Current, Voltage and Resistance

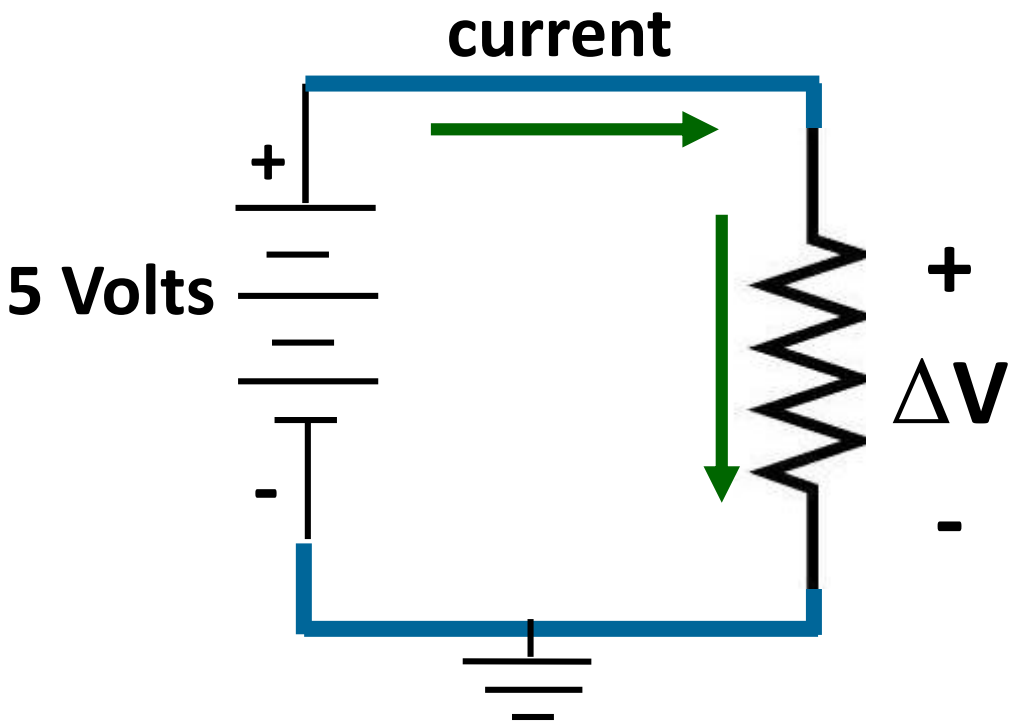
Kyriaki Niotaki
kyriaki.niotaki@mu.ie

Ohm's Law

Ohm's law states that the current (I) through a *resistive path* is directly proportional to the potential difference or voltage (V) across the two points, and inversely proportional to the resistance (R) between them.

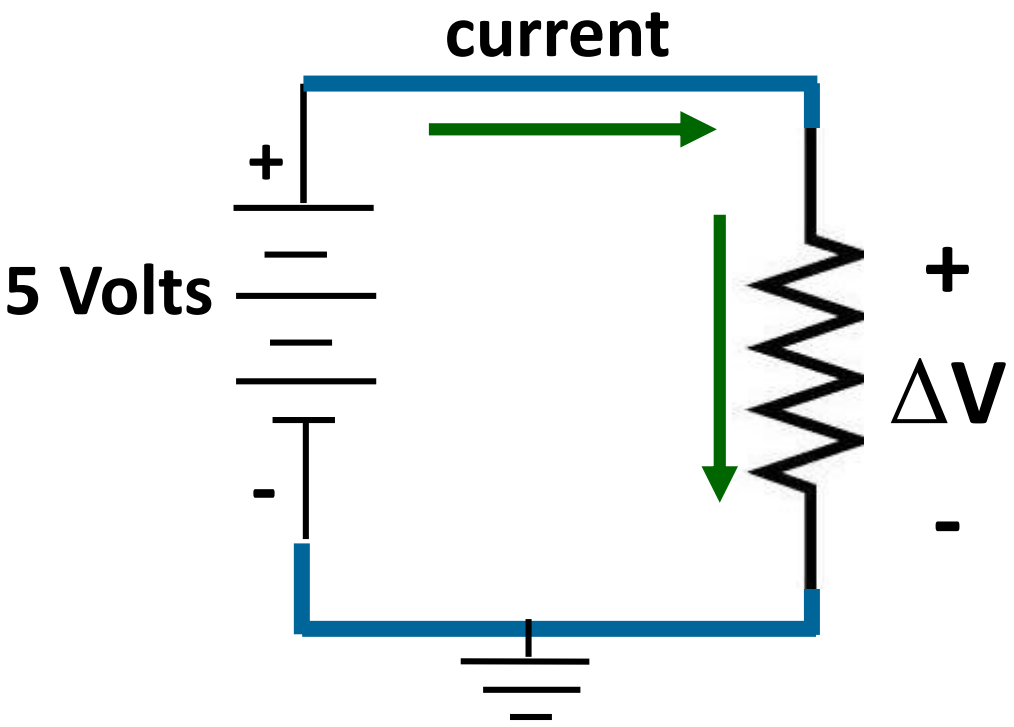
$$I = \frac{V}{R}$$

$$V = IR$$



Example

A 5 volt battery is connected to the ground via a resistor. Calculate the current that can flow for the following resistance values: 100000, 100, 1 and 0 Ohms.



Example

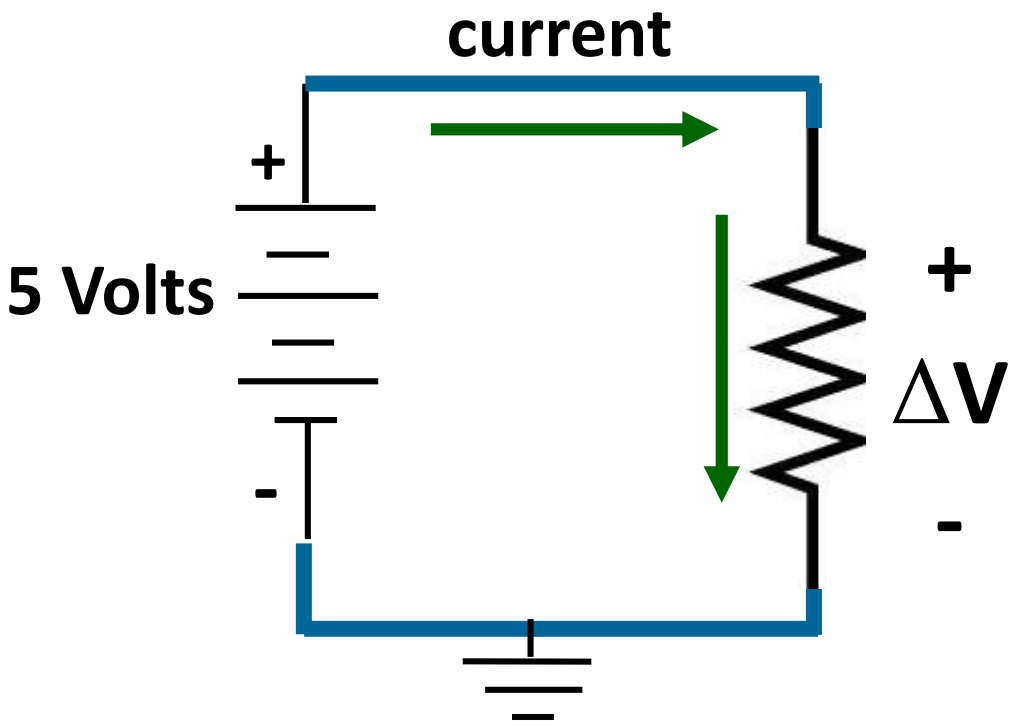
A 5 volt battery is connected to the ground via a resistor. Calculate the current that can flow for the following resistance values: 100000, 100, 1 and 0 Ohms.

$$I_{100k} = \frac{5}{100{,}000} = 50\mu A$$

$$I_{100} = \frac{5}{100} = 50mA$$

$$I_1 = \frac{5}{1} = 5A$$

$$I_0 = \frac{5}{0} = \infty$$



Electrical Power

$$P = V * I$$

This is a useful equation, but we can make two more useful ones from using Ohms Law (V=IR):

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

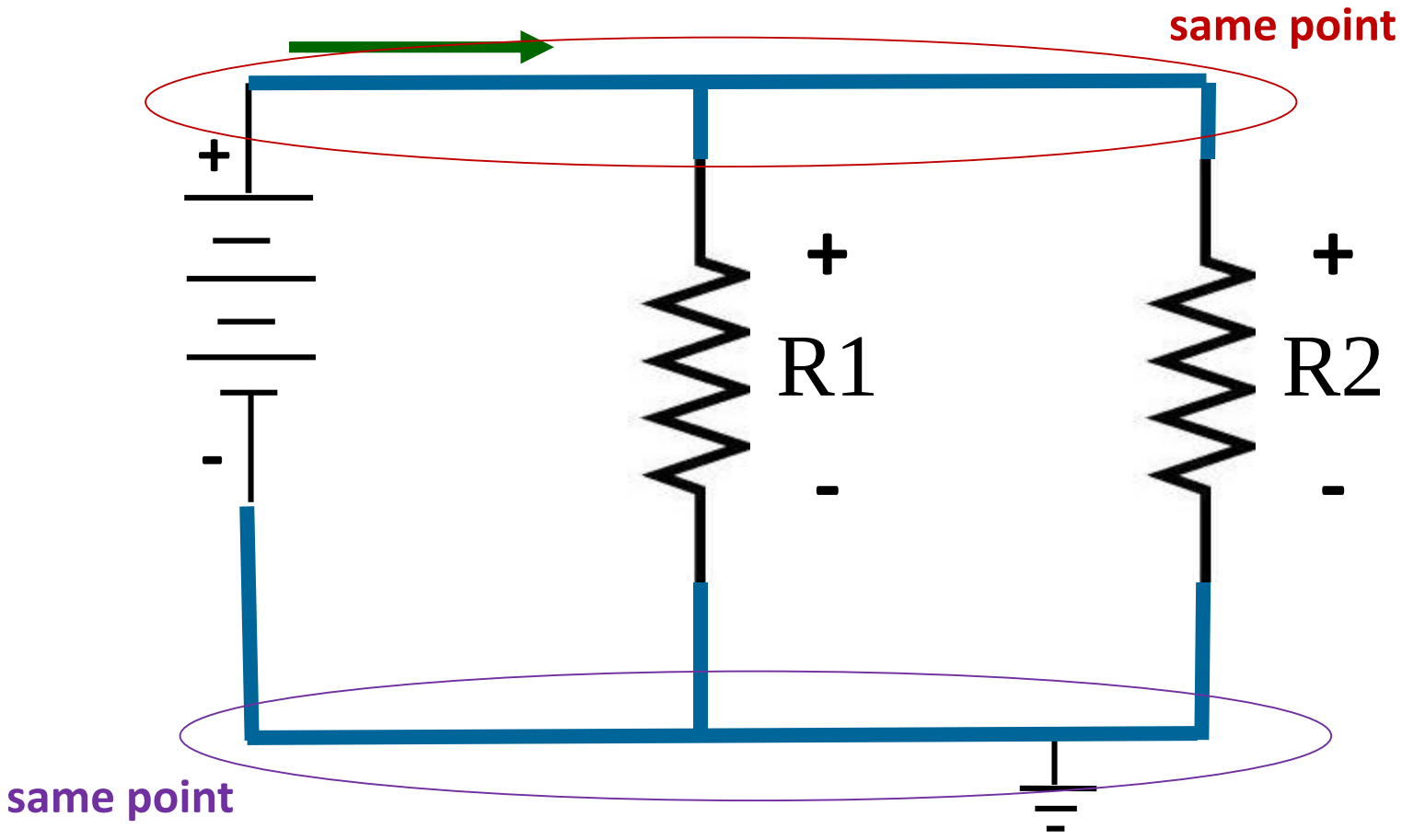
This (and Ohm's Law) are fundamental equations.
You will need to always know these equations!

