options within one or more career clusters and pathways
PCC-2.2 Analyze career trends, options and opportunities for employment and entrepreneurial endeavors for selected career clusters and pathways
PCC-2.3 Evaluate selected careers and pathways for education requirements, working conditions, benefits, and opportunities for growth and change
PCC-2.4 Use appropriate technology and resources to research and organize information about careers

Standards
continued

Integrated Chemistry & Physics
ICP.8.1 Describe electrical current in terms of the motion of electrons within a device and relate the rate of motion of the electrons to the amount of current measured.
ICP.8.2 Describe the relationship among voltage, current, and resistance for an electrical system consisting of a single voltage source and a single device.

Physics I
PI.8.8 Apply conservation of electric charge (i.e. Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed.
PI.8.9 Use a description or schematic diagram of an electrical circuit to calculate unknown values of current, voltage, or resistance in various components or branches of the circuit according to Ohm's Law, Kirchhoff's junction rule, and Kirchhoff's loop rule.

Grade 9-10 Employability Skills
9-10.M.2 Able to view feedback as data' that helps the learning process.
9-10.M.3 Demonstrate an awareness of strengths and weaknesses while accepting constructive criticism from others to improve results.
9-10.WE.2 Complete tasks or activities with minimal prompting and guidance.
9-10.LS.1 Write documents for a variety of purposes and audiences using varied media formats.
9-10.LS.7 Predict outcomes to problems based on data and evidence.
9-10.SE.1 Develop an awareness of personal safety skills and the consequences of irresponsible behavior.

Planning and Implementation

WIRE IT UP

Essential Vocabulary

- SERIES CIRCUIT: A circuit in which electrical current flows in a single path.
- PARALLEL CIRCUIT: A circuit in which electrical circuit flows in two or more paths.
- RESISTANCE: A material's opposition to the flow of electrons (current.)
- VOLTAGE: The difference in charge between two points on a wire.
- CURRENT: The rate at which electrical charge is flowing.
- AMPERES: Abbreviated "amps," the unit of electric current.
- OHMS: The unit of electrical resistance of a material.
- VOLT: The difference of electric potential.
- RESISTOR: An electrical component that impedes the flow of electricity.

Guiding Questions

1. What is the difference between a series circuit and a parallel circuit? Why might one be better for certain applications than the other?
2. How is resistance measured? How can we calculate it from other known data?
3. How might we use our knowledge of circuits and electricity to troubleshoot electrical systems when they aren't working properly?

In this challenge, students will:

- Build simple circuits to understand the difference between parallel and series circuit design and function.
- Learn that different circuit designs result in different electrical behaviors.
- Understand how maintenance technicians use their knowledge of electrical circuits to troubleshoot equipment.

Before Class:

- Read the activity outline sheet and leader notes to become familiar with the activity.
- Gather necessary materials. Be sure that you have enough materials and space for students to work in groups of 3-4. Many of the supplies can be ordered online.
- A few notes on materials:
  - "Bell wire" is a specific type of copper wire with an insulating rubber coating. It is sold in spools and is easily cut with wire cutters. You will want to have a pair of wire cutters, preferably with a "stripper" attached to remove the rubber coating from the ends of the pieces. Use your best judgement on letting students use this equipment.

Before Class (con't)

  - Battery holders can be ordered online and should hold at least one battery and have connectors for wires on each end. There are also holders available that hold more than one battery. You might consider obtaining a few of these for students to work with as an extension activity. Be sure that the light bulb sockets purchased fit your 1.5-volt bulbs. These small bulbs are commonly used in classroom electricity projects and are readily available.
  - Alternatively, holiday lights can be used by cutting the wires between bulbs and stripping them to reveal the wire.
  - 6V lantern batteries can also be used for this activity but you must make sure the students know how to find the amount of voltage in their system (often this is as simple as looking at the battery.)
- Extension Option: You may wish to assemble the necessary materials for each group into kits to save time. Also: this will allow you to build kits that you know will work as well as "sabotaged" kits that will not. Sabotaged kits will require students to test and troubleshoot to find the problem and repair or replace the part.
- Note: Ohm's law does not apply to light-emitting diode (LED) lamps. Incandescent lamps must be used for this activity.

