Lesson 2: Circuit Types and Wiring Skills

Trailer Circuits STEM Kit Curriculum

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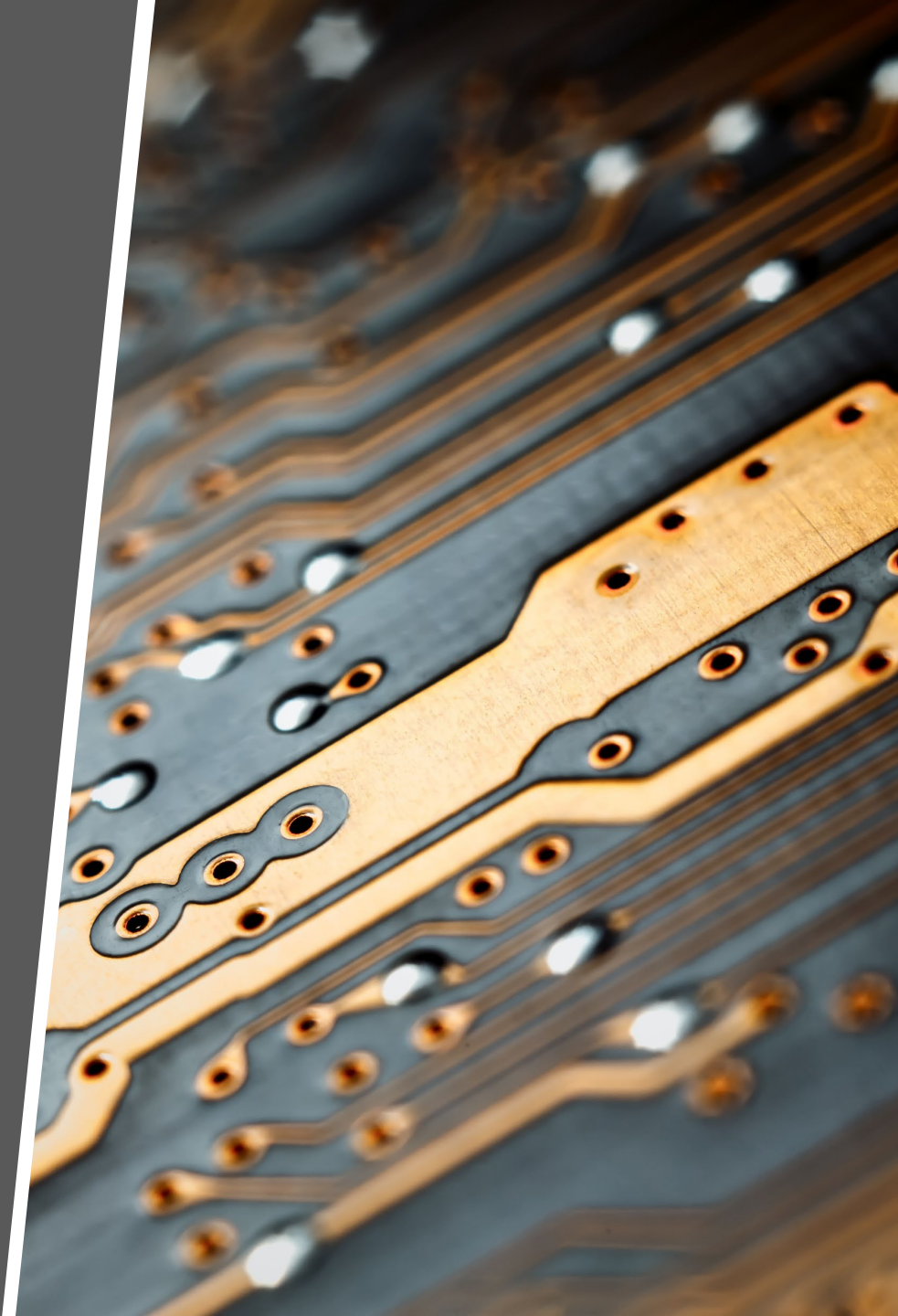
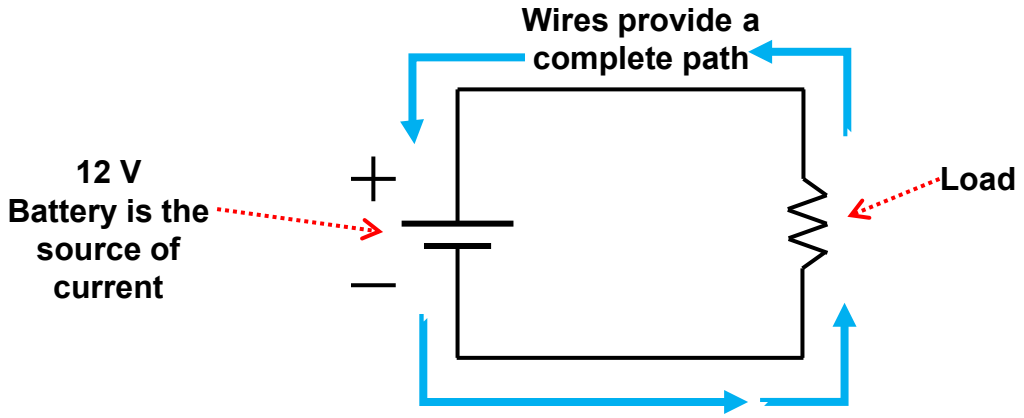


Circuit Concepts

Circuit Definition

A circuit is a complete path for current to flow, from a source of current through a load and back to the source of the current



DC Circuit Concepts

These 2 concepts apply to all direct current (DC) circuits:

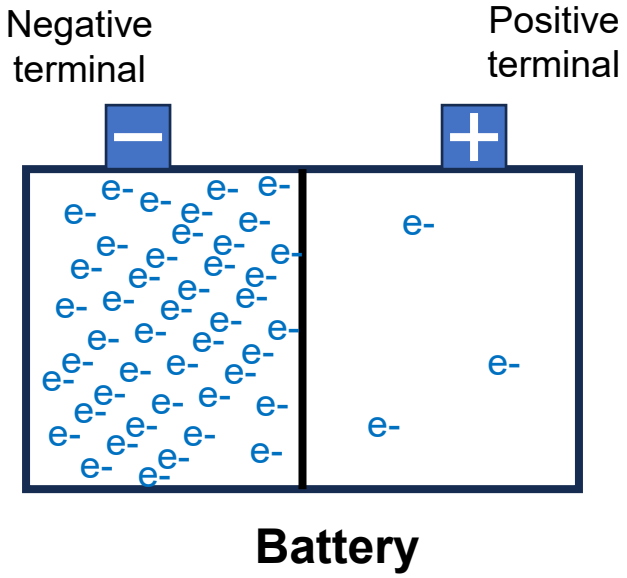
1. Circuit polarity
2. Circuit State: Open, closed, and dead shorts

Understanding these allows you to build and troubleshoot DC circuits.

You can find DC circuits in laptops.

Circuit Polarity

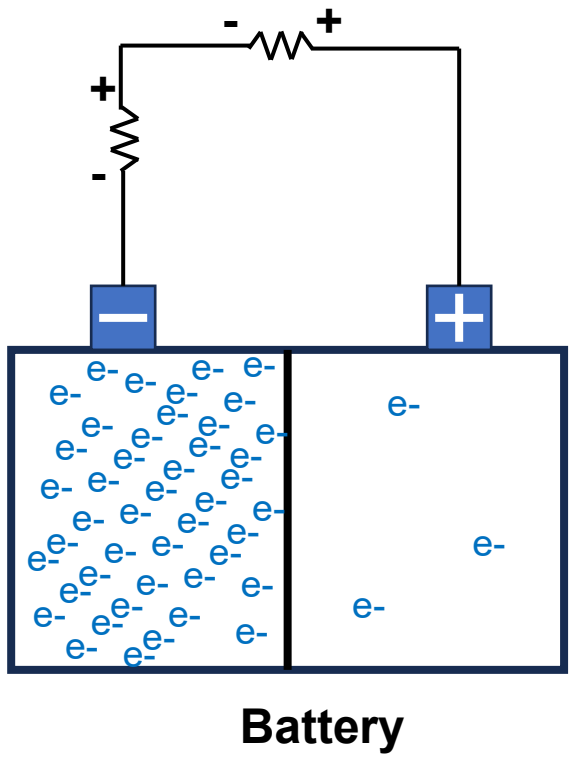
- **Polarity** is used to describe areas with different electrical charges
- It is established when there is an electrical potential difference (think of this as an imbalance of electrons)
- **Batteries are polarized**
  - Chemicals are used to create polarity
  - Negative side has lots of electrons
  - Positive side has very few
- **Direction of Flow:** If 2 areas of different polarity are connected, the current will *flow from – to +*



Battery

Circuit Polarity

- When current starts to flow, **everything** in the circuit becomes **polarized**, having a – and + side
- **Why is this important?**
  - Some circuit components **only** work in 1 direction of polarity
  - *Example*: LED bulbs
    - If you install an LED bulb backwards, it will not work



Battery

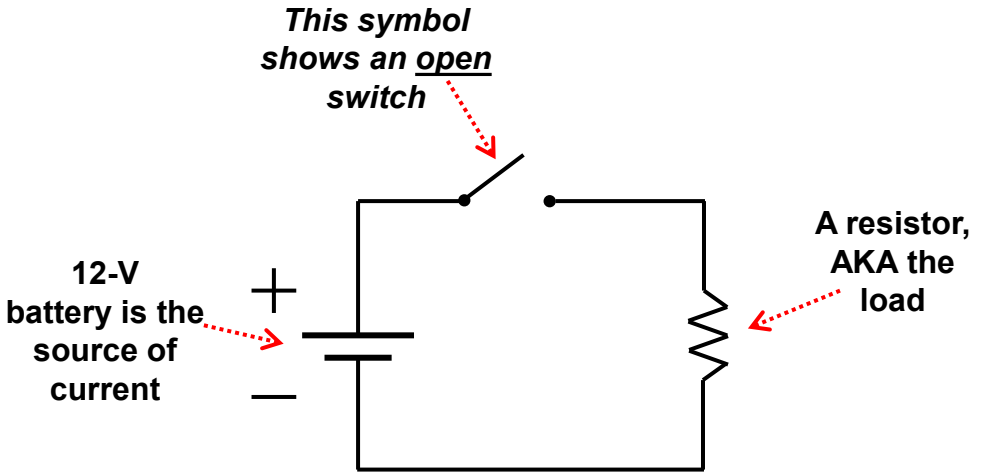
Circuit States: Open, Closed, and Short Circuits

- Every DC circuit is in 1 of these 3 states
- Knowing these 3 states helps you troubleshoot when things are not working right

You can find DC circuits in cameras.