Some Rules for Circuits

Note: many circuit elements will be in parallel or in series,

BUT NOT EVERYTHING

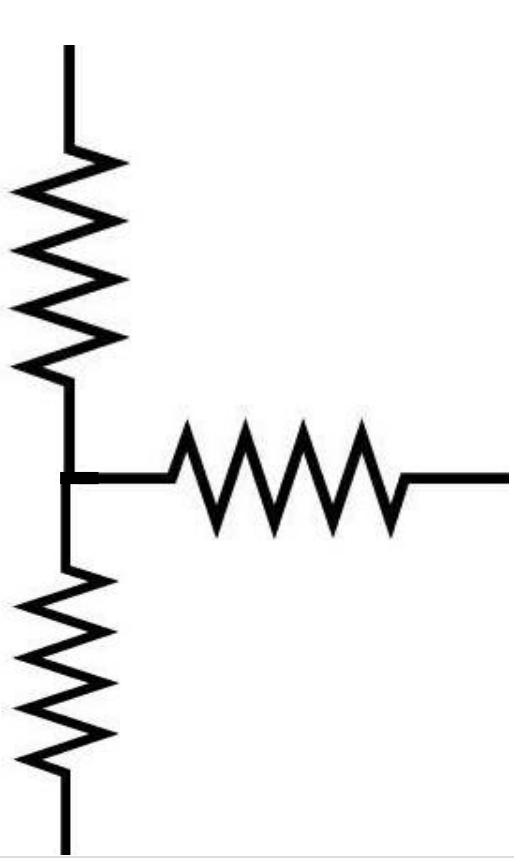
Some Rules for Circuits

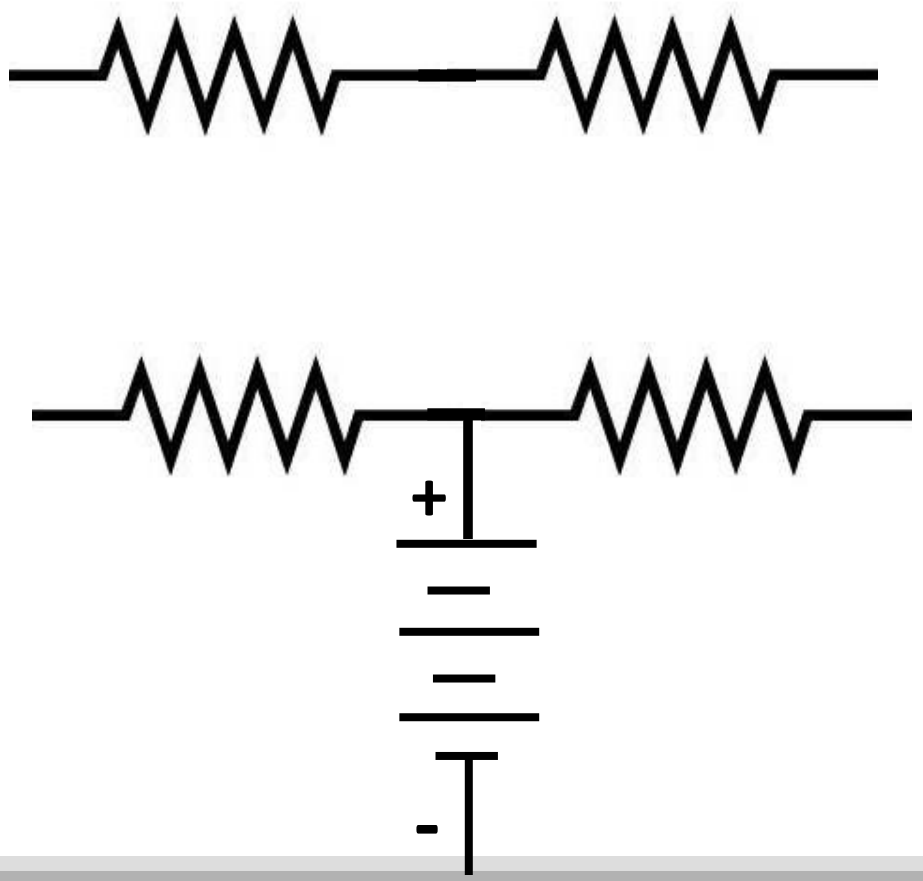


Rule 1: All points on a wire are assumed to be the same point as the wire has perfect conductivity.

Some Rules for Circuits

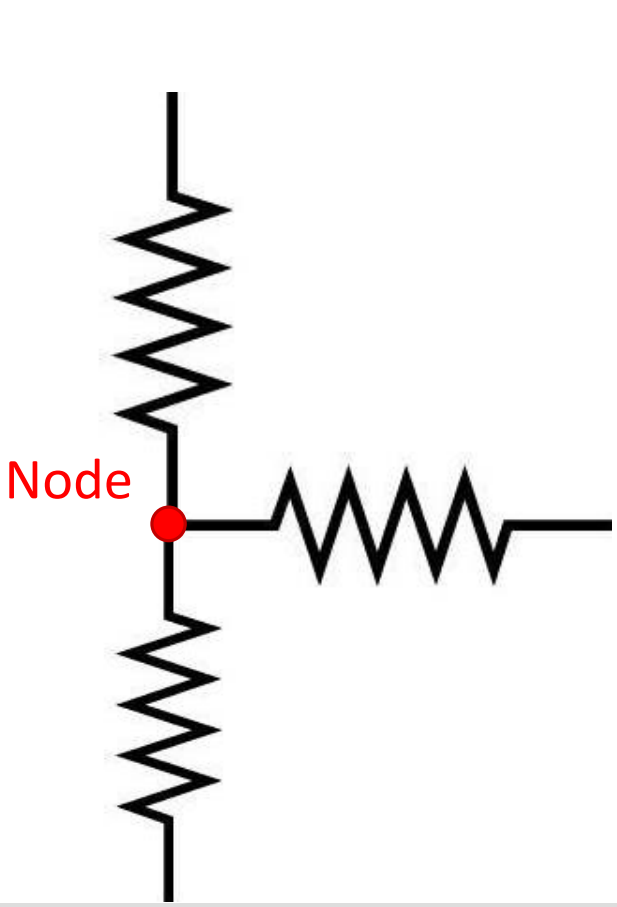
Rule 2: A point in the circuit where 2 or more components are connected is called a node. A 2-path node is trivial, the more interesting ones are 3 or more *(note that ground is always a node).*

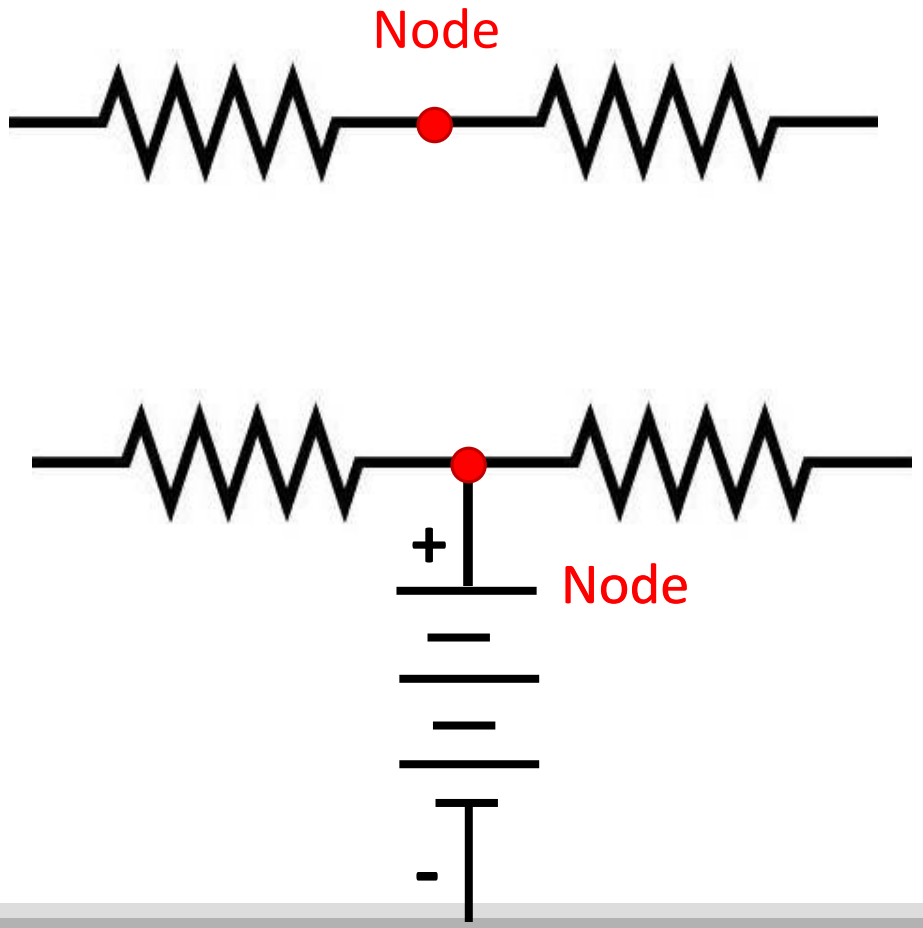




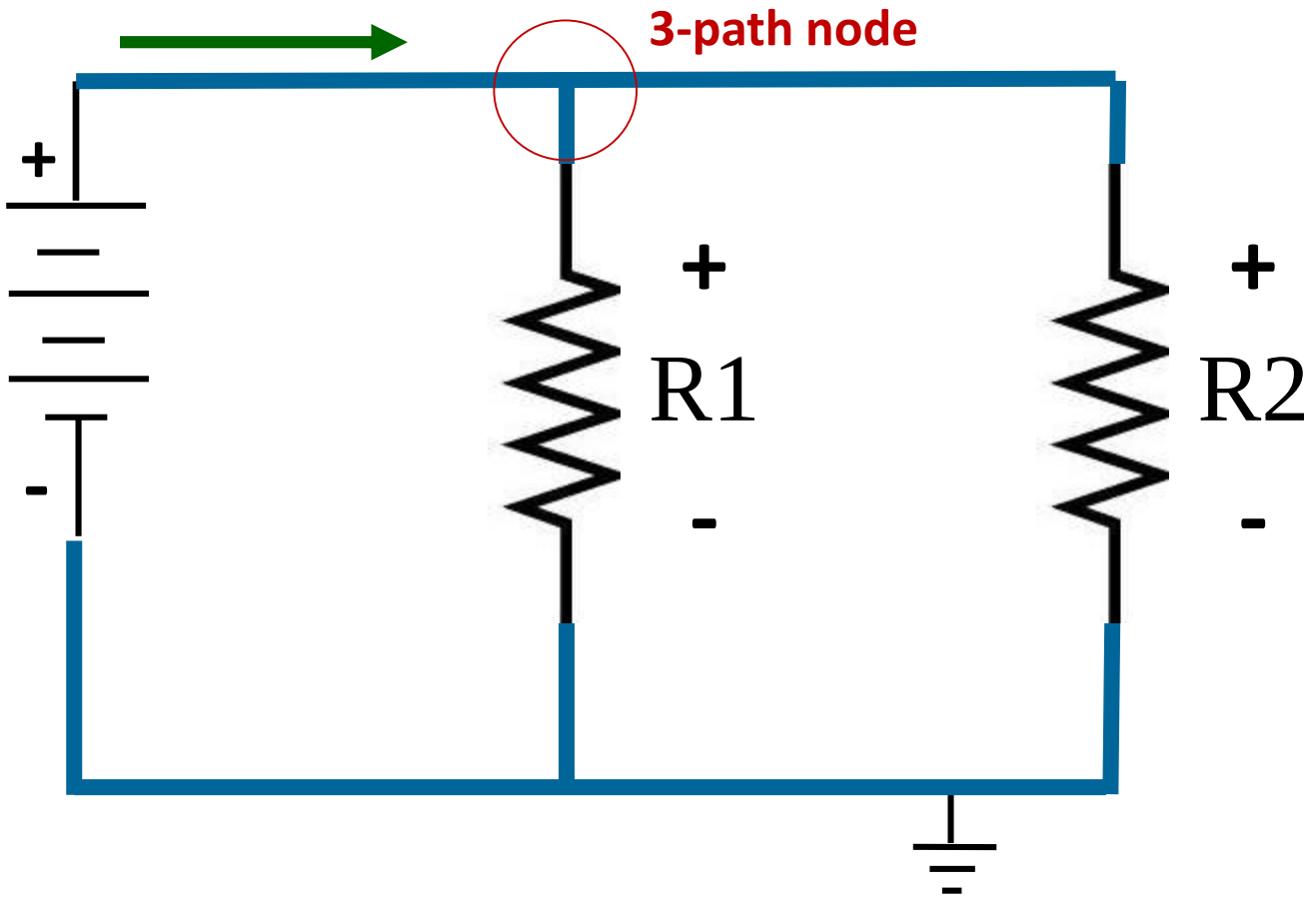
Some Rules for Circuits

Rule 2: A point in the circuit where 2 or more components are connected is called a node. A 2-path node is trivial, the more interesting ones are 3 or more *(note that ground is always a node).*





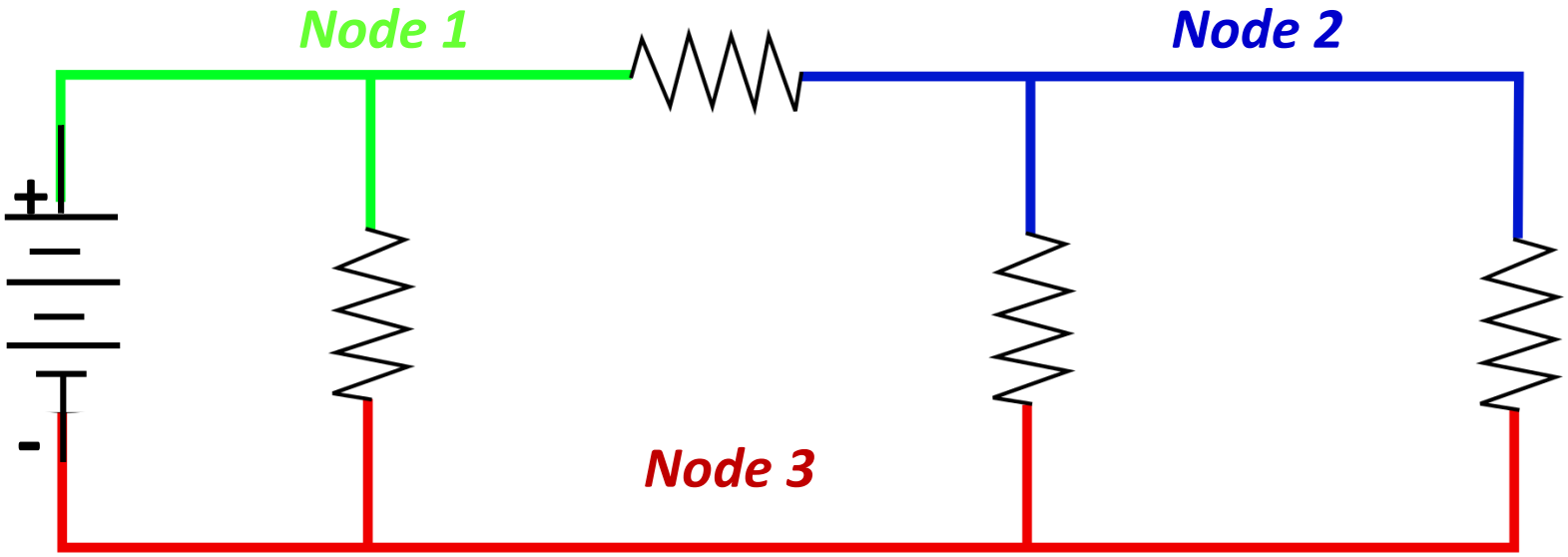
Some Rules for Circuits



Rule 2: **A point in the circuit where 2 or more components are connected is called a node.**

Some Rules for Circuits

Each color in the circuit represents one node.