Day 1: Introduction

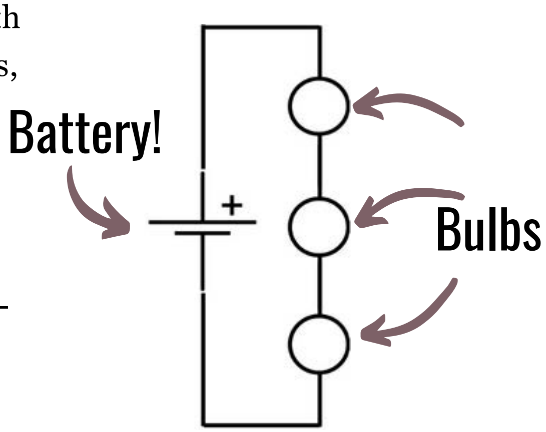
10 minutes

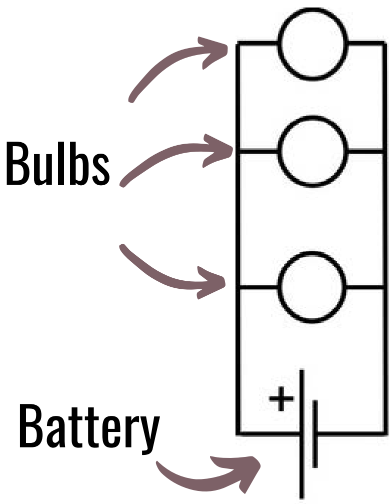
Show students Nick's career shadow video, available at https://regionalopportunityinc.org/nick. Nick is a maintenance technician, a person who keeps manufacturing equipment working and troubleshoots it to find the problem when it doesn't. Quickly and efficiently identifying the root cause of a problem is crucial to keeping the production line at MasterBrand functioning.

Almost all of the equipment that Nick maintains has some kind of electrical circuitry in it. The two simplest kinds of circuits used are series and parallel circuits. There are, of course, many other components in electrical machines— different types of wiring, capacitors, resistors, computers, etc, but these are all arranged in one of these two basic types of circuits.

Series Circuits

In a series circuit, the electricity flows along one path from the battery through the various resistors (wires, lightbulbs, actual resistors) and returns to the battery. If you've ever seen old fashioned holiday lights where one burnt out bulb caused the whole string to go dark, that's a series circuit. Since the electricity can only flow through one path, a burned-out bulb at one point in the series will break the circuit and stop the flow of electricity. Removing a bulb will have the same effect.





Parallel Circuits

In a parallel circuit, electricity has multiple paths to travel on. In this case, if you had multiple bulbs on a string, each bulb (or small groups of bulbs) would be on its own circuit that connects back to the power source. Since electricity has more than one path to travel on, a burned-out bulb here wouldn't break the circuit and the others would stay lit. If the bulb were removed, the others would stay lit as well.

Resistance

Resistance plays a role in all circuits as well. In a perfect world, electricity would flow along wires and through equipment with no loss of power until it was needed to do work, like turn a wheel or light up a lightbulb. In reality, everything that electricity flows through reduces the current by some amount. Some materials have high conductance, like copper wire, and the resistance to the flow of electrons is low. However, other materials, like plastic or rubber, generally have very high resistance. In fact, these act as insulators and it's why things like our bell wire is coated in rubber. You wouldn't want to touch the bare copper when the electricity is flowing!