State: Open Circuits

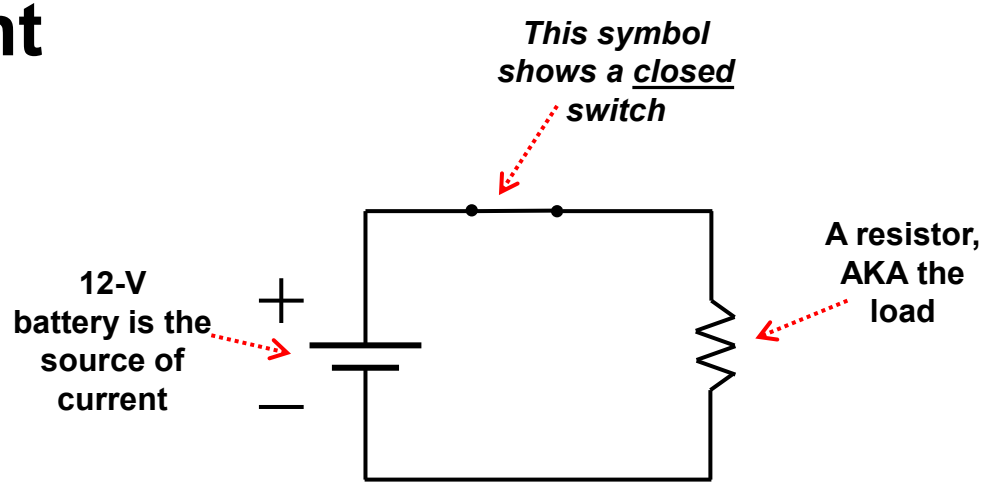
- **An open circuit prevents current flow**
  - The current is zero
  - Current cannot flow past the open switch
- **Circuits might be open due to:**
  - Switch
  - Broken wire
  - Loose connection
  - Corroded connection
  - Burnt-out bulb
  - Anything that puts a break in the complete path



Because there is not a complete path for current to flow out of the source (battery) and back, the current in this circuit is zero.

State: Closed Circuits

- **A closed circuit allows current to flow**
  - The current is positive
  - Current can flow past the closed switch



There *is* a complete path for current to flow out of the source (battery) and back, so the current would be positive.

State: Short Circuits

There are 2 ways for a circuit to short out:

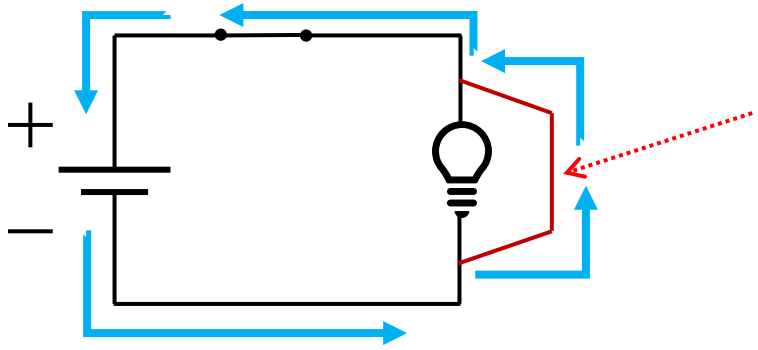
1. **Short Circuit:** Current ***continues*** through a short circuit
2. **Dead Short:** Current ***stops*** in or with a dead short

Knowing what each is will help you identify and troubleshoot.

Source: https://openverse.org/image/2e51c0ed-873b-4f02-ba74-45010c7d1cde?q=short+circuit

State: Short Circuits

- A short circuit is a high-current that has an easier path back to the source that skips the load
- A short circuit has almost no resistance and a high current flow
- Current continues flowing



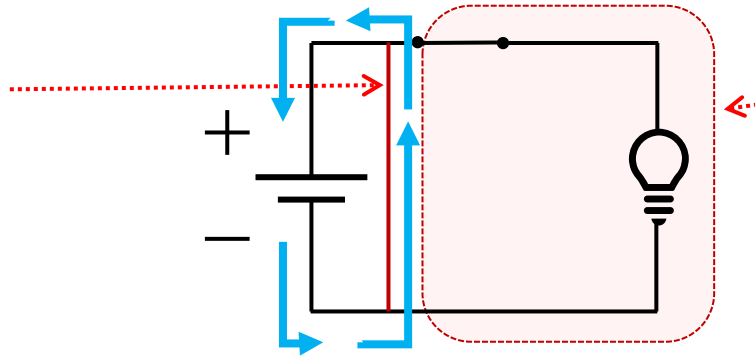
This wire creates an easier path for the current to flow along, allowing the current to skip the light bulb.

Electricity is like water… it always follows the easier pathway.

State: Dead Shorts

- If a grounded object (like a jumper cable clamp that you are not paying attention to) contacts a live circuit, the electricity will immediately take that path to ground, shorting out the circuit
- Known as a **dead short** because this immediately turns off everything in the circuit past the short
- Current no longer flows through the rest of the circuit
- ***Sparks may fly!***
  - Because there is no resistance in the new path, the current is dangerously high

Accidental connection = New path for current to flow = DEAD short



No current flows through the rest of the circuit… it is dead

Circuit Types

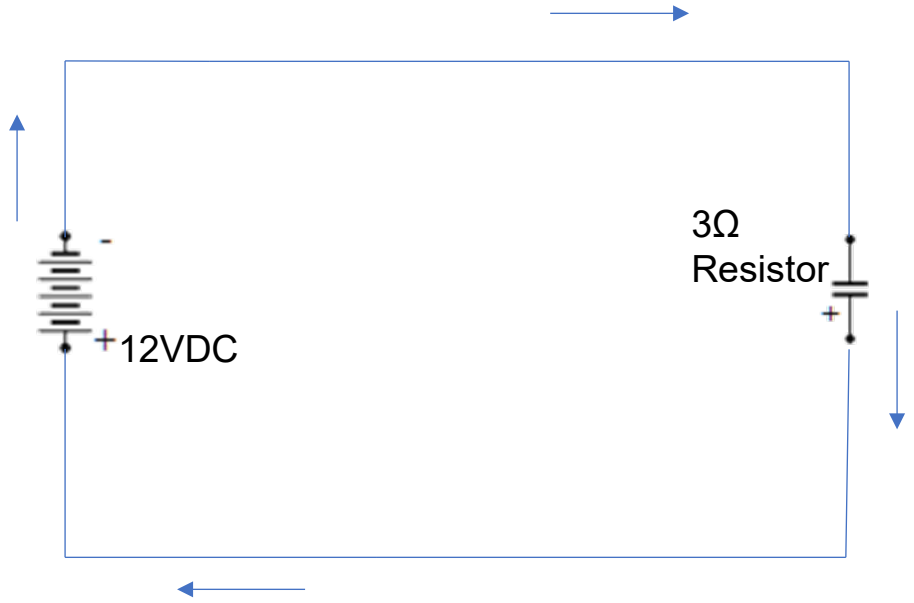
DC Circuit

Remember… A circuit is a complete **electrical path** for current to flow through

You can find DC circuits in vehicles.

DC Circuit = Path

- Current flows out from positive to negative
- Here, the path is complete or ***closed***

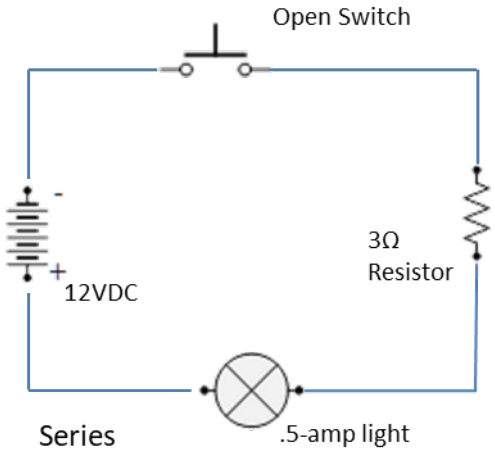


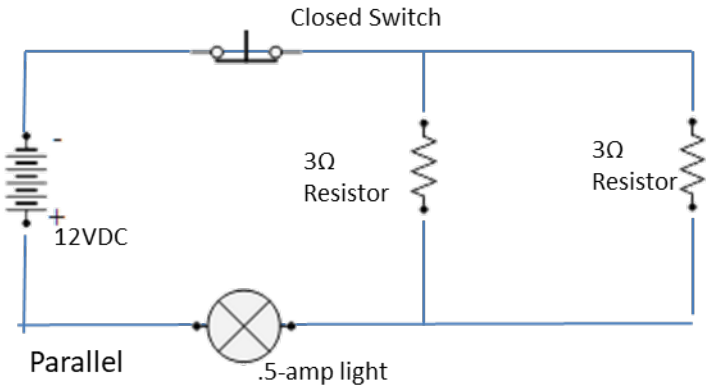
Circuit Types

- DC circuits come in 3 types:
  - Series
  - Parallel
  - Combination

You can find DC circuits in laptops.

Series Circuits vs Parallel Circuits





What do you notice?
How are they different?

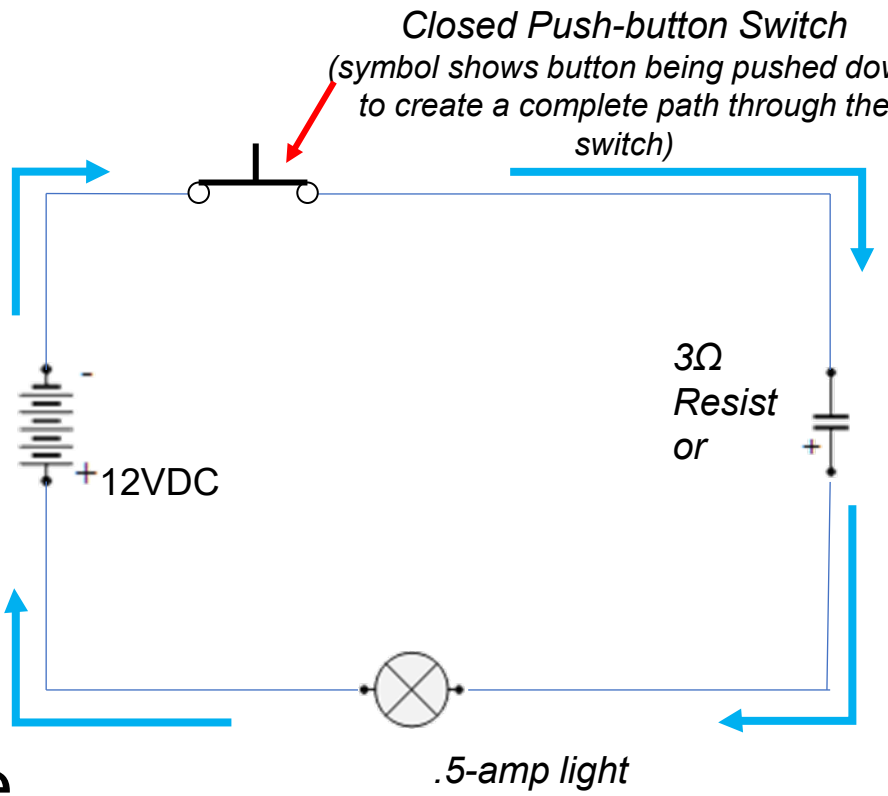
Series Circuits

Series Circuits

- Series circuits have ***1 single path*** for current to flow
- Current flows out from positive to negative

Properties of Series:

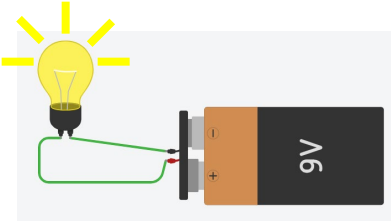
- **Voltage:** Divided up between the circuit components:
  - ***Ex:*** $V_{source} = V_{light} + V_{resistor}$
- **Current:** Stays the same throughout the whole circuit
- **Resistance:** Each component's resistance adds together
  - ***Ex:*** $R_{Total} = R_{light} + R_{resistor}$



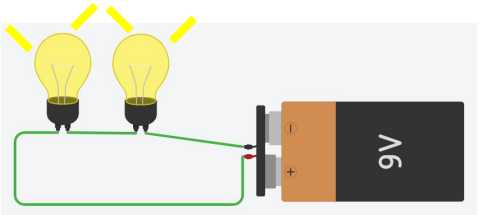
How Electricity acts in a Series Circuit

- Each of these is a series circuit with 1 path for current to flow out of the negative terminal, through the circuit, and back to the positive terminal of the battery
- Each circuit only has 9 V of electrical energy to use
  - 1 bulb circuit = all the energy (9 V) goes to the 1 bulb = super bright!
  - 3 bulb circuit = the energy is shared equally (3 V each) = dim.