3 elements (2 resistors and a source) are connected at Node 1

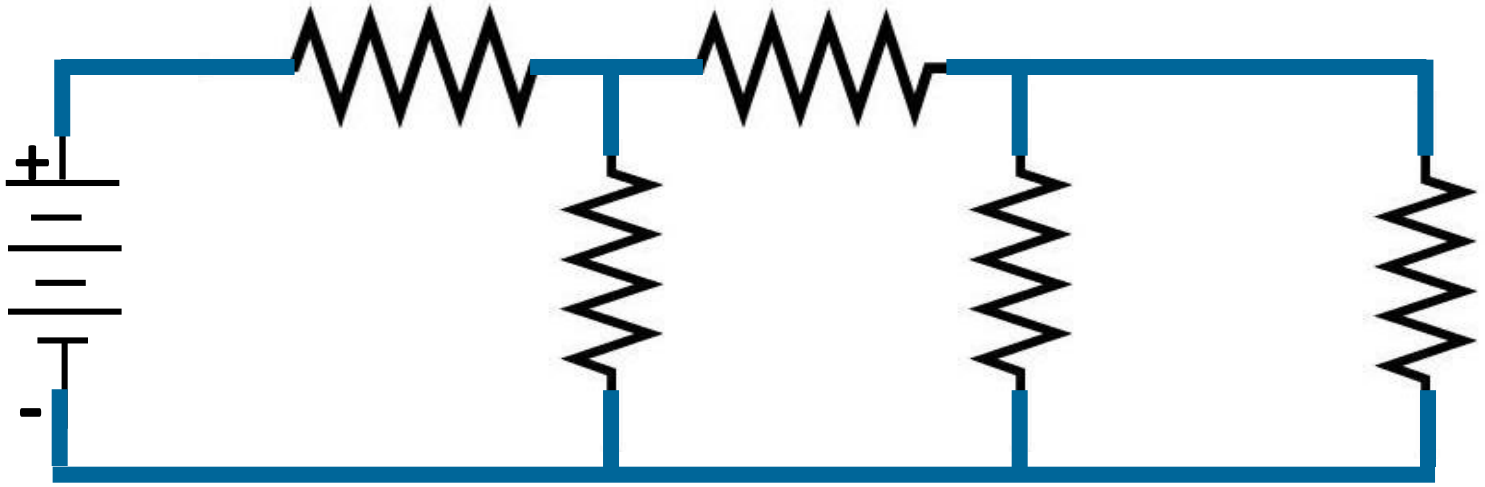
3 elements (3 resistors) are connected at Node 2

4 elements are connected at Node 3

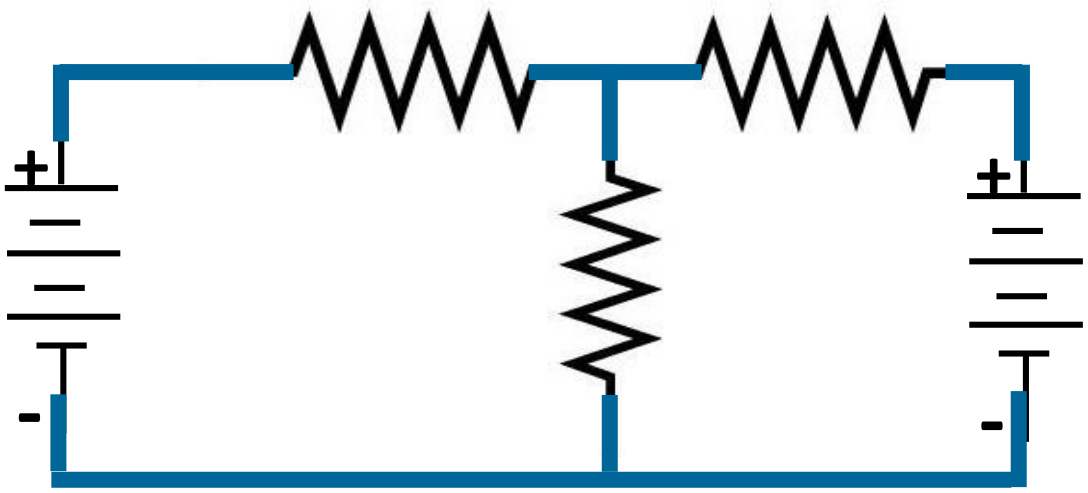
*Node is a **point** in the circuit where two or more elements are connected.*

Some Rules for Circuits

How many *nodes* are in this schematics below?



(a)



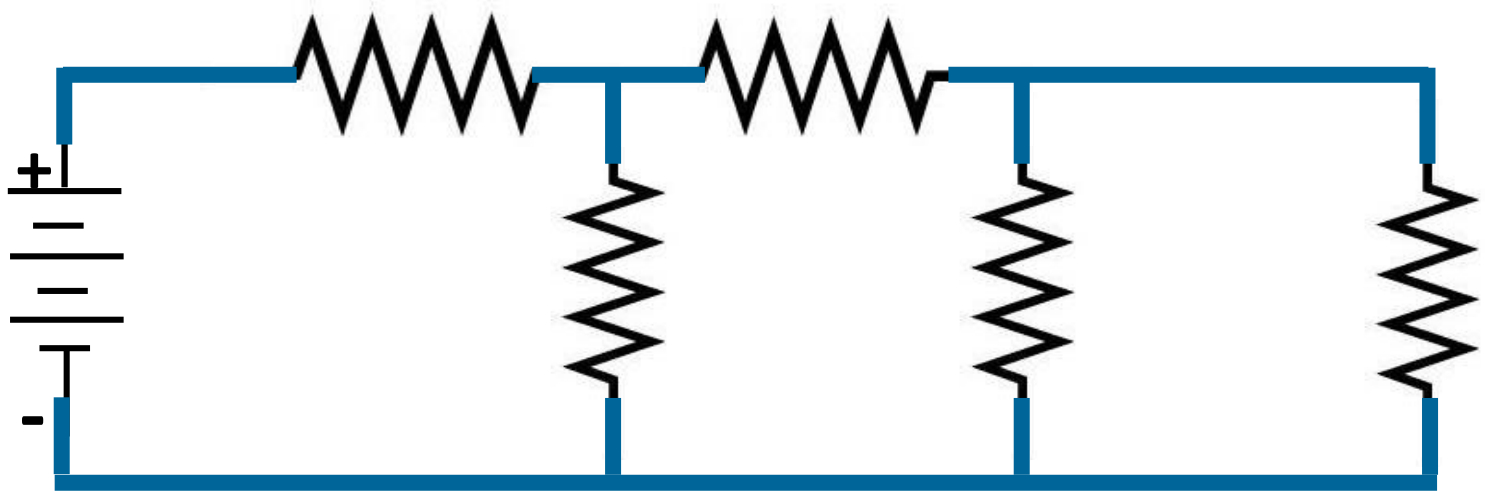
(b)

Some Rules for Circuits

Branch is a single component, such as resistor/source. **In other words, a branch represents any two-terminal element**.

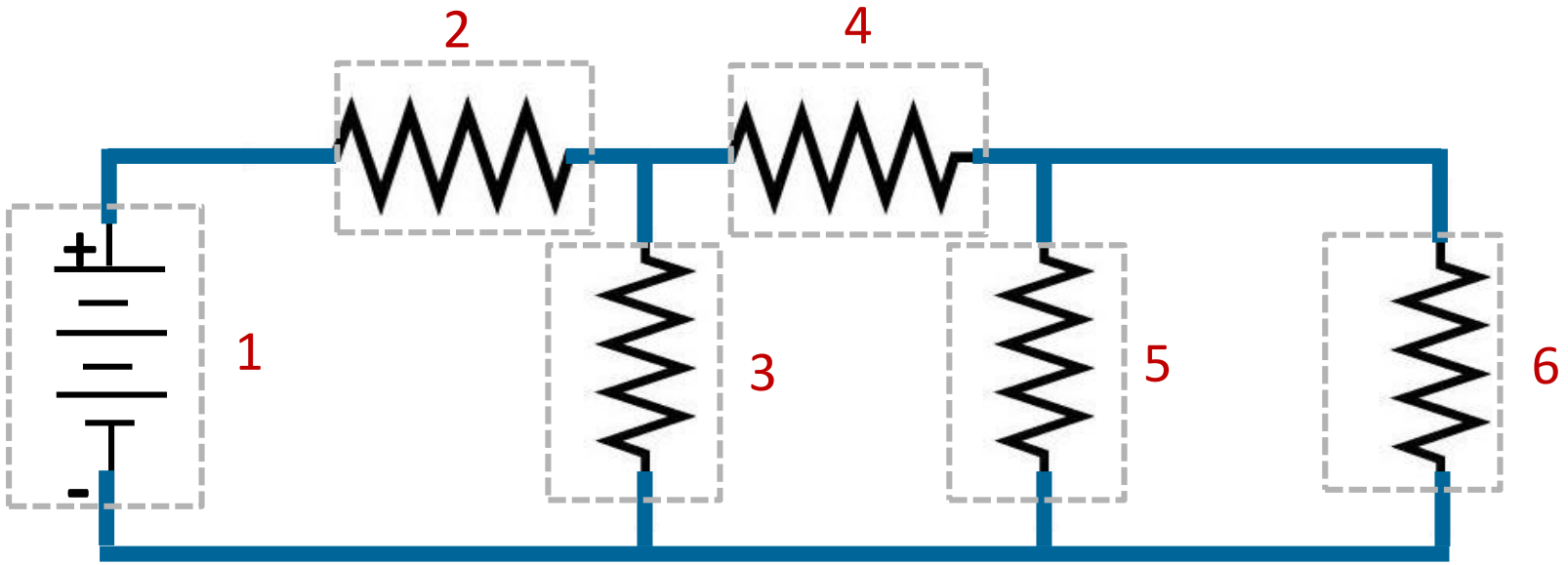
How many *branches* are in this schematic?

Example:



Some Rules for Circuits

How many *branches* are in this example?

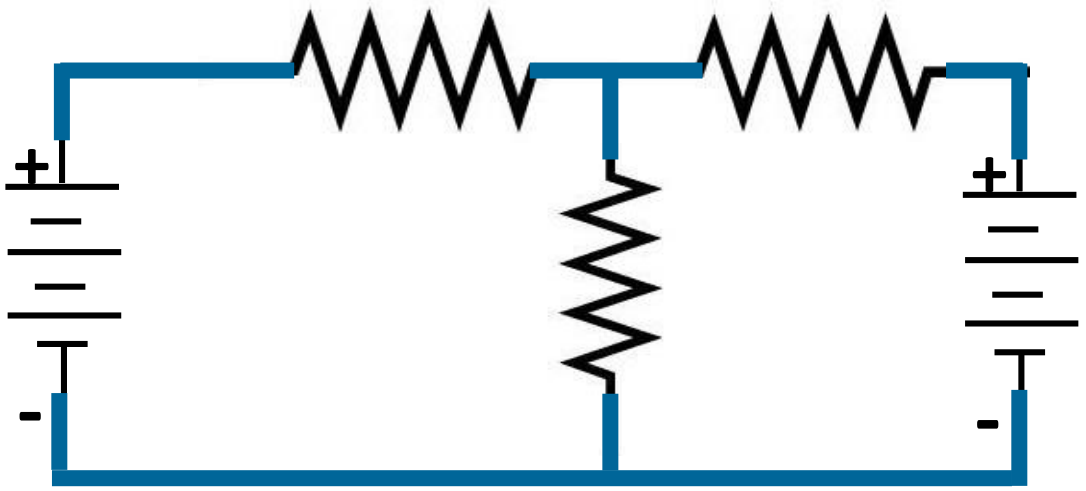


Branch is a single component, such as resistor/source. In other words, **a branch represents any two-terminal element.**

Some Rules for Circuits

How many *branches* are in the example below?