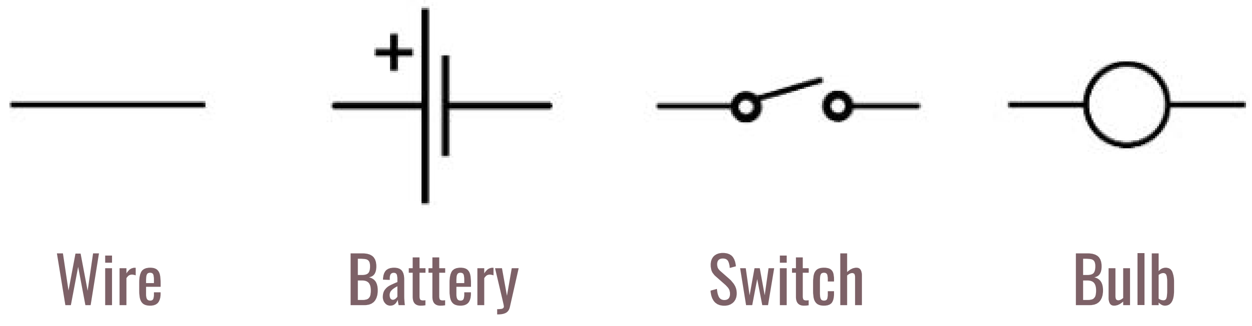
In a series circuit, the resistance of the circuit is equal to the total resistance of all the bulbs on the circuit. The more bulbs (each acting as a resistor, impeding the flow of electrons just a little bit), the dimmer they will light up. Parallel circuits have each bulb wired back to the electrical source so the overall resistance of the circuit is lower. Multiple paths for the electricity mean less of a voltage drop and a brighter string of lights.

In this activity, students will build series and parallel circuits and investigate Ohm's Law. They will then make connections to how maintenance technicians like Nick investigate electrical failures in machinery.

Part 1: Building Circuits

Provide student groups with the materials and handouts as well as access to a voltage-Ohm multimeter or VOM (four or five of these should be sufficient for most classes.) Show the students how to use the multimeter to measure Current, Voltage, and Resistance. Note: for the light bulbs, one multimeter lead must touch the silver threading and the other must touch the metal contact on the very bottom of the bulb for an accurate reading. Challenge them to build a series circuit with at least two bulbs and a parallel circuit with at least three bulbs. Have them record their findings, as prompted, on the student sheet.

When drawing their circuits, encourage them to use appropriate electrical diagram symbols for wires, batteries, switches, and bulbs:



Part 2: Ohm's Law

Once students have successfully built both circuits, have them dismantle them and set the pieces aside. Introduce students to (or remind them about) Ohm's Law. Ohm's Law explains the relationship between Voltage, Current, and Resistance within electrical circuits:

$$E = I \times R$$

Where:

- E = Voltage, or the difference in charge between two points on a wire. This is measured in volts.
- I = Current, or the rate at which electrical charge is flowing. This is measured in amperes, or amps
- R = Resistance, or a material's opposition to the flow of electrons (current). This is measured in Ohms.

With this equation, they can figure out any of the three variables as long as they know the other two. Students will calculate the resistance of each circuit two ways:

- First by measuring the resistance of their bulbs and using the equations for series and parallel circuits to determine total resistance.
- Then they will use their multimeter to test the current across their circuits. Once they know the current, I, they should be able to calculate R. You may need to remind them that they know the voltage in the system (a single D battery is 1.5 volts so the voltage total will be the number of D batteries times 1.5).

Discuss and Report

Each student group should share out about their circuit designs. If you've chosen to "sabotage" their circuits in the second part of the activity, ask students to share how they were able to troubleshoot their materials to find the damaged part of the system.

- What were the most difficult parts of building a circuit?
- You found the resistance of each circuit in two ways: first by measuring and adding up resistance and then by calculating it using current and voltage. Did your resistances match? If not, why might this be?
- If your circuit didn't immediately work, how did you troubleshoot it?
- If you were presented with a piece of electrical equipment that wouldn't turn on, where would you start?

Career Exploration and Extension

Once the students have successfully completed their circuits, you may want to have them trade in their working circuit kits for one that has been sabotaged. These could include burned-out bulbs, dead batteries, or damaged wires (note: ensure that these are not safety hazards!) Students should be able to diagnose the problem fairly quickly, either by process of elimination or testing with their multimeter.

Prompt students to think about and research what a career as a maintenance technician might entail.