BRIGHT!

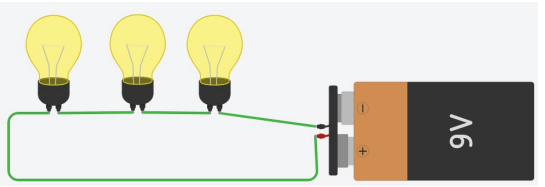


9 V goes to 1 bulb



4.5 V goes to each bulb

Dim



Only 3 V goes to each bulb

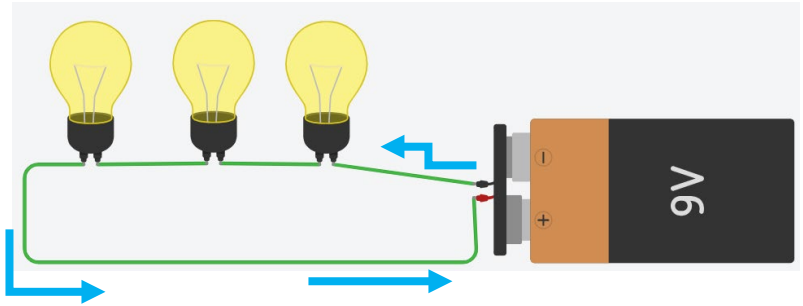
Series Math Rules

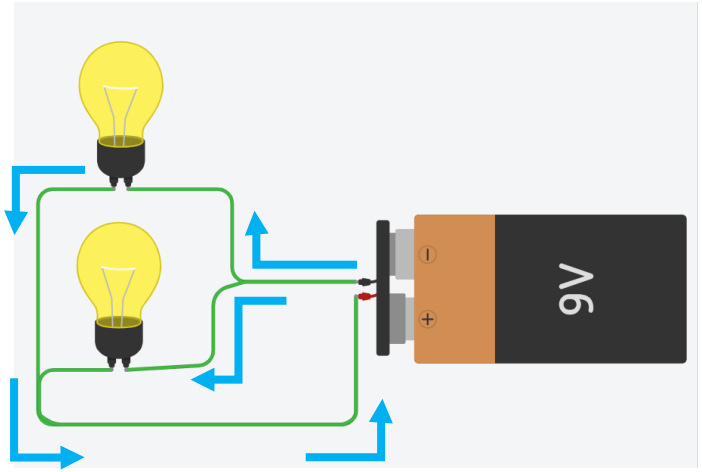
- Voltages add up to equal the total
  - $V_{total} = V_1 + V_2 + \ldots + V_n$
- Current is the same throughout
  - $I_{total} = I_1 = I_2 = \ldots = I_n$
- Resistances add up to equal the total
  - $R_{total} = R_1 + R_2 + \ldots + R_n$

You can find series circuits in flashlights.

Parallel Circuits

Not all circuits have 1 path





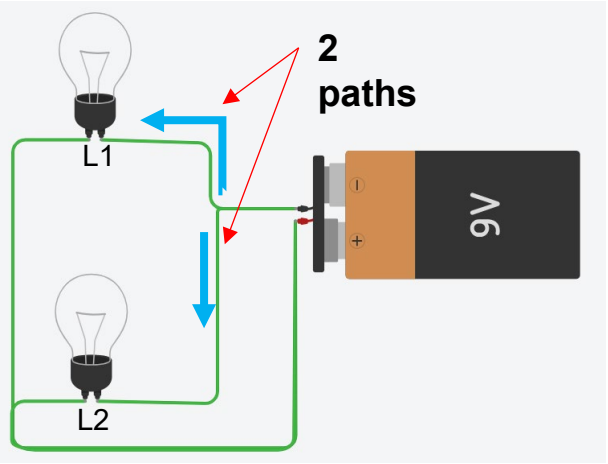
Can you trace the current from – to +?

Parallel Circuit

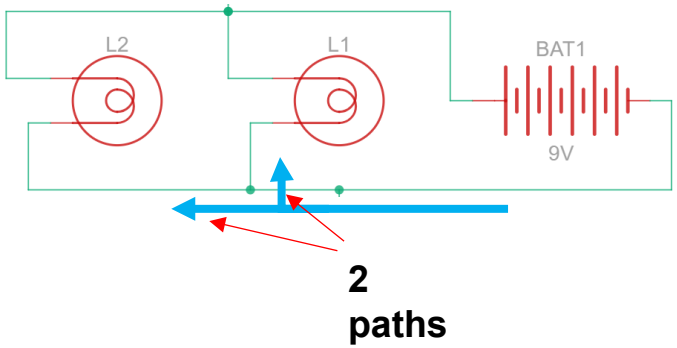
- Parallel circuits have ***more than 1 path*** for current to flow
- Current flows out from positive to negative

Properties of Parallel Circuits:

- **Voltage:** The same in each branch of the circuit
  - ***Ex:*** $V_{source} = VL_1 = VL_2$
  - ***So, in this circuit everything has V = 9 V***
- **Current:** Each components current adds together
  - ***Ex:*** $I_{Total} = I_{L1} + I_{L2}$
- **Resistance:** Each component's resistance adds together as it's reciprocal
  - ***Ex:*** $1/R_{Total} = 1/R_{L1} + 1/R_{L2}$

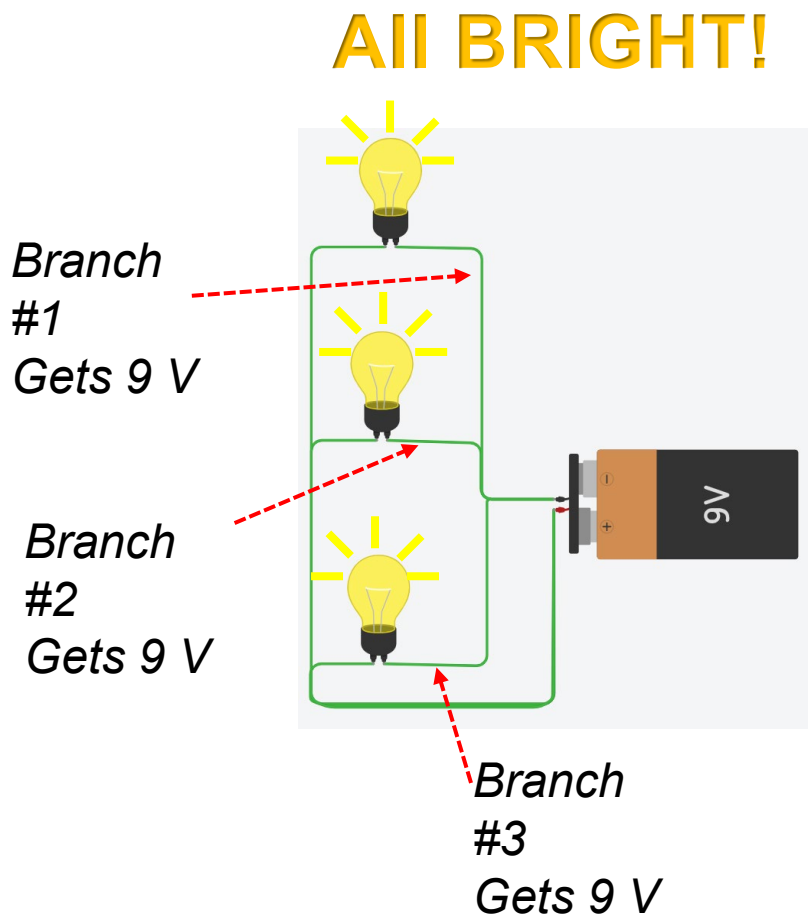


***Notice**: These are the same circuit!*
Below is a schematic drawing of the above.



How Electricity Acts in a Parallel Circuit

- Voltage stays same in each circuit branch
  - Each of these bulbs is in its own branch of the circuit
  - Each branch gets 9 V, so each bulb gets 9 V = bright!



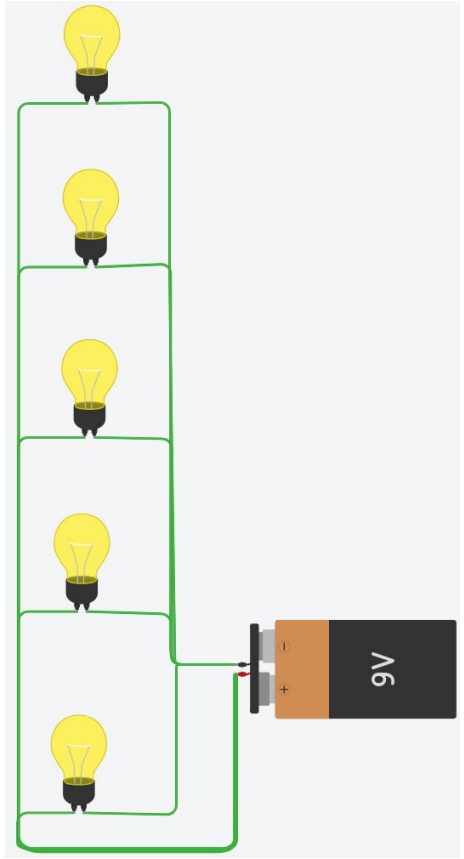
Math Rules for Parallel Circuits

- $V_s = V_1 = V_2 = V_3$
- $I_{total} = I_1 + I_2 + I_3$
- $\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

You can find parallel circuits in string lights.