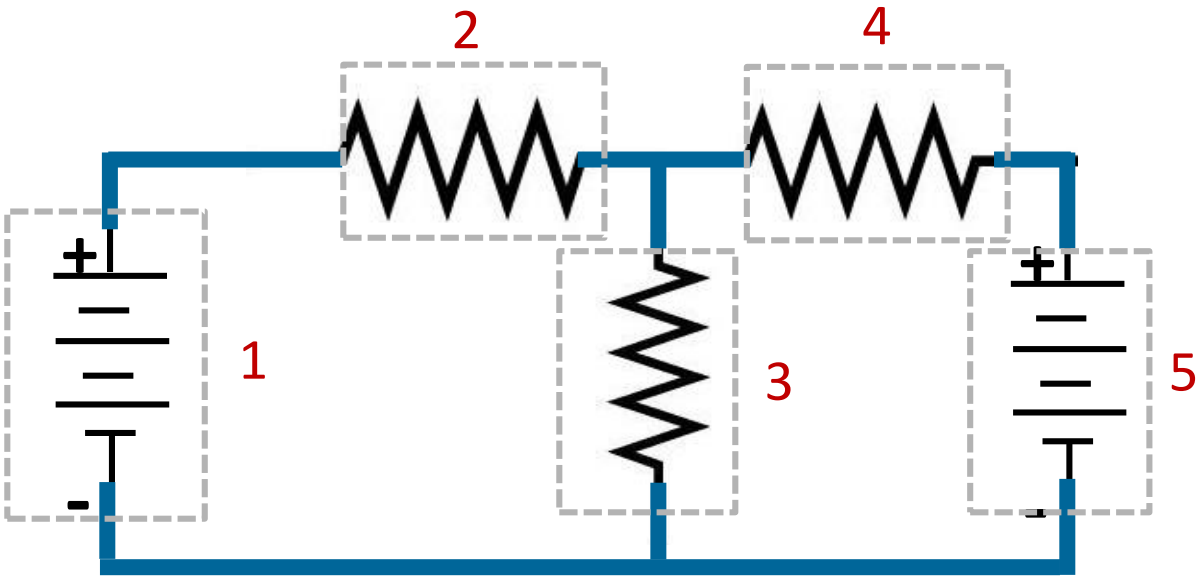
Another Example:



Branch is a single component, such as resistor/source. In other words, **a branch represents any two-terminal element**

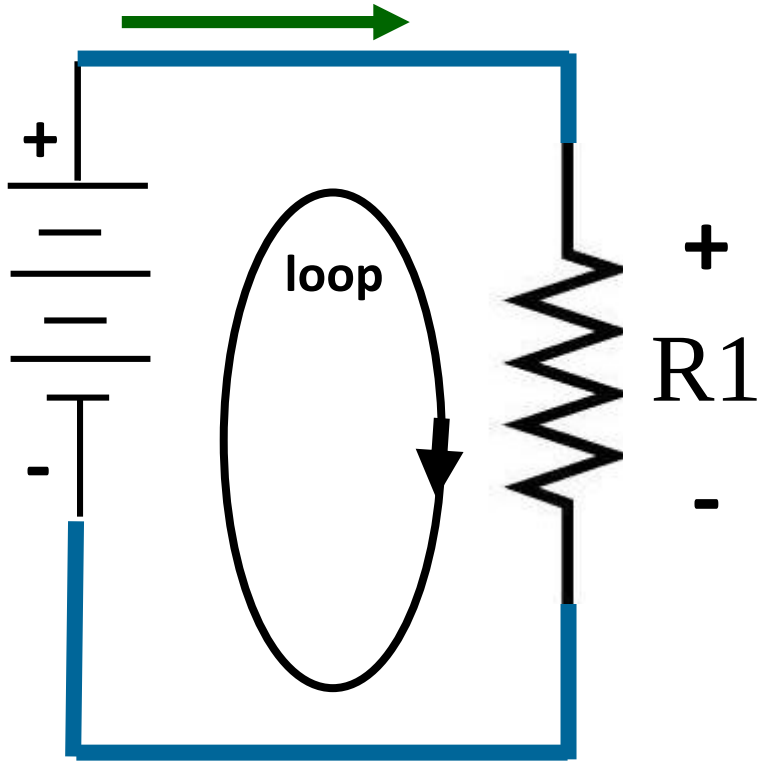
Some Rules for Circuits

How many *branches* are in the example below?



Branch is a single component, such as resistor/source. In other words, **a branch represents any two-terminal element**

Some Rules for Circuits

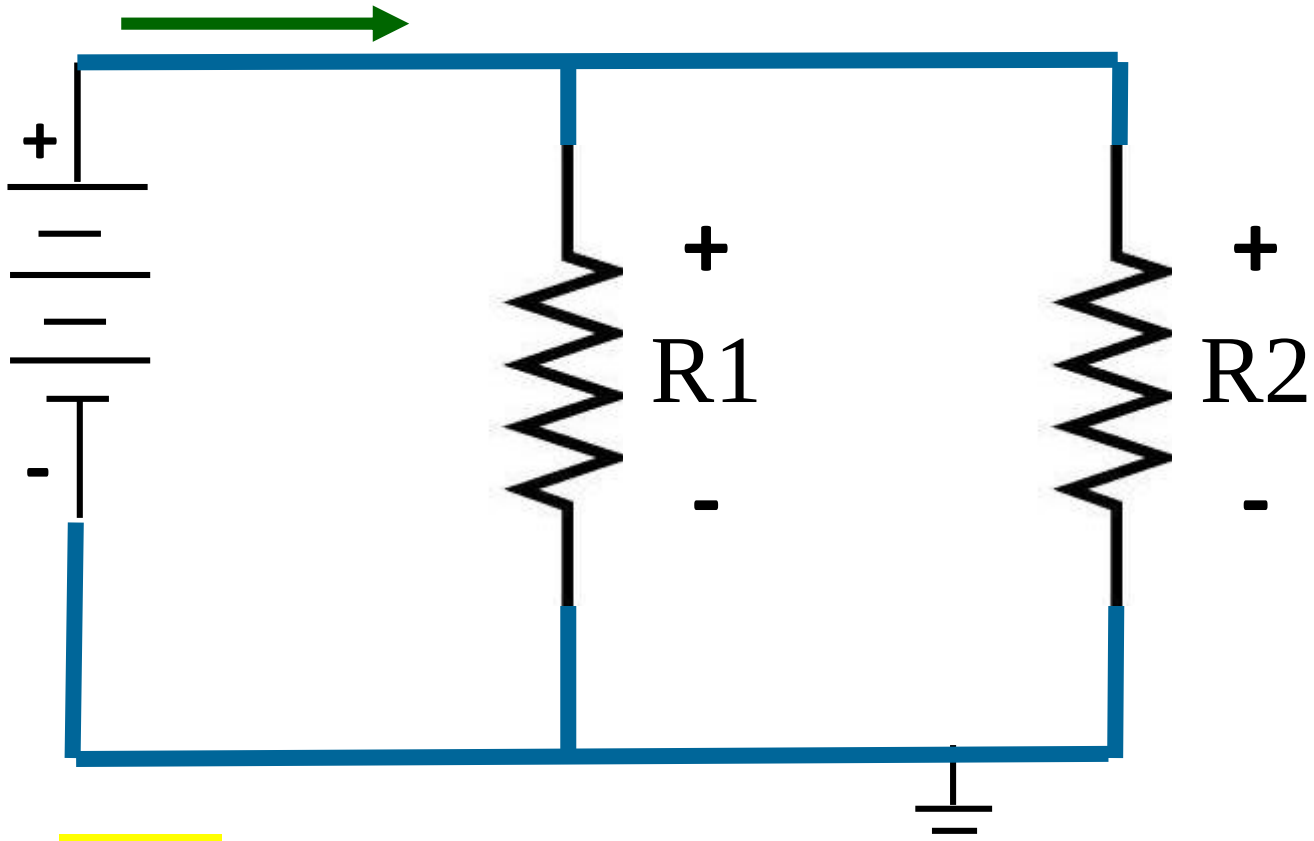


Rule 3: **All circuits must have at least one loop so that current can flow back to where it started (*a loop is a closed path through a circuit that visits each element no more than once*).**

The direction of the arrow tends to indicate current direction, but it doesn't matter if you get it wrong as long as you are consistent.

Some Rules for Circuits

Let's see another example:

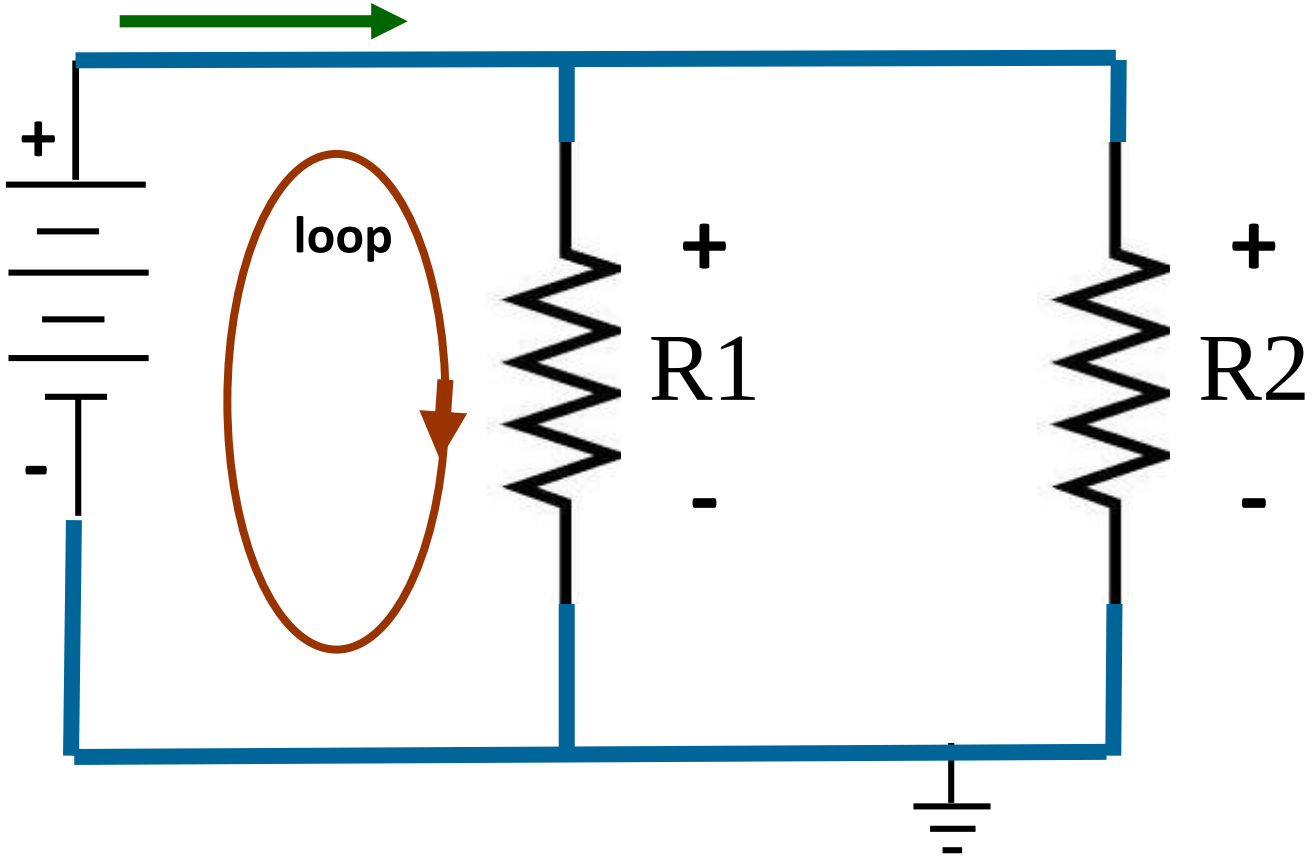


A loop is a closed path through a circuit that visits each element no more than once.

Closed means **complete** (it finishes at the point that it starts)

Some Rules for Circuits

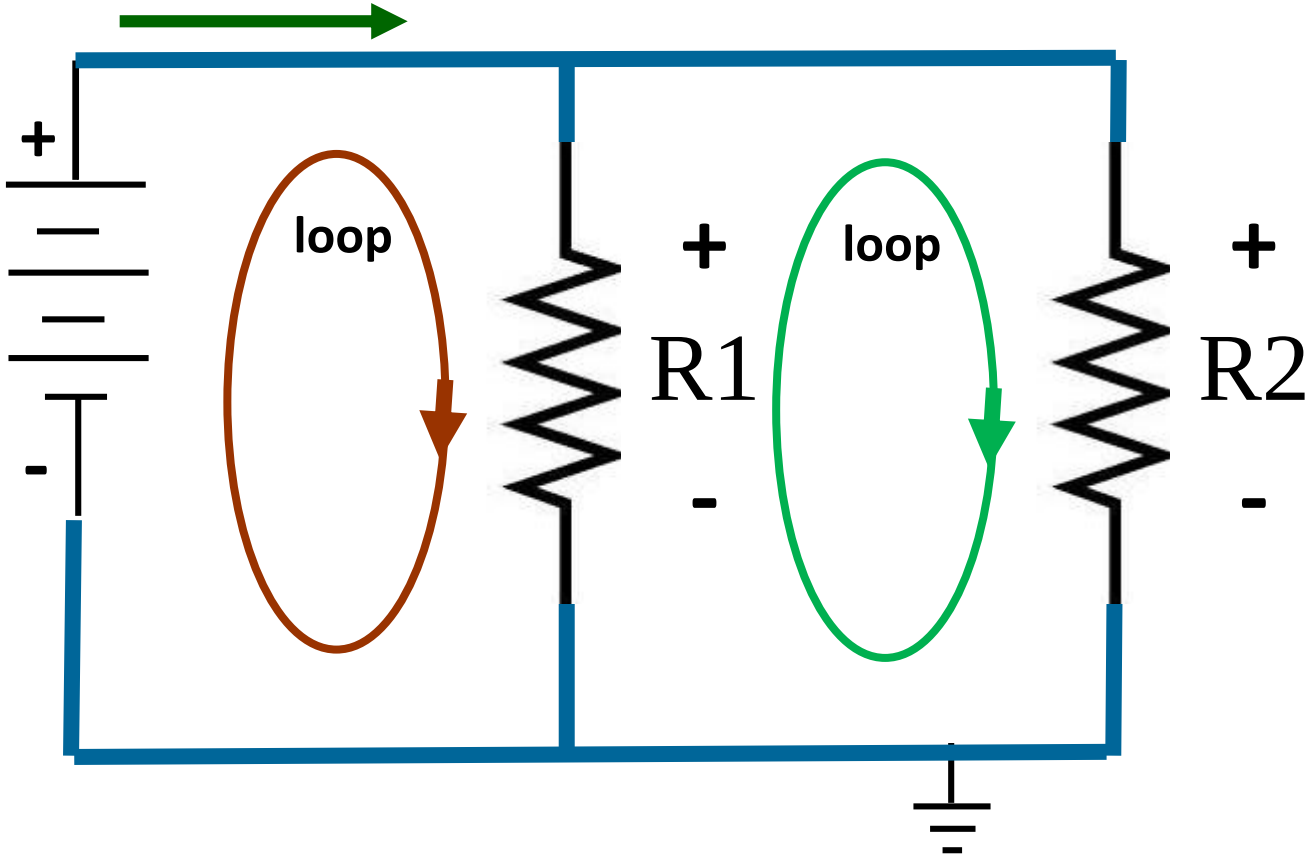
Let's see another example:



A loop is a closed path through a circuit that visits each element no more than once.