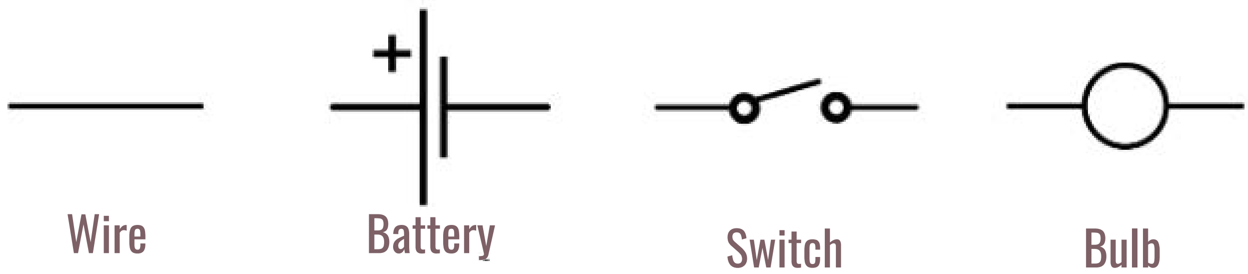
- What does a maintenance technician do all day? What does Nick do?
- What kind of training would a student need to become a maintenance technician? What other types of technicians are there?
- Are jobs like Nick's in high demand? Will more people be hired to be maintenance technicians in the future?
- What kind of education is needed to be a maintenance technician? Where could a student be trained locally for this career? What types of classes are important?

Name: ________________

Wire It Up

Student Data Sheet

You are a maintenance technician and you are tasked with finding the best way to wire up indicator lights within a piece of machinery. You need to design circuits that will allow one switch to turn on multiple lights. You will need to construct both a **series** circuit and a **parallel** circuit. Once you have successfully built each type of circuit, the team should sketch the circuit below using proper diagram symbols.



Sketch your **series** circuit below:

Sketch your **parallel** circuit below:

Name: ________________

Observations

What did you notice about the brightness of the bulbs in the different circuits? Can you explain this effect?

What happens if you remove a bulb from the series circuit? What about from the parallel circuit?

Ohm's Law

Ohm's law is a mathematical equation explaining the relationship between Voltage, Current, and Resistance within electrical circuits:

$$E = I \times R$$

Where:
- E = Voltage
- I = Current
- R = Resistance

Dismantle your last circuit and set the multimeter to measure resistance in Ohms (using it as an ohmmeter) and test the lightbulbs.

What is the resistance of each bulb?

Bulb 1	
Bulb 2	
Bulb 3	

Name: ______________

What is the resistance of your wires? This should be extremely low but let’s check them anyway in case any of them are damaged.

Wire 1	
Wire 2	
Wire 3	
Wire 1	
Wire 2	
Wire 3	

To find the total resistance on a series circuit, we simply add up the values for each item on the circuit.

$$R_T = R_1 + R_2 + R_3 \ldots$$

Where R_T is the total resistance, and each R# is a bulb (we’ll forget about the wires for now.)

The total resistance for your **series** circuit is:

Name: ________________

For parallel circuits, things are a little more complicated. Each path that electricity can take has its own resistance and these are added up. Each branch is represented by a fraction, $1/R_N$, so:

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3$$

The total resistance of your **parallel** circuit is:

What if we only had an ammeter (for testing Current) and couldn't just test each bit for resistance? How could we use Ohm's Law to find out the total resistance of our circuits?

Name: ________________

Re-create your series circuit. Using your multimeter as an ammeter, find the Current in amps across your series circuit. Use this to calculate the total resistance, R.

Does this match the resistance you calculated from your ohmmeter readings? If not, what could be the source of error?

Go back to your series circuit (or re-make it, if need be). Use your multimeter as an ammeter and find the current in amps across your parallel circuit. Use this to calculate the total resistance, R.

Did your calculations for your **series** circuits match? If not, why might this be?

Did your calculations for your **parallel** circuits match? If not, why might this be?

How might a maintenance technician use these strategies to diagnose problems with machinery?

ACKNOWLEDGEMENTS

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IMAGE AND CONTENT CREDITS

Images

Still video images from "Nick - Maintenance Technician," available at https://regionalopportunityinc.org/nick/

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One cell bettery, switch, and bulb by Studio Refine

Content

Lesson adapted from Get Connected: Ohm's Law (2021, April 15). Retrieved from https://tryengineering.org/teacher/get-connected-ohms-law/

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