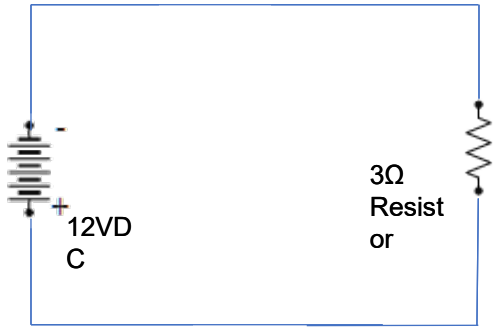
Parallel Circuits Are Everywhere

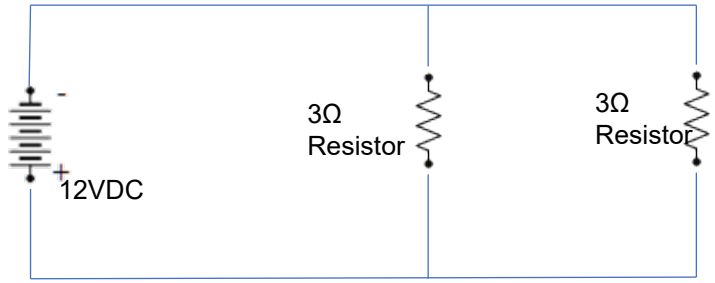
- **Examples:**
  - Holiday lights
  - Household circuits (wall outlets, lights, etc.)
  - Vehicles
  - Trailer wiring
- **Can you just keep adding branches?**
  - Must be careful; each branch adds to the load of the circuit, increasing the current flow
- Too much load = ***Dangerous!***
  - Fuses blow if there is too much load
  - Circuit breakers trip if too much load



Difference Between Series and Parallel

Series Circuits Versus Parallel Circuits





One Path

Voltage adds

$$V = V_1 + V_2 + \ldots$$

Current stays the same

$$I_T = I_1 = I_2$$

More Than One Path

Current adds

$$I_T = I_1 + I_2 + \ldots$$

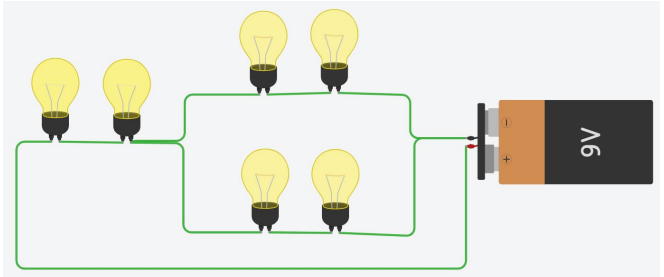
Voltage Stays the same

$$V_T = V_1 = V_2$$

Combination Circuits

Combination Circuits

- The world is filled with complex combination circuits
- Combination circuits contain any combination of **series** or **parallel** circuits within them
- Can be confusing… focus on the component that is giving you trouble!



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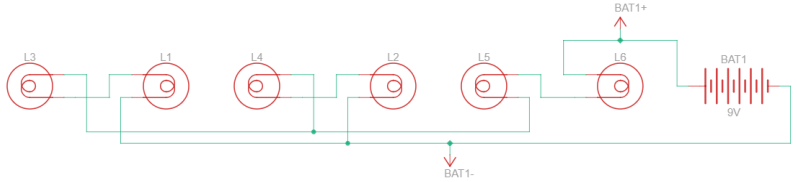
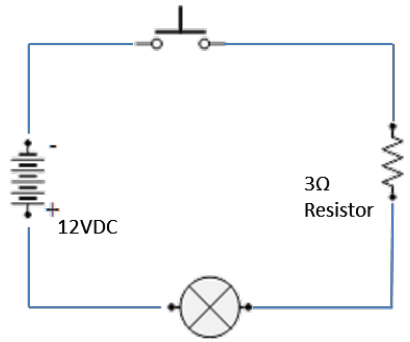
Below is a schematic drawing of the above.

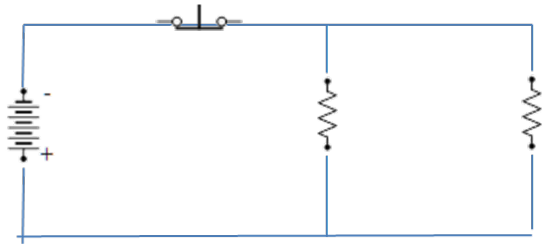


Circuits Summary

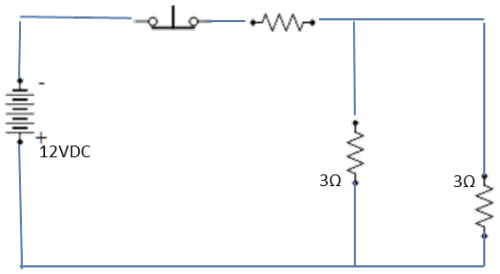
Series



Parallel



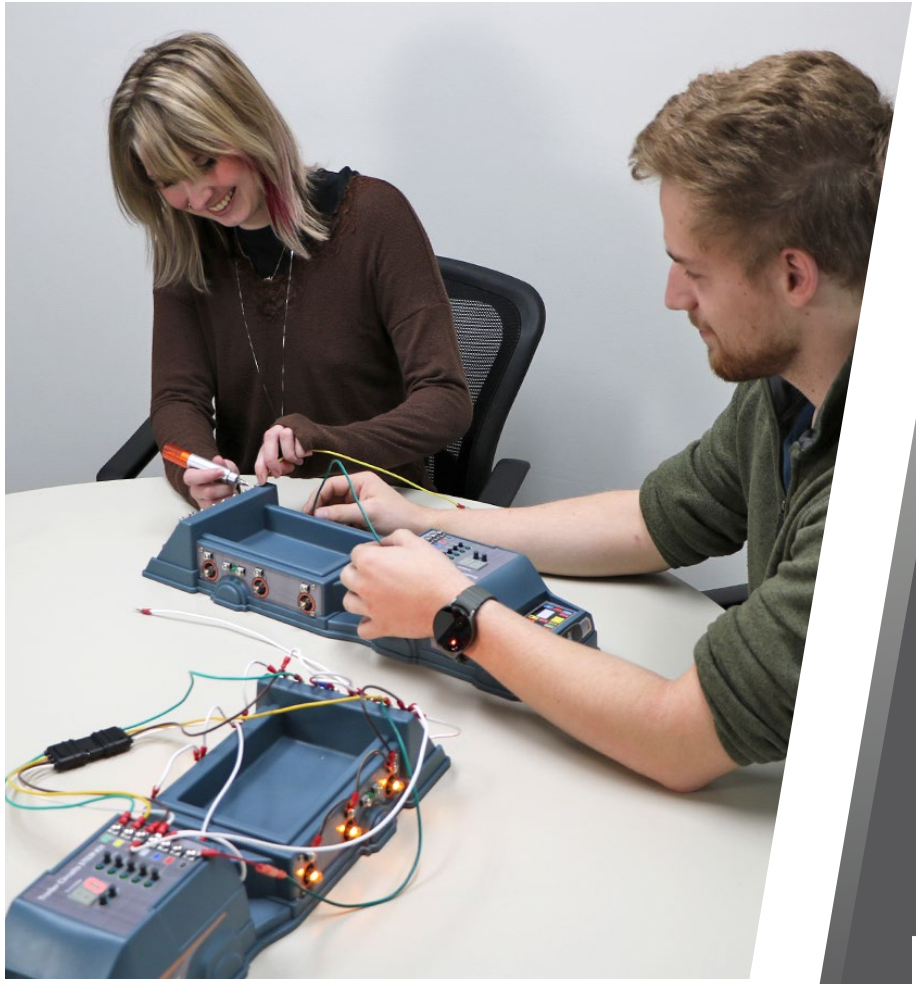
Combination



Start Wiring the Trailer Circuits Trucks

Start Wiring the Trailer Circuits Trucks

- **We will use the Trailer Circuits Trucks to build and test:**
  1. Simple series circuits
  2. Simple parallel circuits
- **Look under the truck and ensure the power switch is *off***
- ***Rule 1: Never work on or build circuits with live power***



You Will Need These Tools

Series Circuit: Step 1

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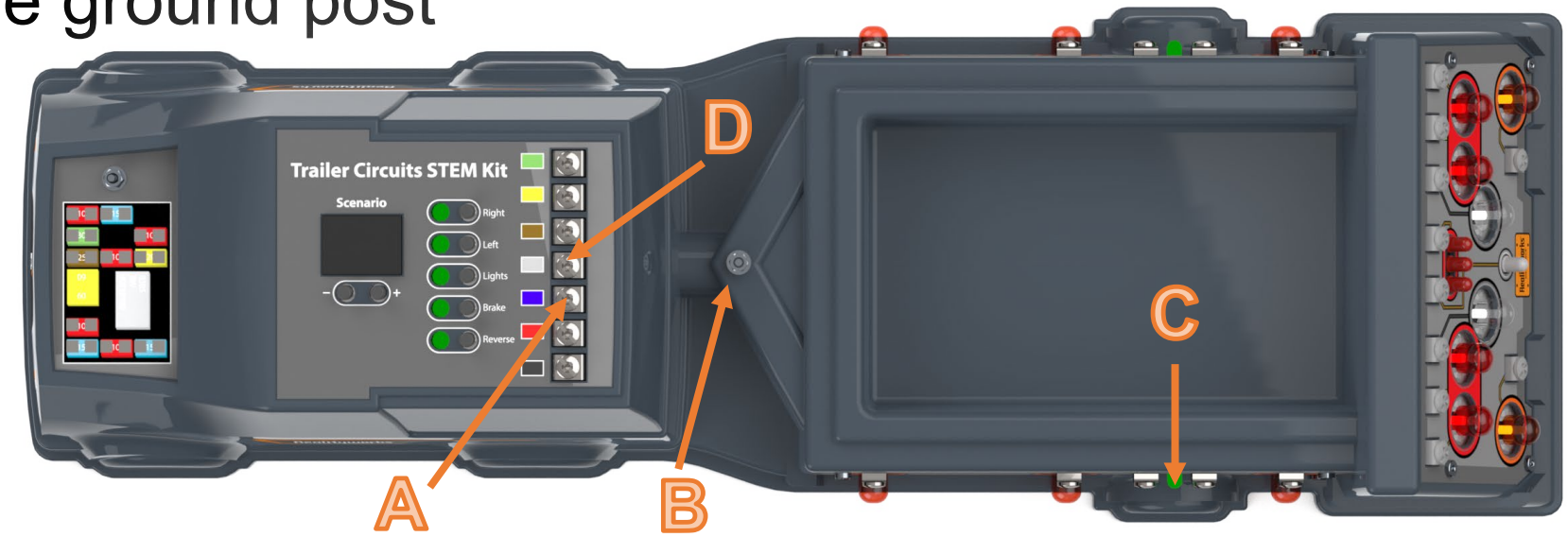
Identify these points on the Trailer Circuits Truck:

Look underneath the truck and ensure the *power switch is off.*

A. Blue brake control terminal
B. Trailer ground post
C. Driver's side electric brake indicator light
D. Vehicle ground post



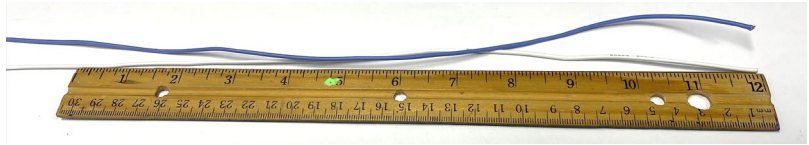
Series Circuit: Step 2

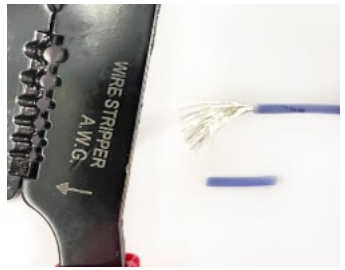
You will need 3 wires:

- 1 blue wire, measuring 12”
- 2 white wires, measuring 6” and 10”

Instructions:

1. Using a ruler, measure each wire. Ask your instructor for the wire spools.
2. Using the wire cutter, cut off 12” of wire from the blue spool as well as 6” and 10” from the white spool.
3. Strip off the insulation on both ends of the wires, exposing ½” of the inner metal.