Some Rules for Circuits

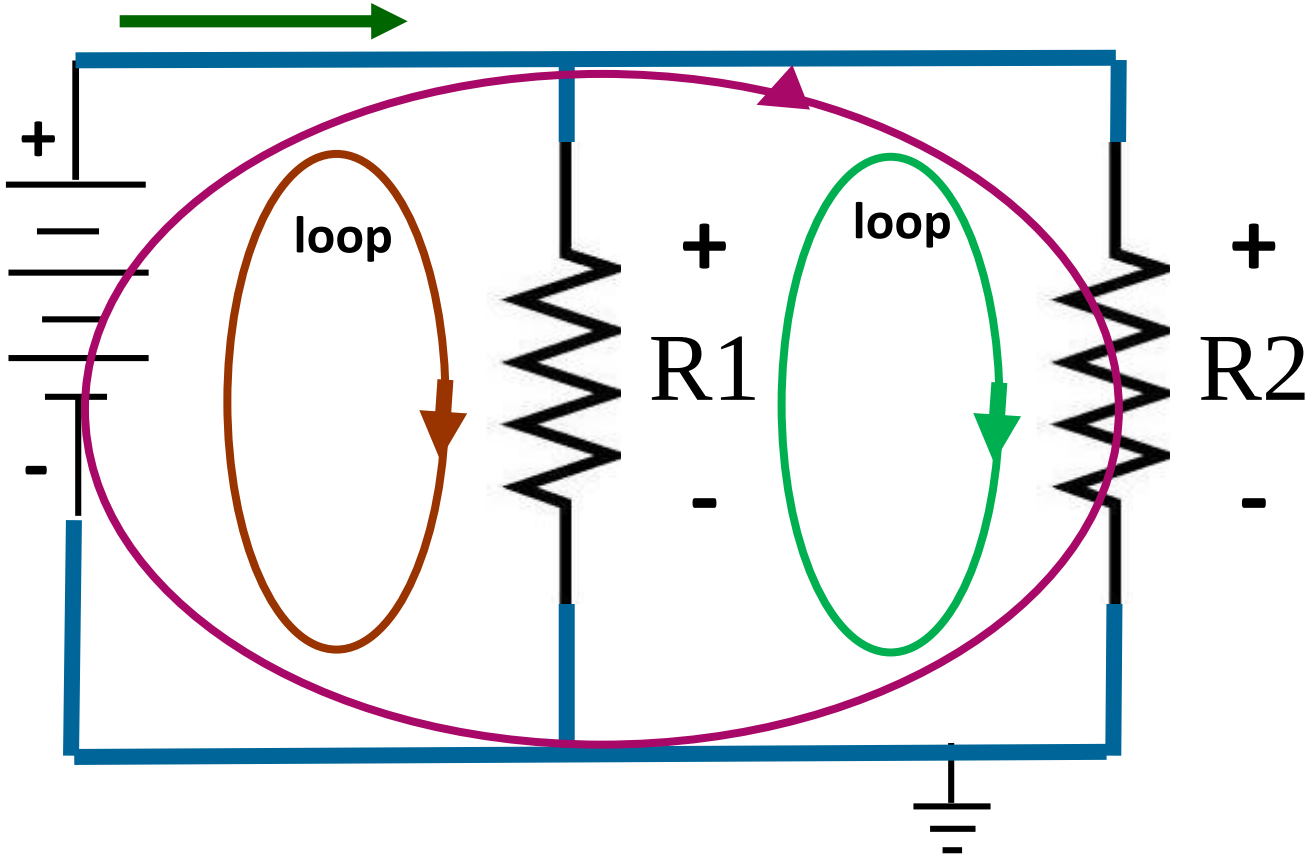
Let's see another example:



A loop is a closed path through a circuit that visits each element no more than once.

Some Rules for Circuits

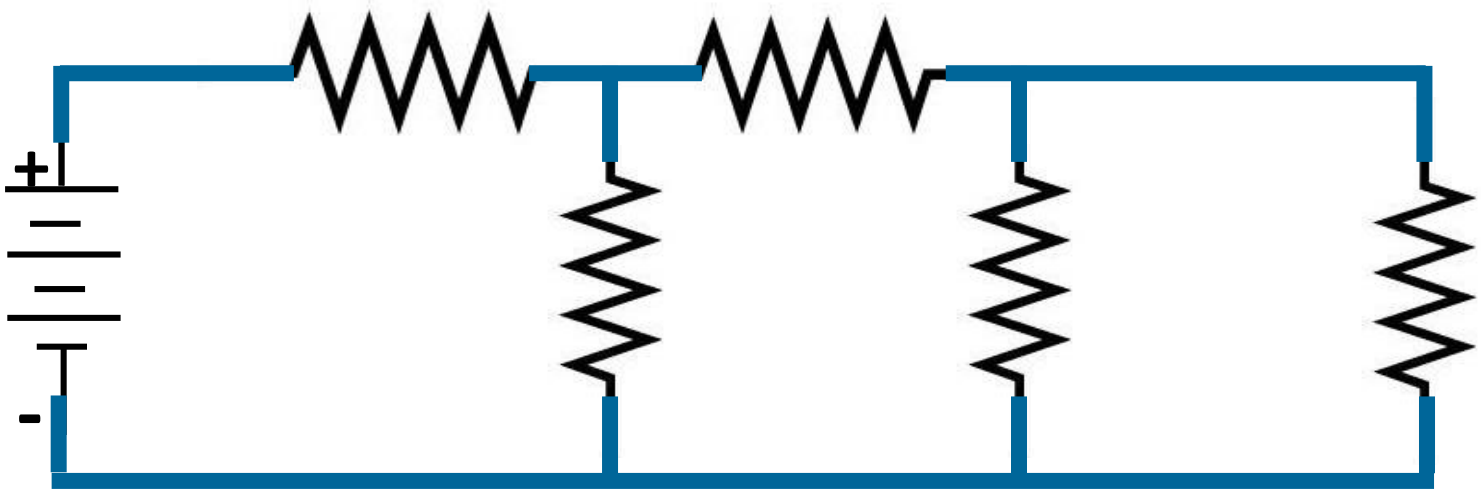
Let's see another example:



A loop is a closed path through a circuit that visits each element no more than once.

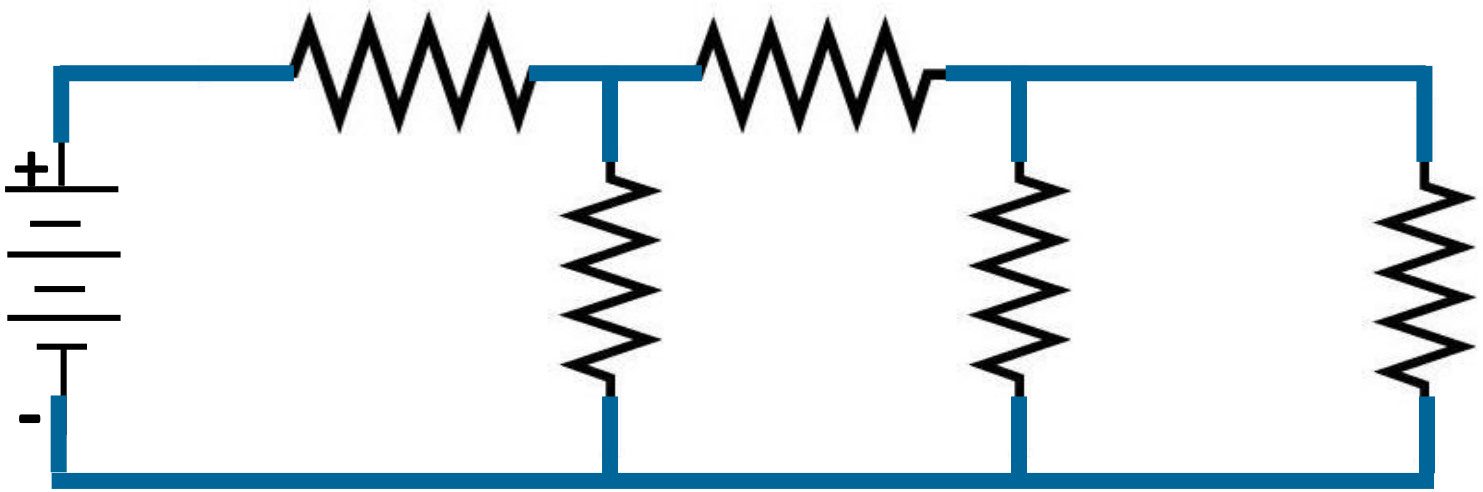
Some Rules for Circuits

How many *loops* are in this schematic?



Some Rules for Circuits

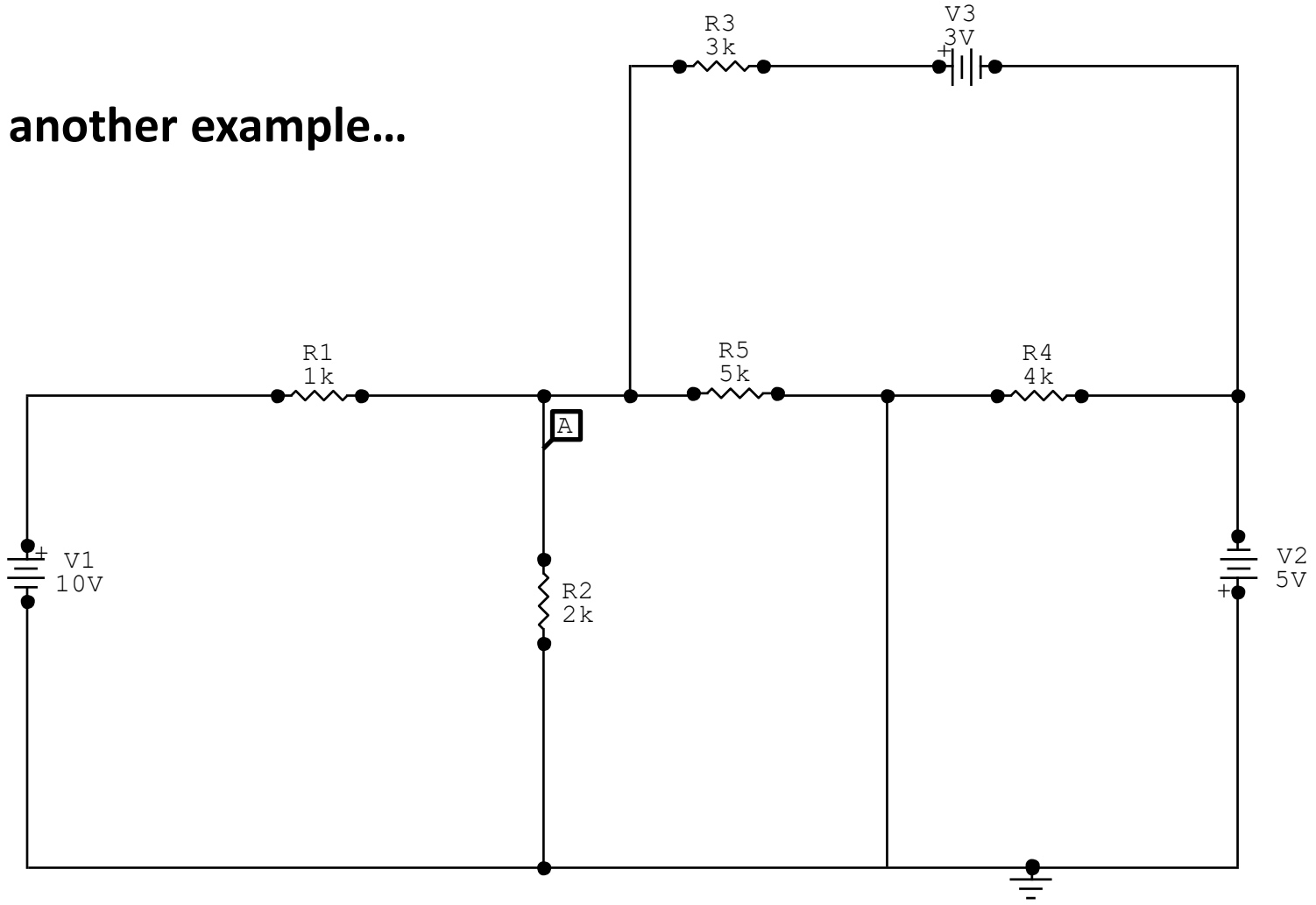
How many *loops* are in this schematic?



Answer: 6

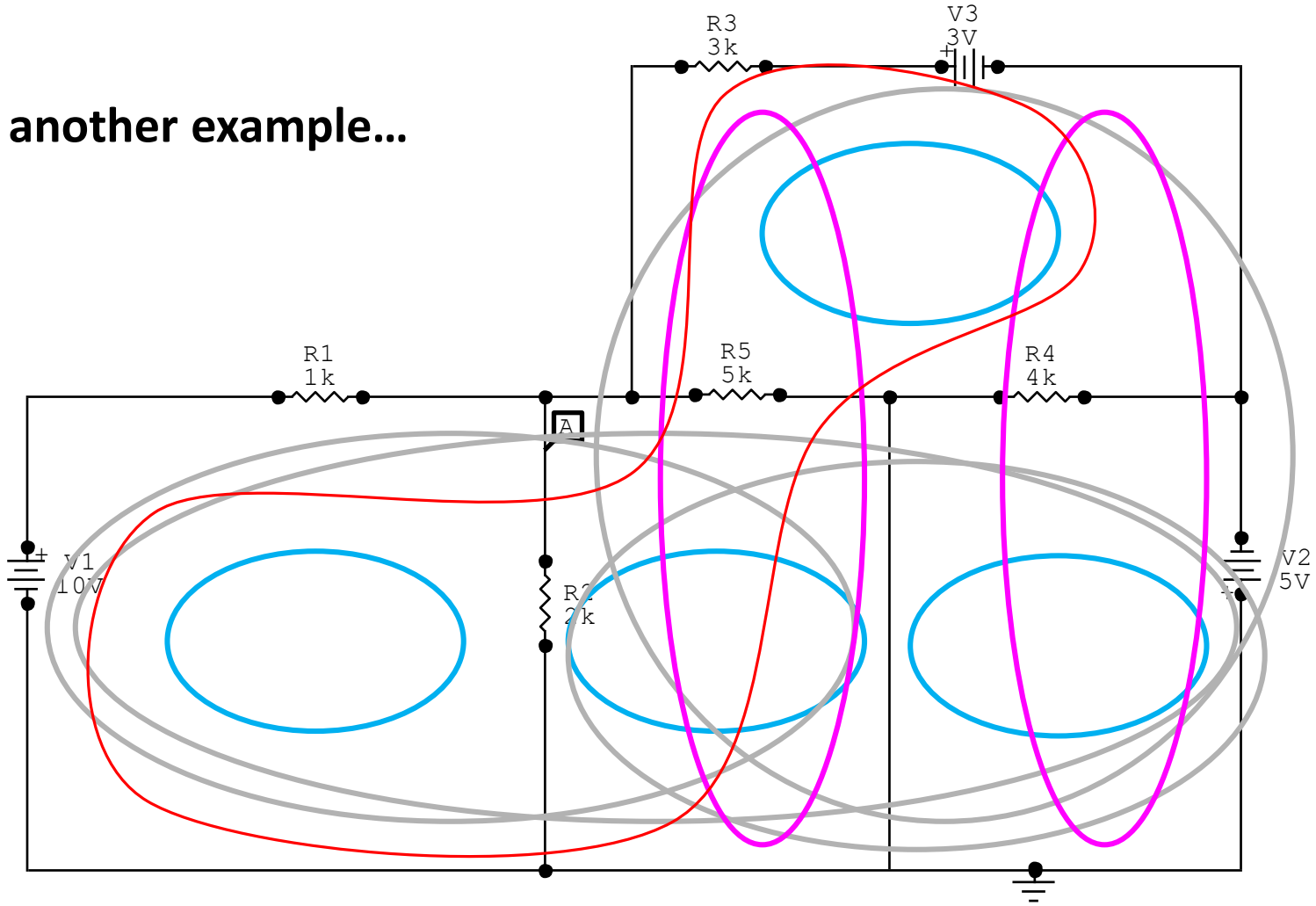
Some Rules for Circuits

And another example…

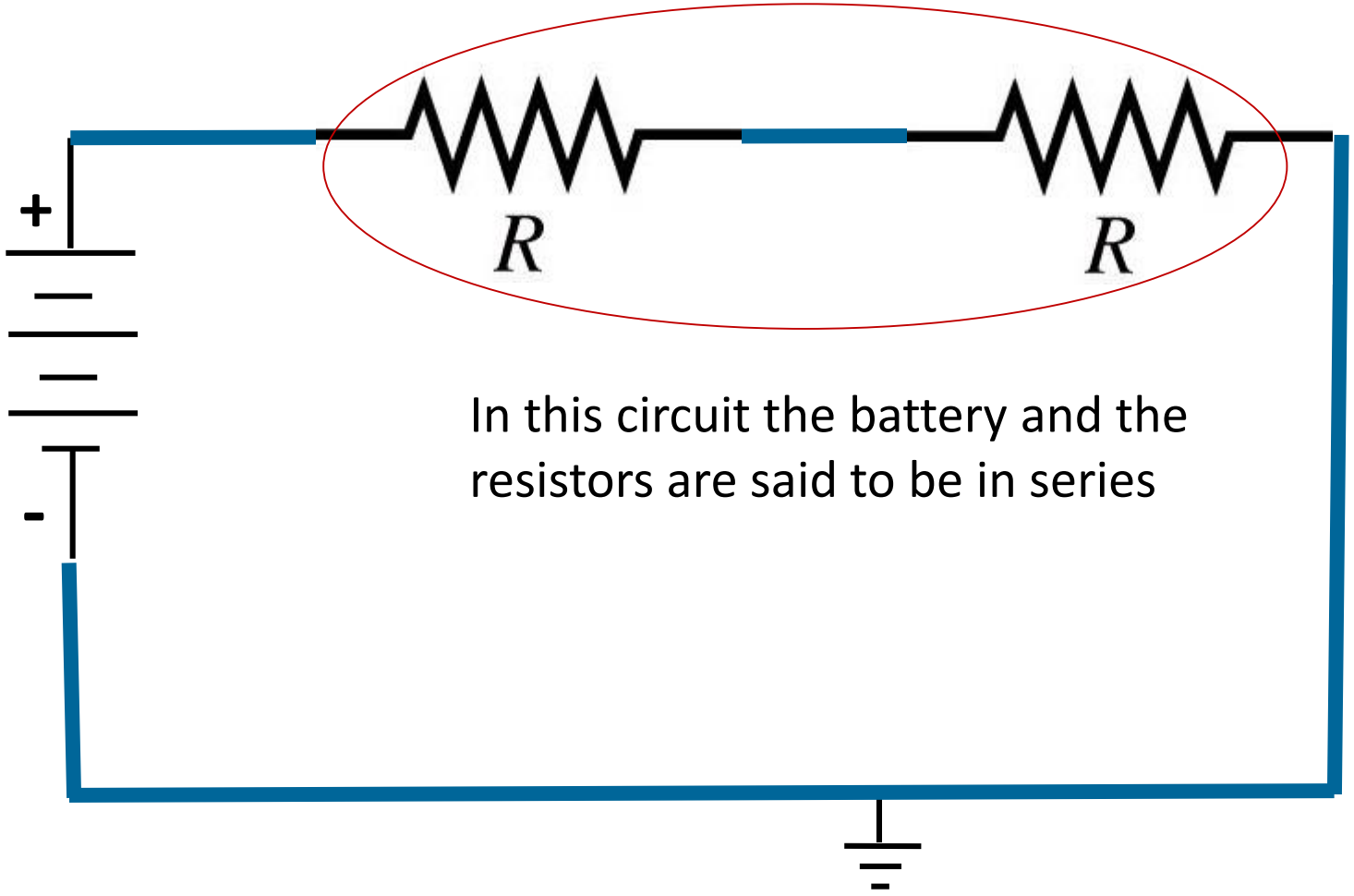


Some Rules for Circuits

And another example…

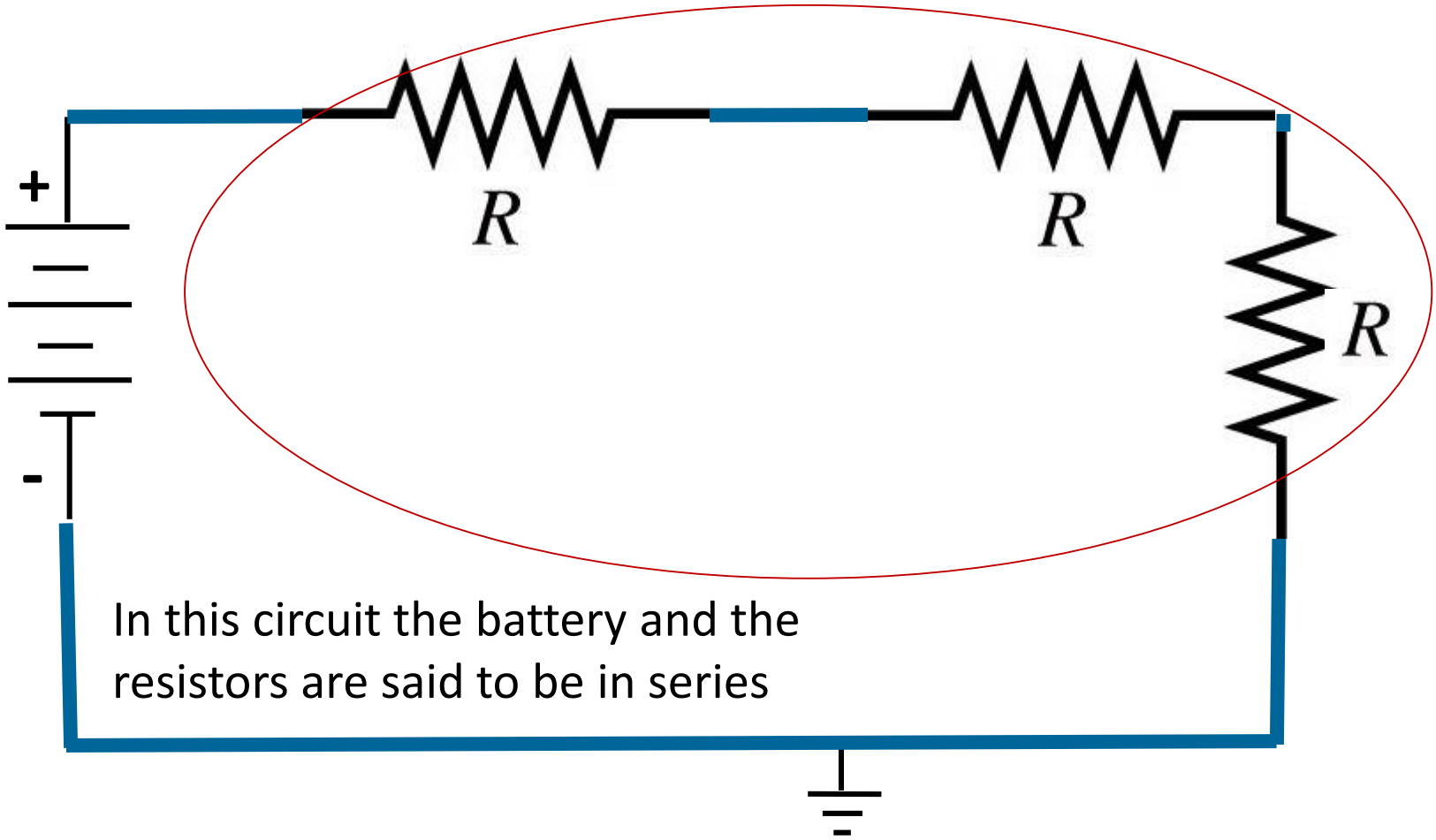


Some Rules for Circuits



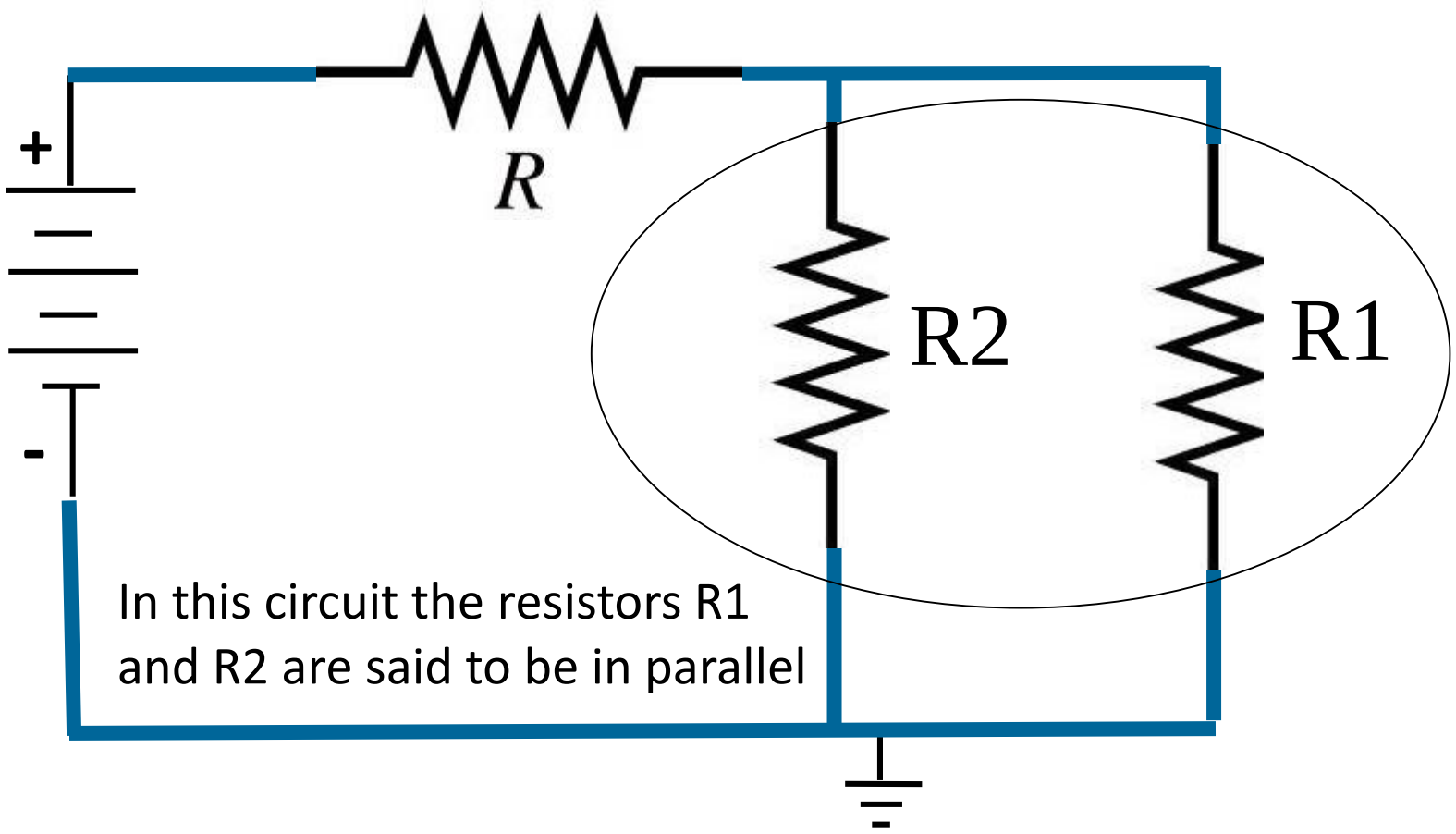
Rule 4: If 2 circuit elements are connected only by a 2-path node (ie a wire), then they are said to be in SERIES.