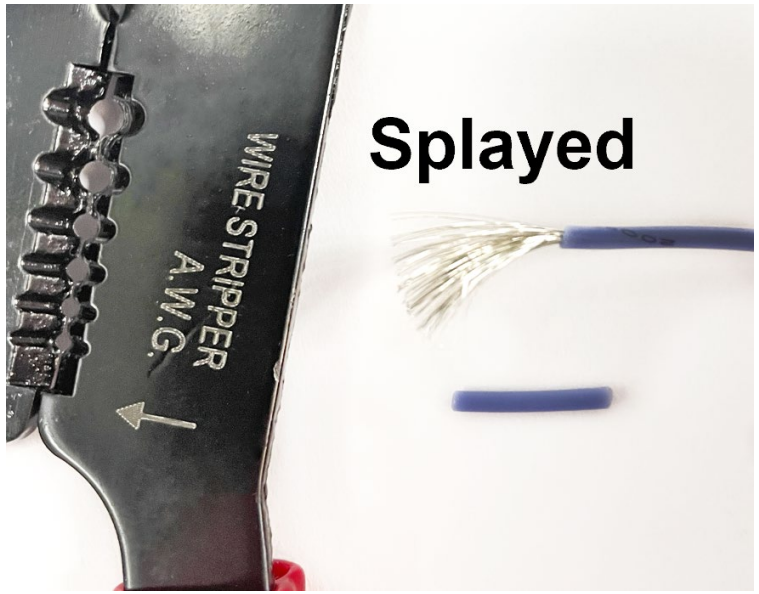




Series Circuit: Step 3

J-hook your wires

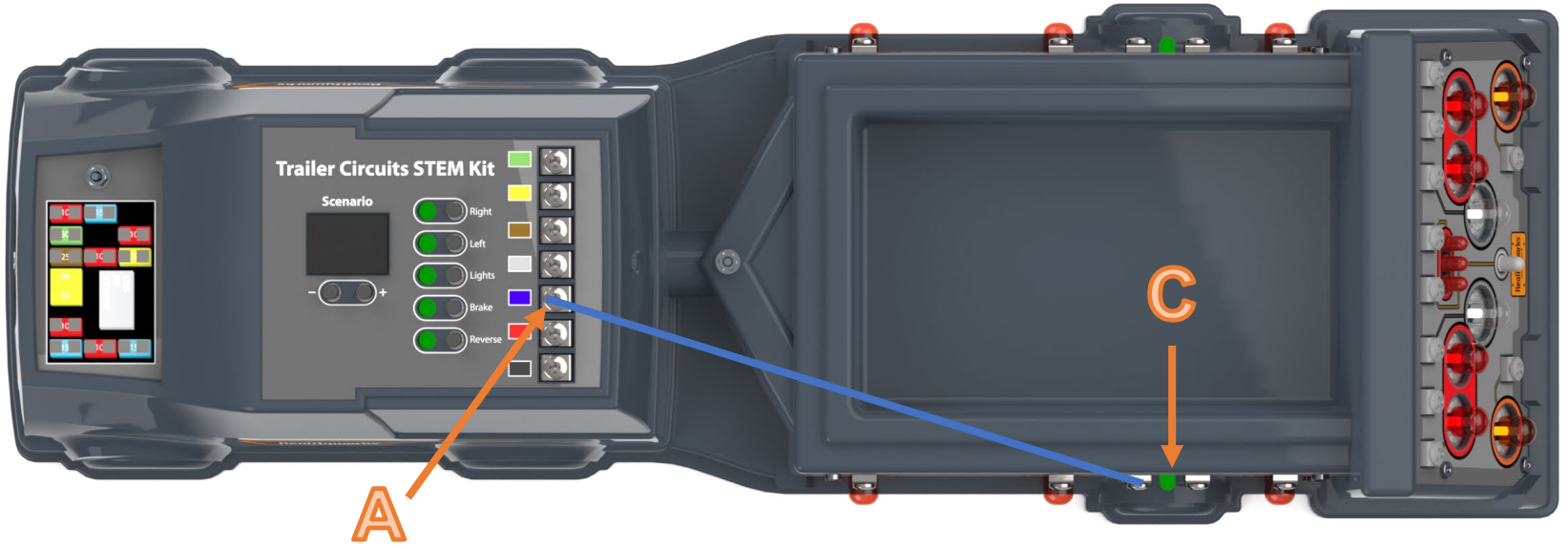
1. Use your fingers to twist the wires so they are not splayed.
2. Use your fingers to bend the ends of both wires into a J.



Series Circuit: Step 4

Connect A to C with the blue wire.

1. Wrap 1 J-hook end of the blue wire around the screw terminal at A.
2. Wrap the other end of the blue wire to the screw terminal on the left side of C.



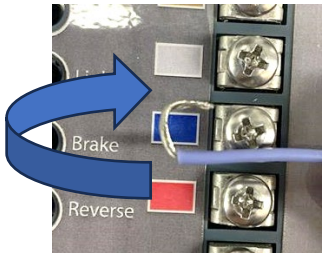
Series Circuit: Step 5

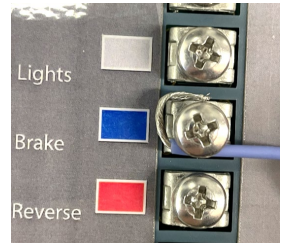
Check direction and tighten the terminal screws.

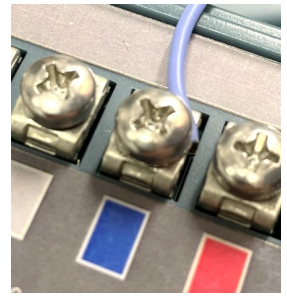
1. Ensure the J-hook is wrapped around the terminal as shown. When you tighten the scree, it should wrap the wire around the screw clockwise.
2. Use the screwdriver to tighten the screw just enough to secure the blue wire in place.

   Clockwise = “Righty tighty” to tighten the screw

   Counter-clockwise = “Lefty loosey” to loosen



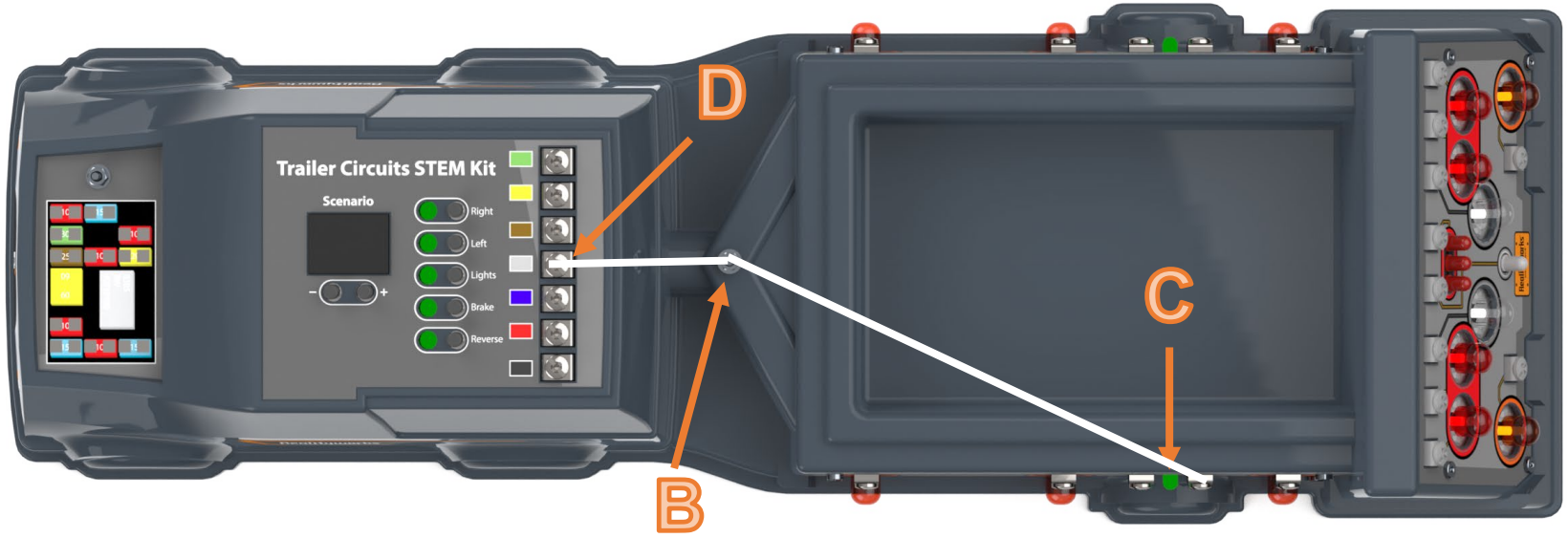




Series Circuit: Step 6

Connect B to C with the 10” white wire *and* B to D with the 6” white wire.

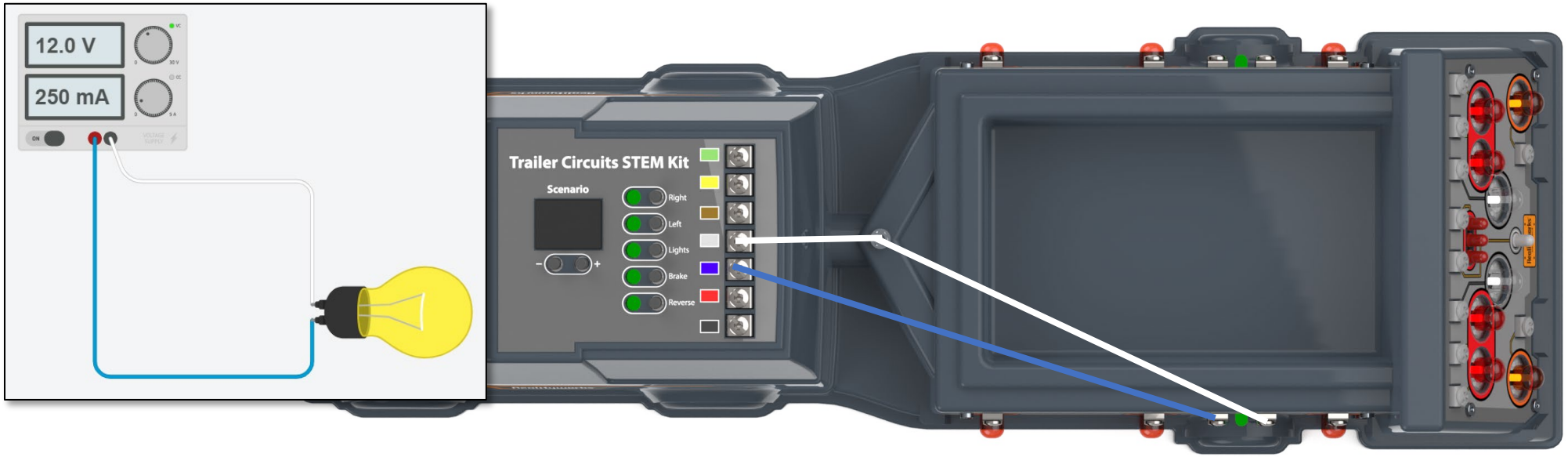
Repeat the same steps you did with the blue wire, using the white wires with J-hooks to connect the screw terminal to the right of C and the ground terminal at B.