Some Rules for Circuits



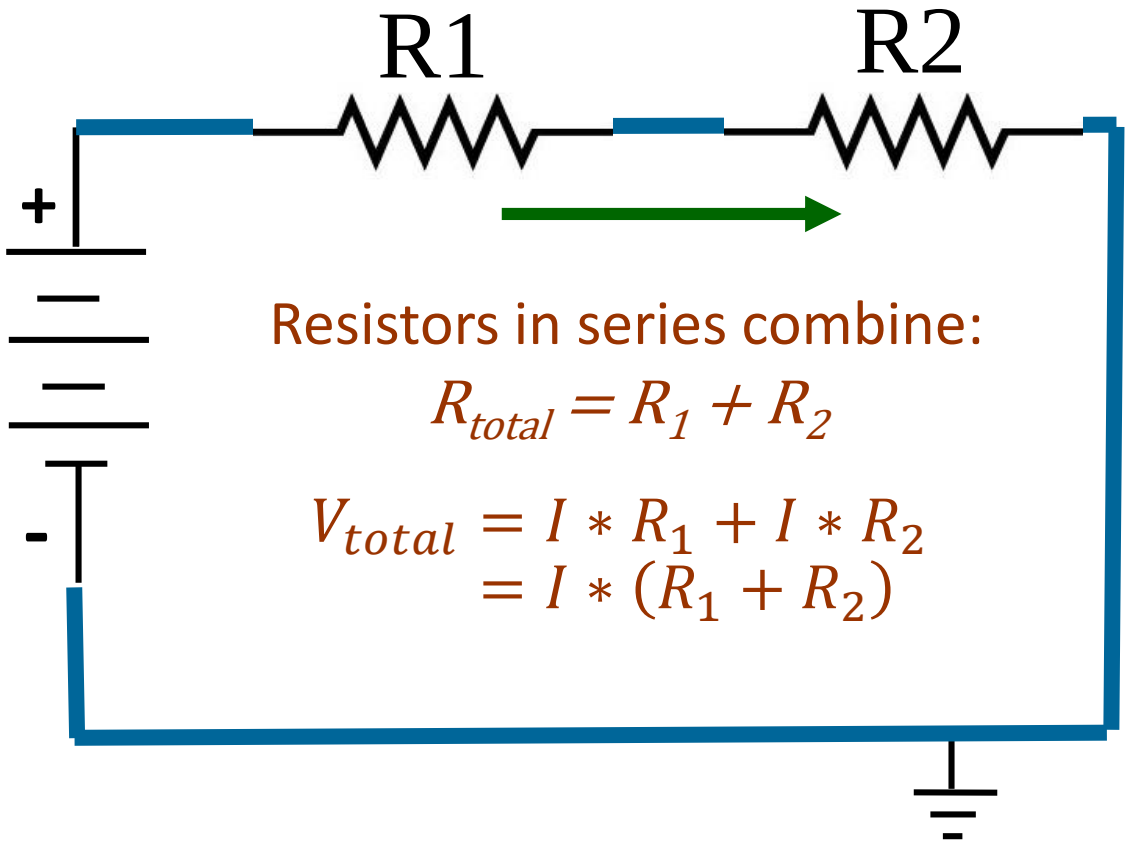
In this circuit the battery and the resistors are said to be in series

Some Rules for Circuits



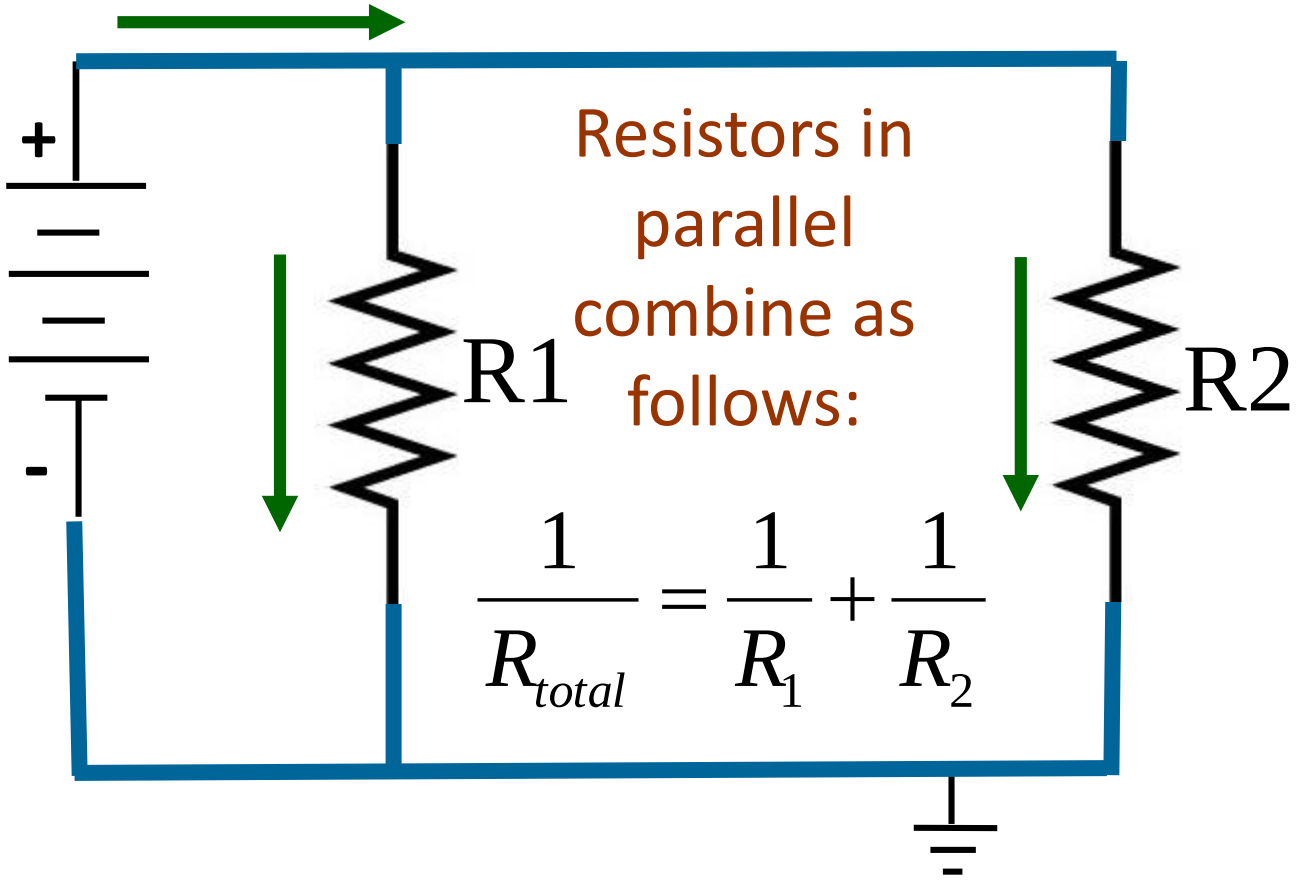
Rule 5: If 2 or more circuit elements are connected between the same nodes, then they are said to be in PARALLEL.

Some Rules for Resistors

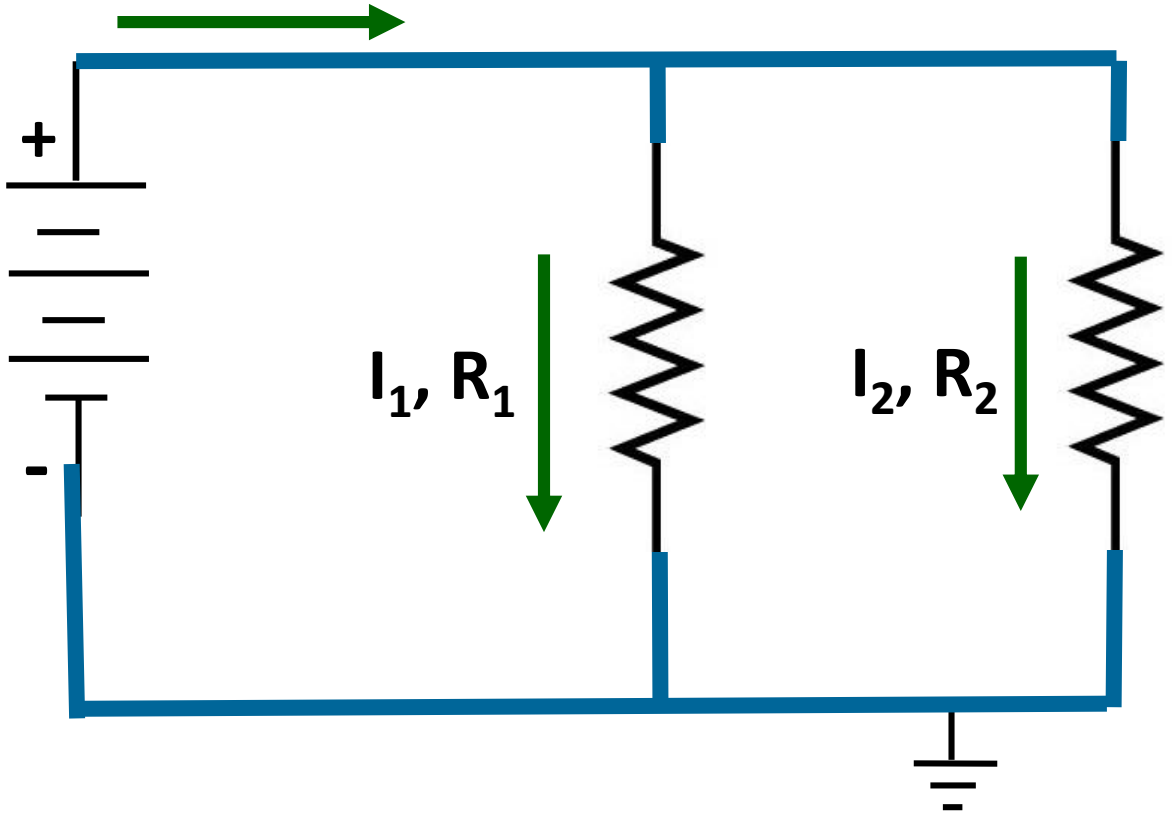


Rule 6: **If the current must pass through two resistors (assuming that there is no other path of escape), then the total voltage drop is shared across the two resistors.**

Some Rules for Resistors



Rule 7: If the voltage across two resistors is equal, then the current in each path is inversely proportional to the resistance in each path.