Series Circuit: Step 7

Confirm circuit.

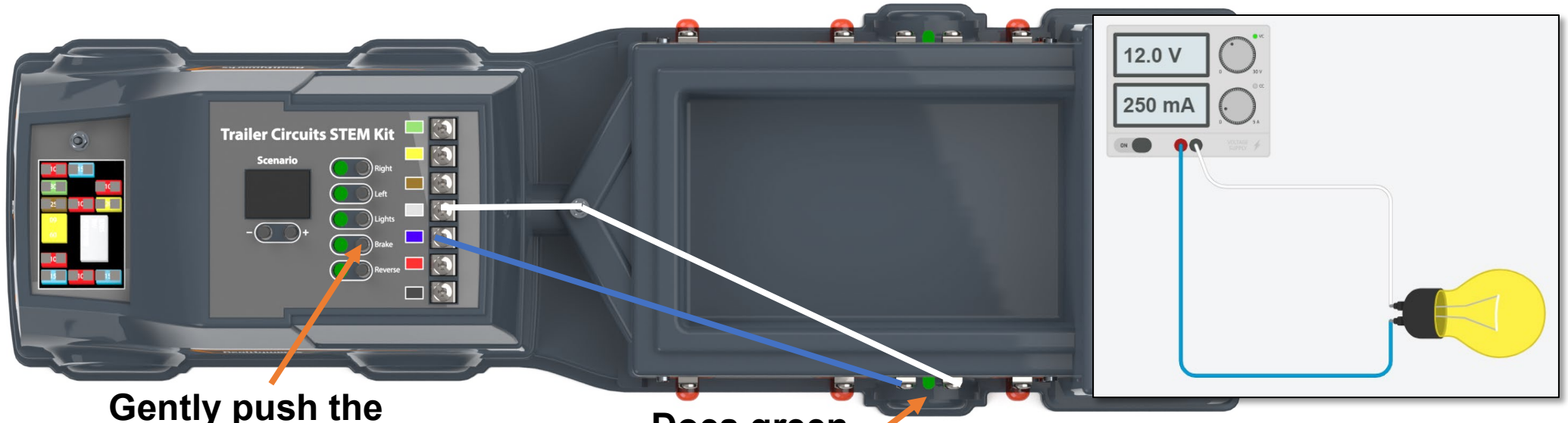
- The blue wire connects the 12-V car battery to the electronic brake of the trailer
- The white wire completes the circuit by connecting to the ground of the trailer and vehicle



Series Circuit: Step 8

Test the circuit.

1. **Turn on the Trailer Circuits Truck** using the switch on the bottom. Ensure batteries are installed.
2. **Gently push the *Brake* button.** You should see the green light turn on.
3. **If the green light turns on, *you successfully built a series circuit!***



Parallel Circuit

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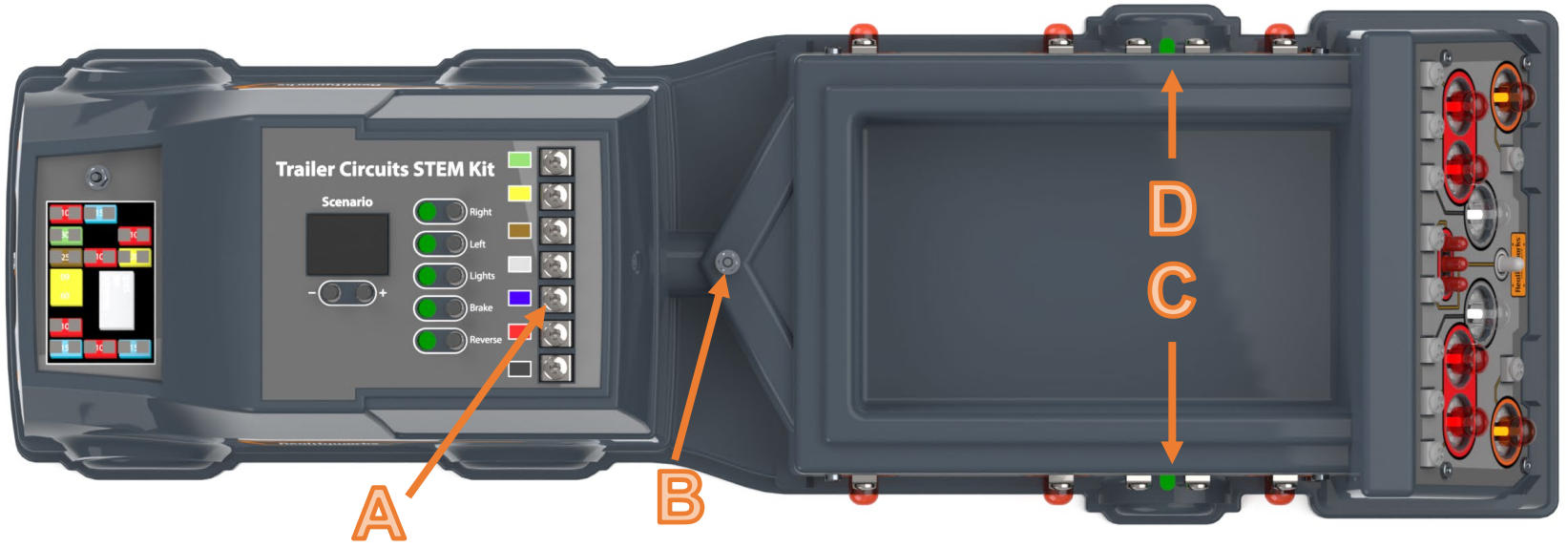
Large, heavy trailers have brakes on **both** sides…

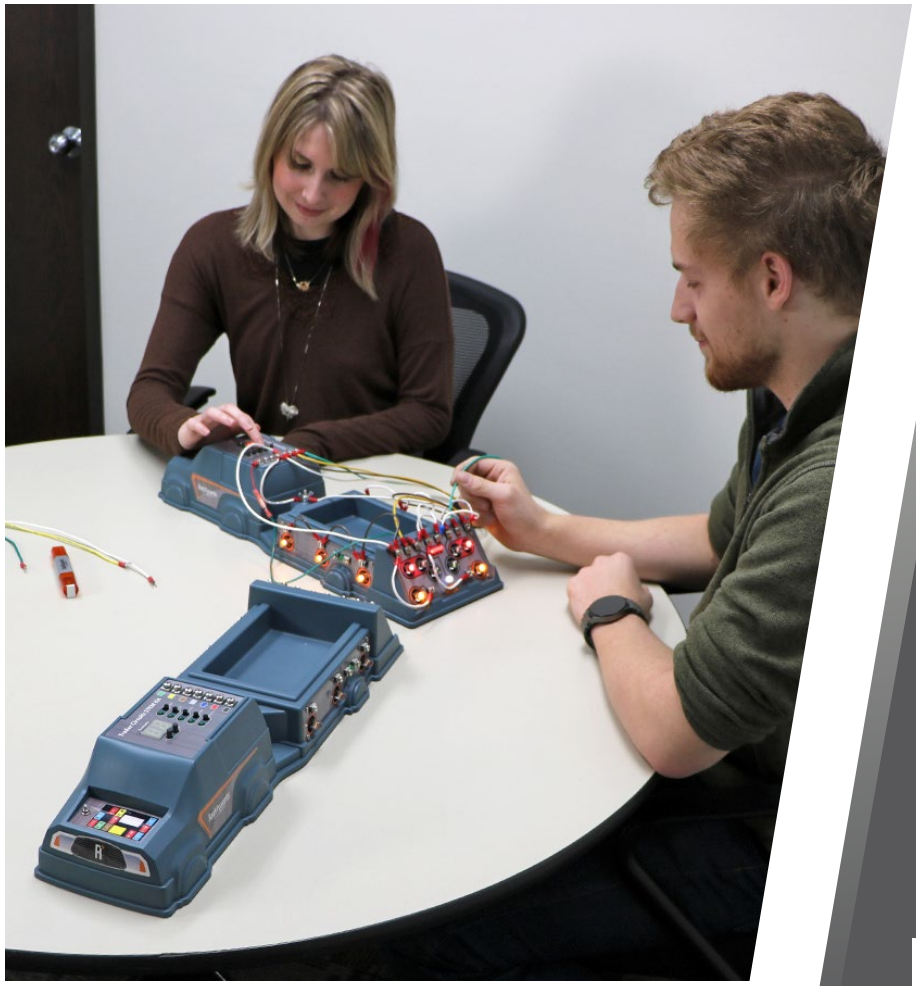
Now, let's turn our series circuit into a parallel circuit so both brakes receive 12 V of power.



Parallel Circuit: Step 1

Power it off.

- **Ensure the power switch is off**

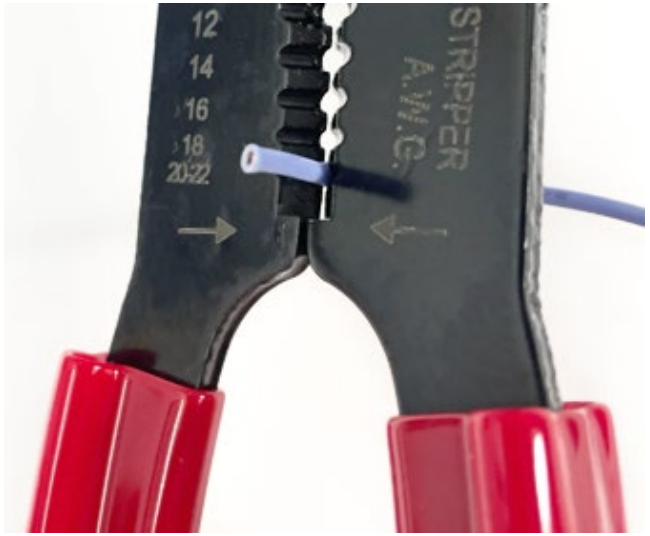


Parallel Circuit: Step 2

Prepare another blue wire.

Instructions:

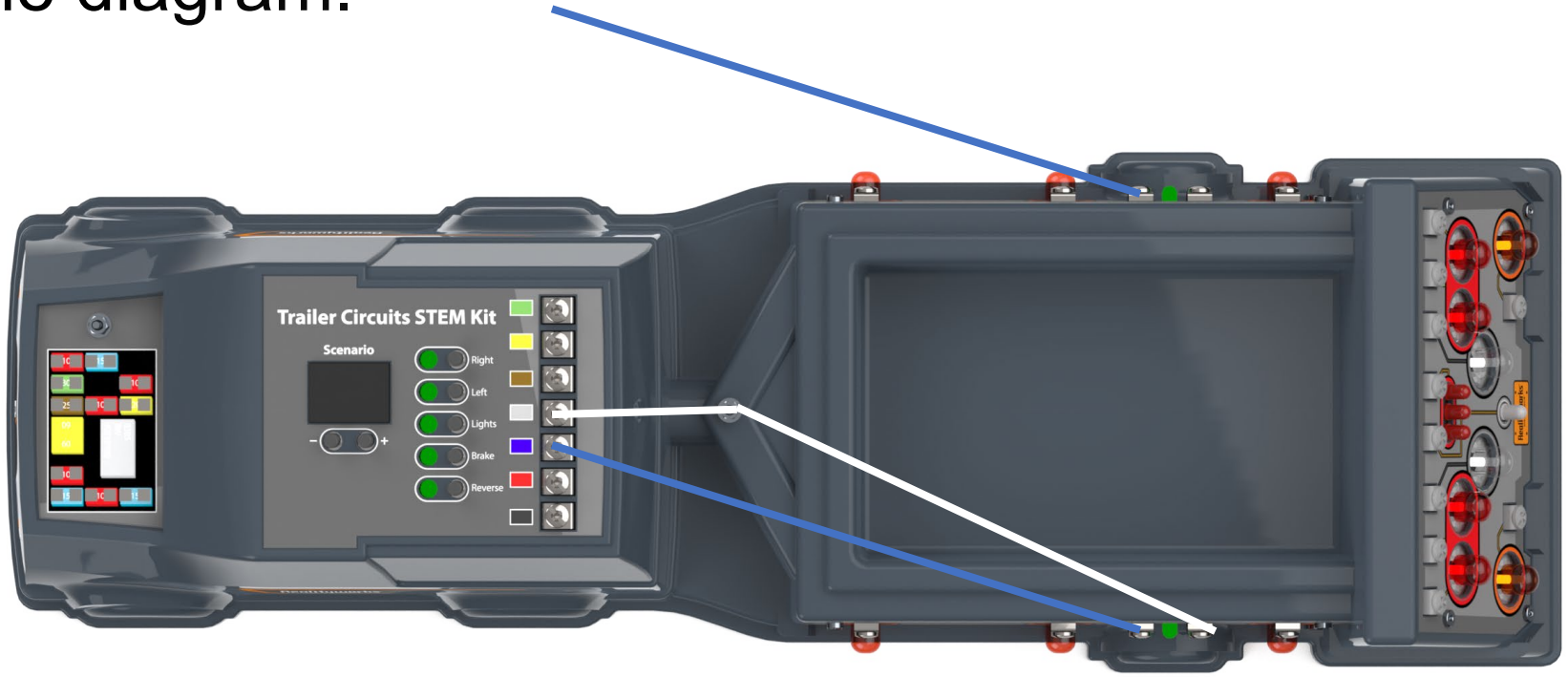
1. Using a ruler, measure 8” of blue wire.
2. Using the wire cutter, cut off 8” of blue wire from the spool.
3. Strip off the insulation on both ends of the wires, exposing ½” of the inner metal.
4. **J-hook *only 1 end* of the blue wire.**



Parallel Circuit: Step 3

Connect the J-hook end of the blue wire.

Securely connect the J-hook end of the blue wire to D, using the terminal shown in the diagram.

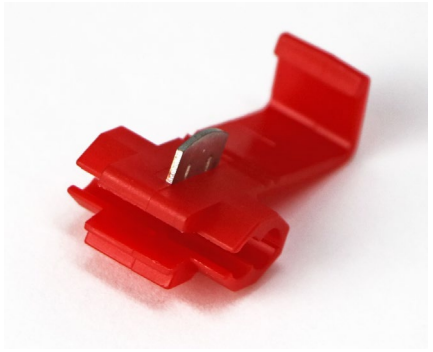
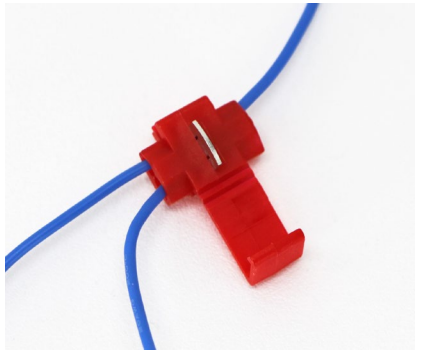
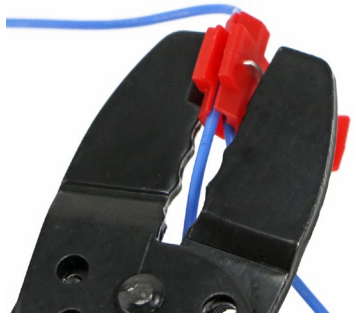
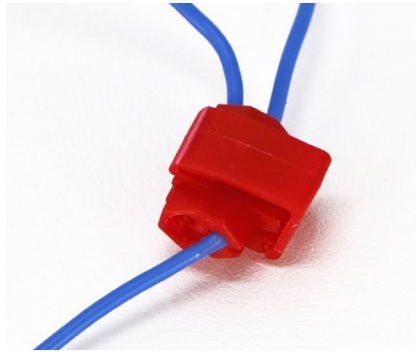


Parallel Circuit: Step 4

Connect the blue wires using the red 3-way connector.

Instructions:

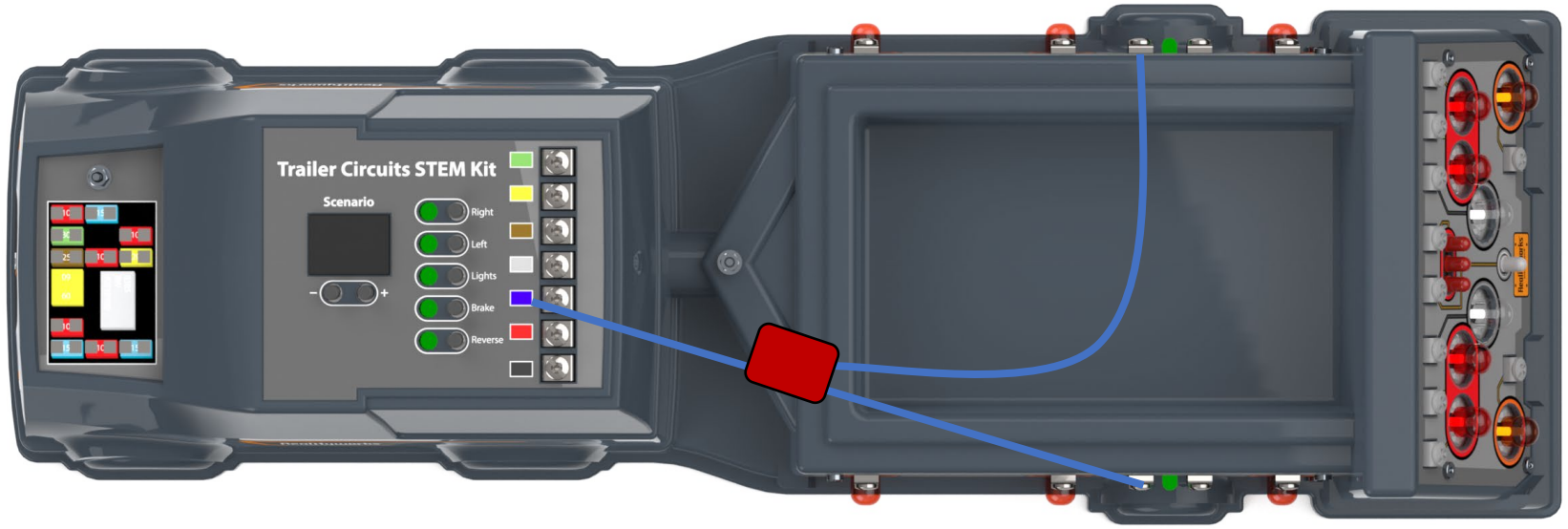
1. Open the red 3-way connector.
2. Insert the connector onto the already installed blue wire.
3. Slide the end of the new blue wire into the connector. Do not let the end stick out the other side of the connector.
4. Use the wire cutter to squeeze the metal lock down, trapping the 2 wires into the connector. This metal cuts through the protective coating of the wires and creates a conductive pathway for electricity to flow.

Parallel Circuit: Step 5

Confirm the blue wire to blue wire connection with the red 3-way connector.

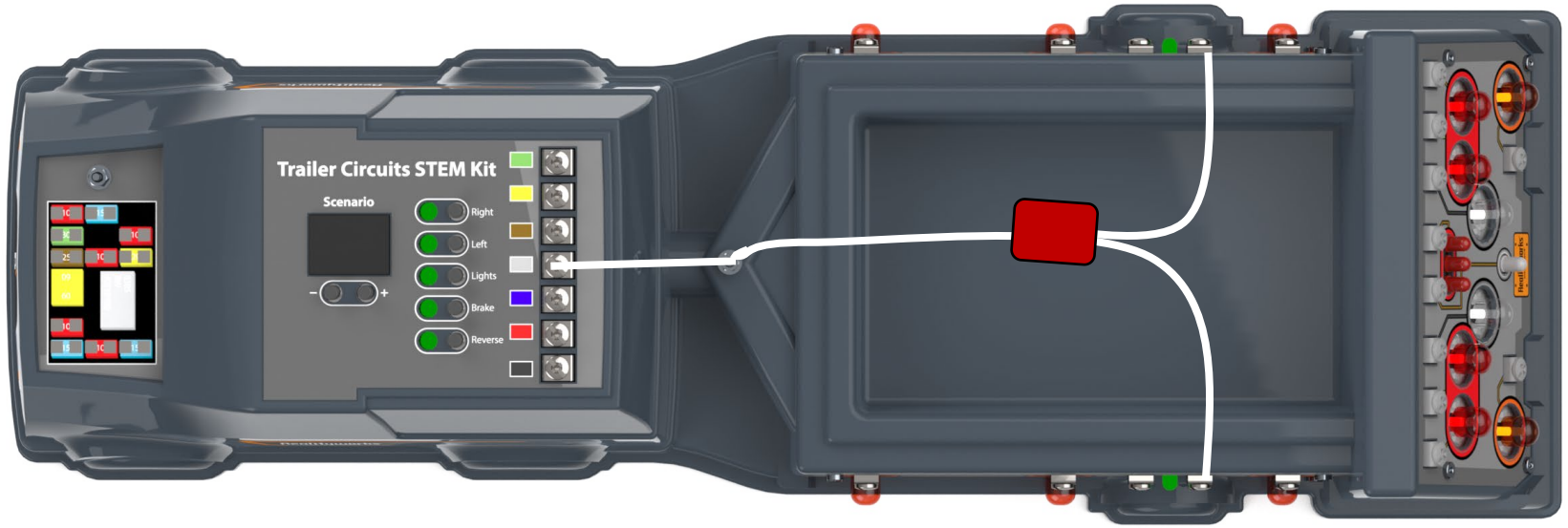
This is what your blue wires should look like now.



Parallel Circuit: Step 6

Repeat with a second white wire.

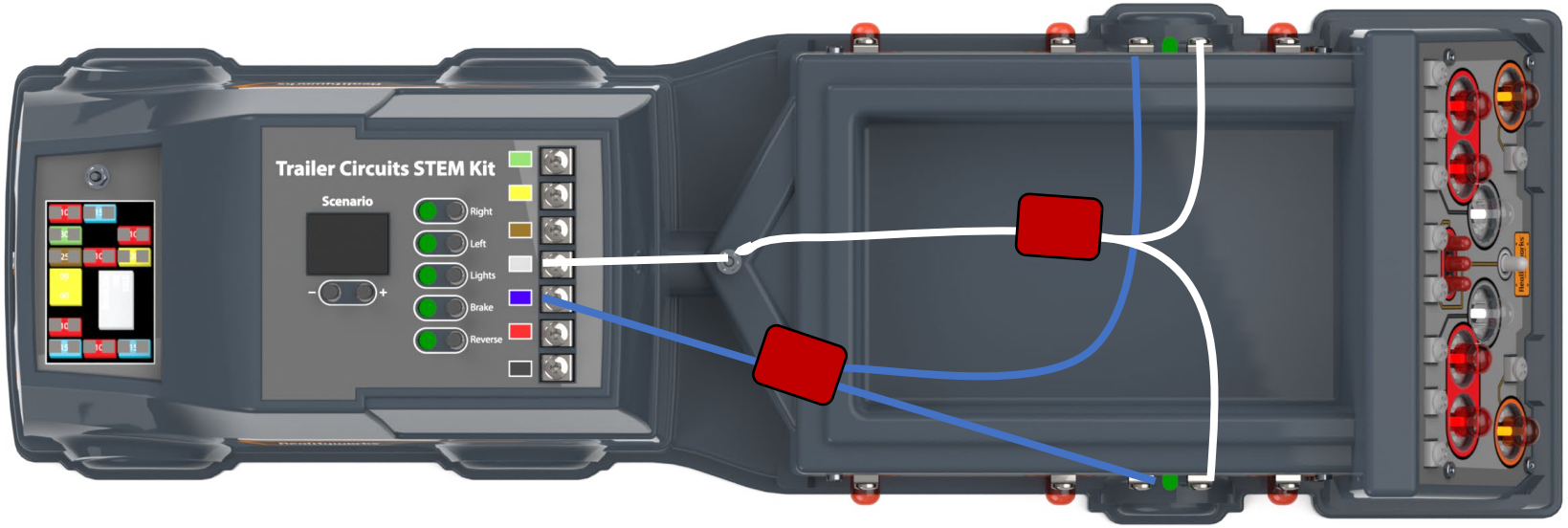
- Install the new white wire using the same steps you just used for the blue wire
- Your 2 white wires should look like this



Parallel Circuit: Step 7

Confirm wire connections.

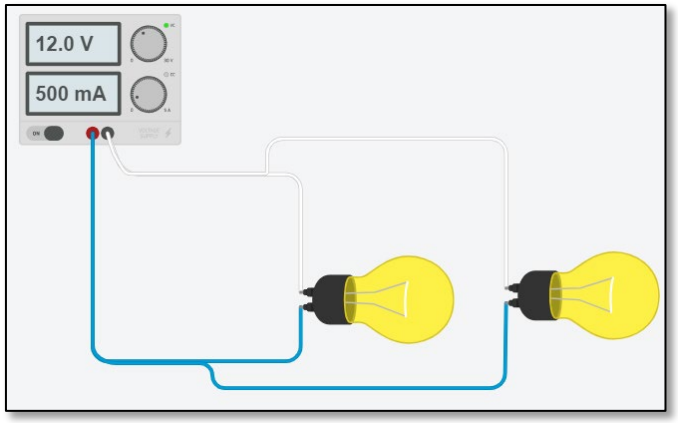
This is what your 2 blue wires and 2 white wires with 3-way connectors should look like now.

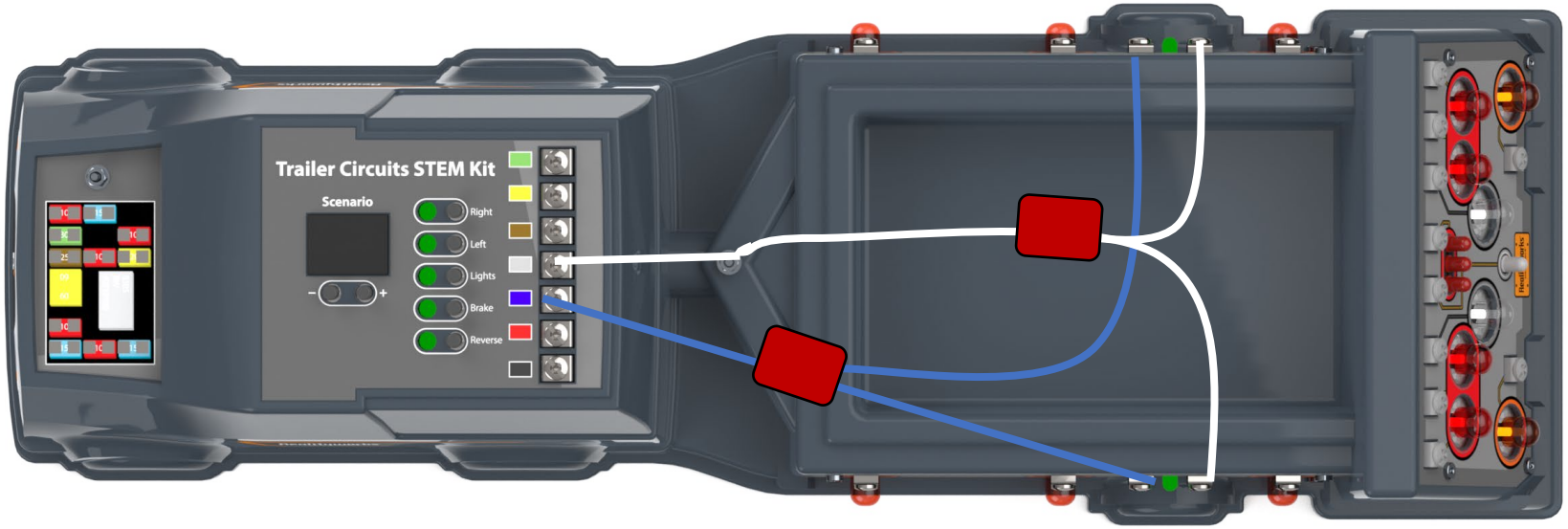


Parallel Circuit: Step 7

You built this parallel circuit:

This is what your Trailer Circuits Truck should look like now.

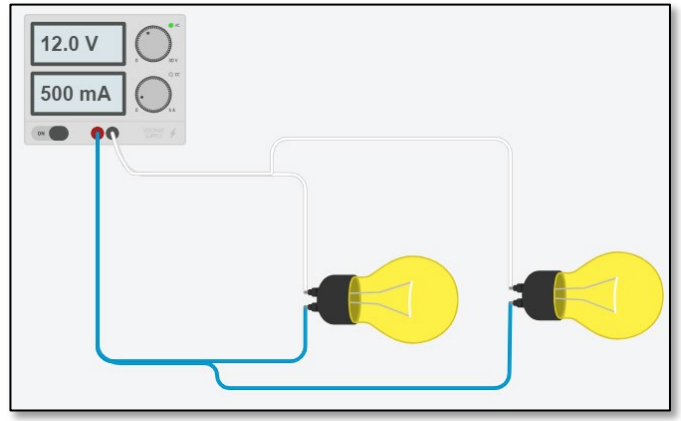


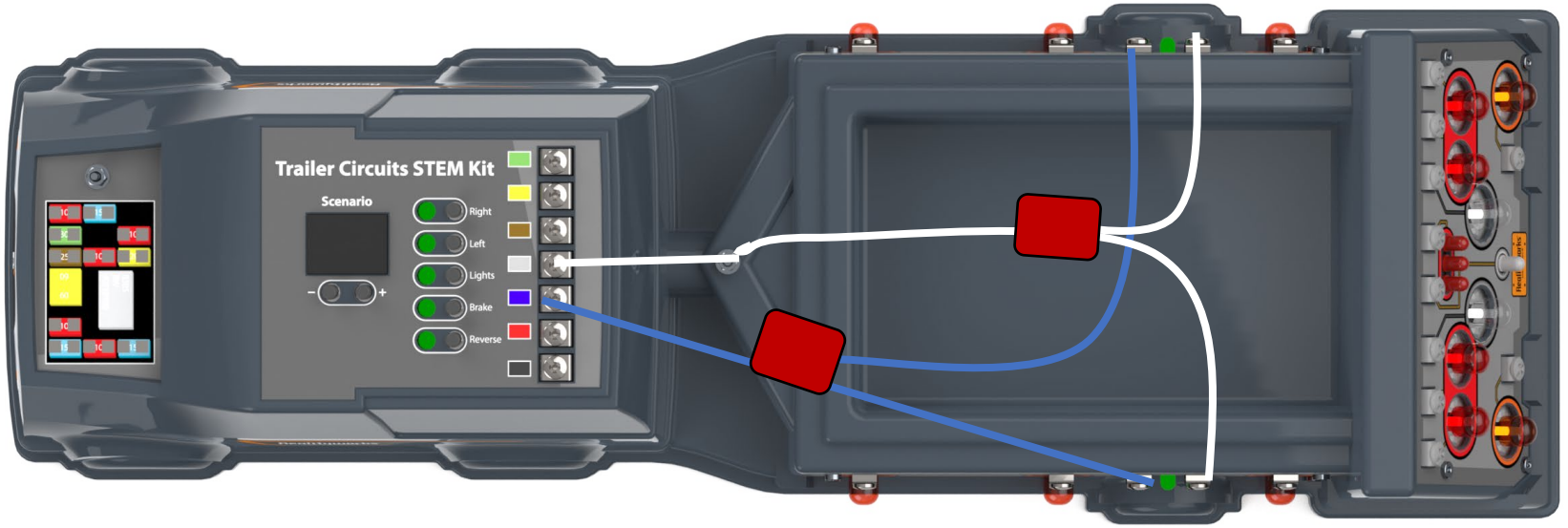


Parallel Circuit: Step 8

Test

1. Power on the Trailer Circuits Truck with the switch underneath.
2. Gently push the *Brake* button.
3. Do both green brake lights turn on?





Congratulations!
You have built a parallel circuit that supplies power to both trailer electric brakes.

Done with the Student Workbook for Lesson 2?

See your instructor to check the key and/or turn in.

For more information, please contact Realityworks, Inc.
through email at information@realityworks.com
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