$$I_{total} = I_1 + I_2$$

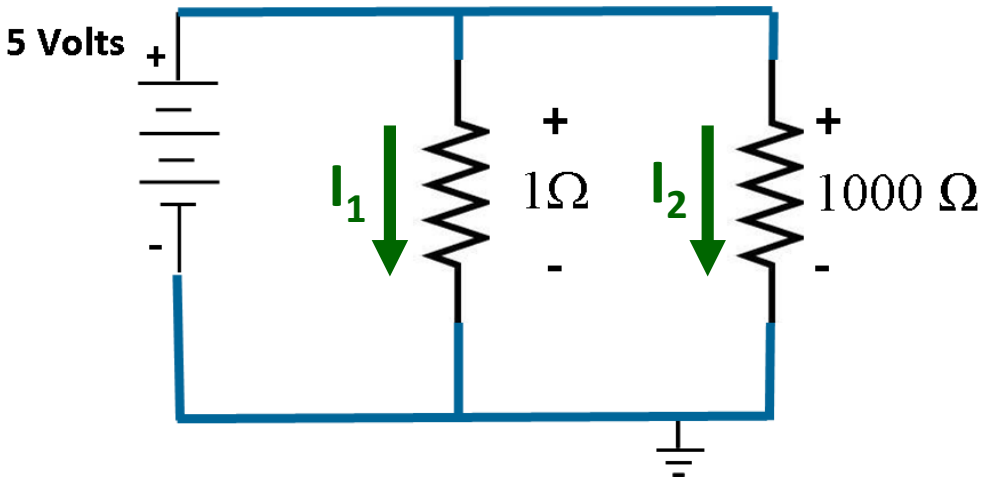
As top to bottom is the same voltage

$$\frac{V}{R_{total}} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

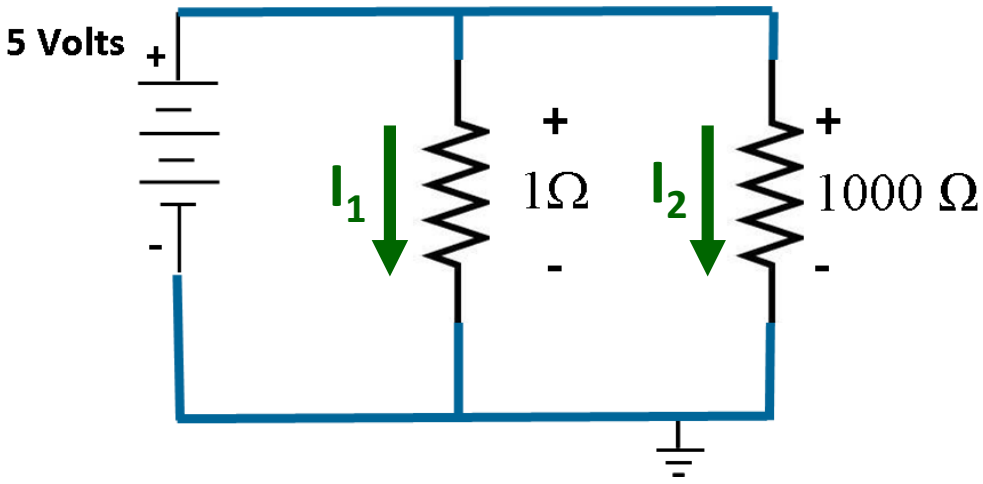
Example 1

Calculate the current through each resistor



Example 1

Calculate the current through each resistor



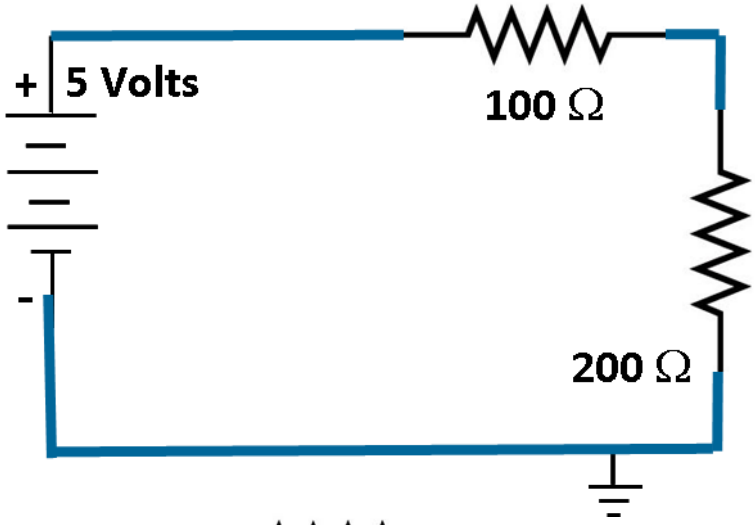
$$V = IR$$
$$I = V/R$$
$$I_1 = 5/1 = 5A$$

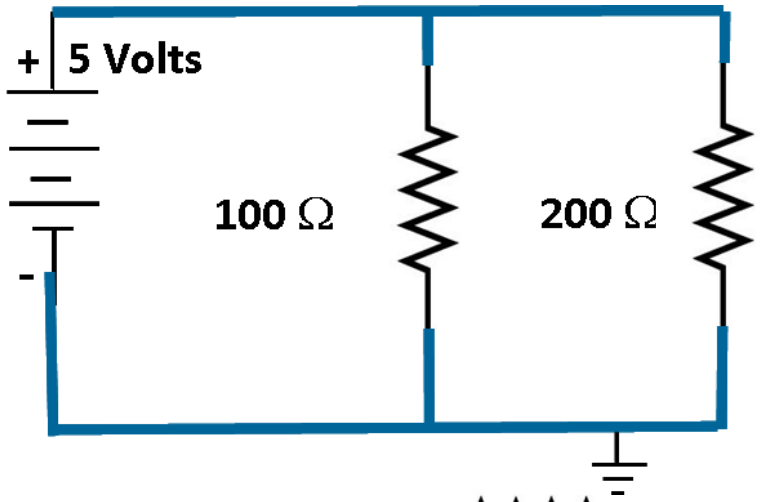
$$V = IR$$
$$I = V/R$$
$$I_2 = 5/1000 = 0.005A$$

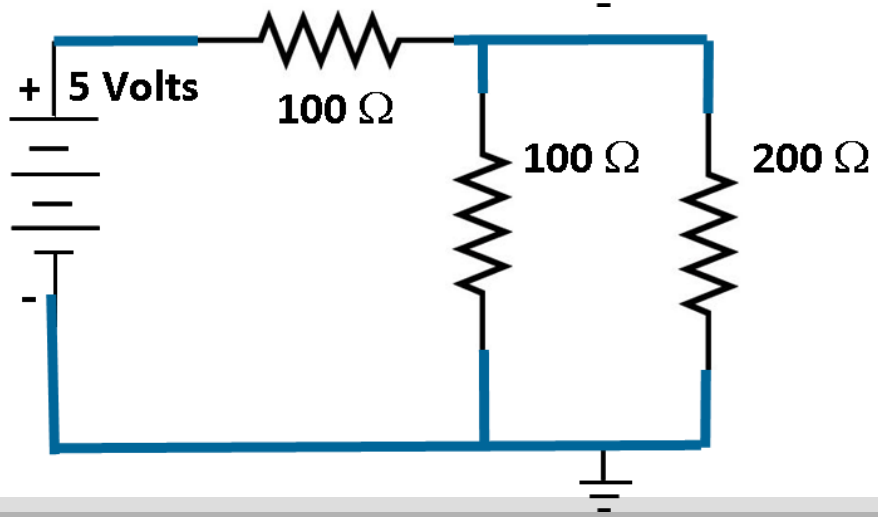
In parallel combinations, most of the current will go through the low resistance path (recall the example of the fat pipe versus the narrow straw)!

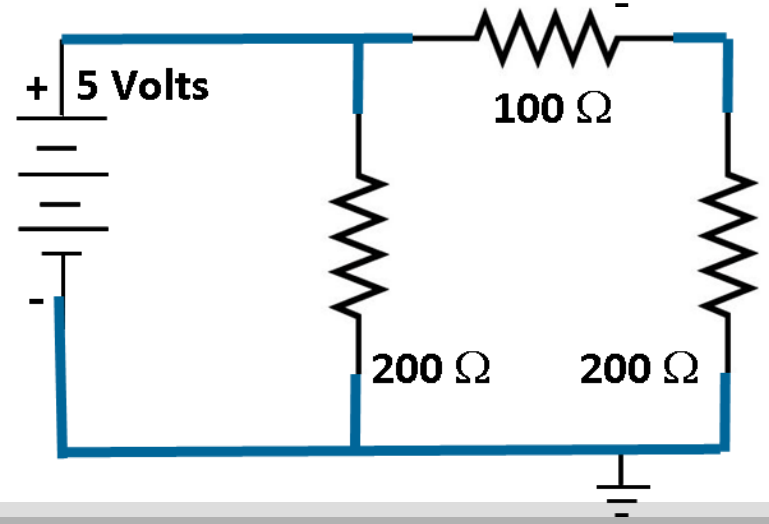
More Examples

Calculate the equivalent resistance for the following circuits, and the current that flows from the battery.



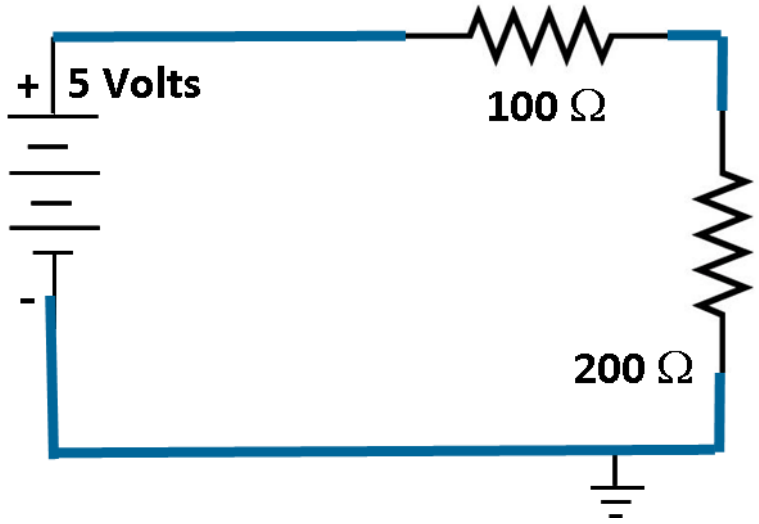






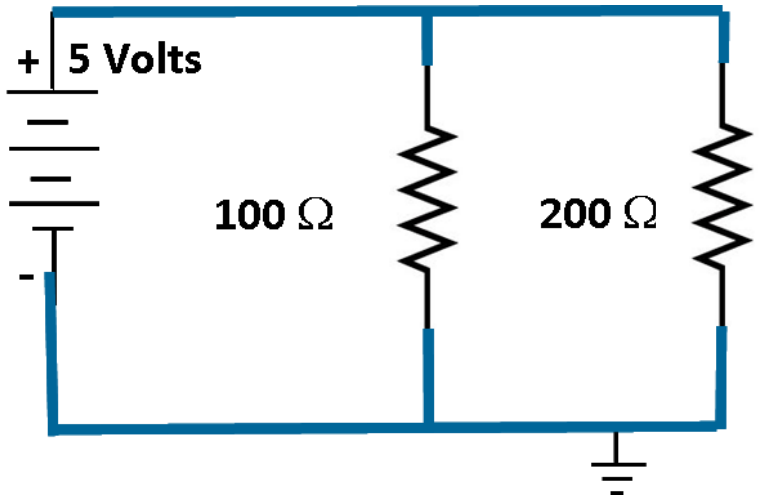
Example 1

Calculate the equivalent resistance for the following circuits, and the current that flows from the battery.



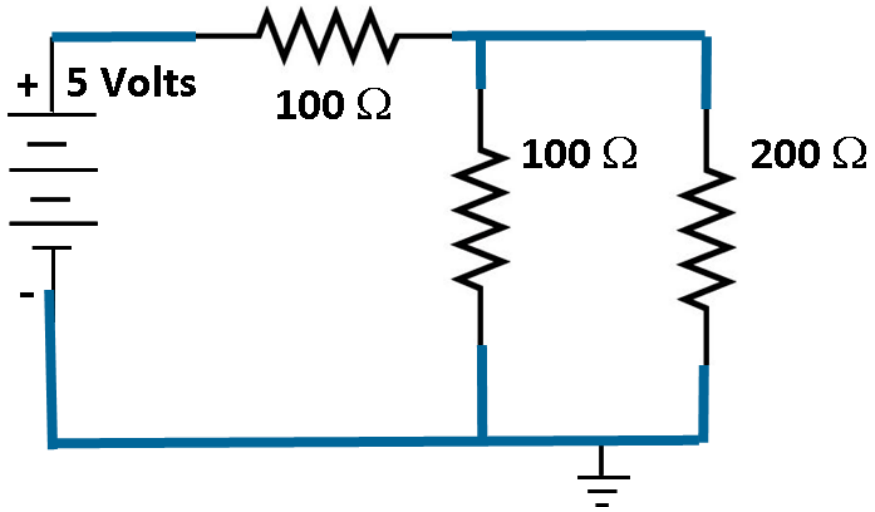
Example 2

Calculate the equivalent resistance for the following circuits, and the current that flows from the battery.



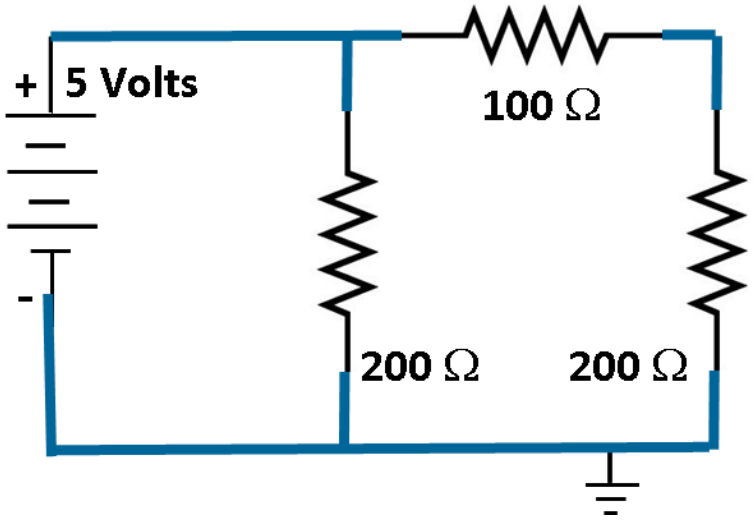
Example 3

Calculate the equivalent resistance for the following circuits, and the current that flows from the battery.



Example 4

Calculate the equivalent resistance for the following circuits, and the current that flows from the battery.



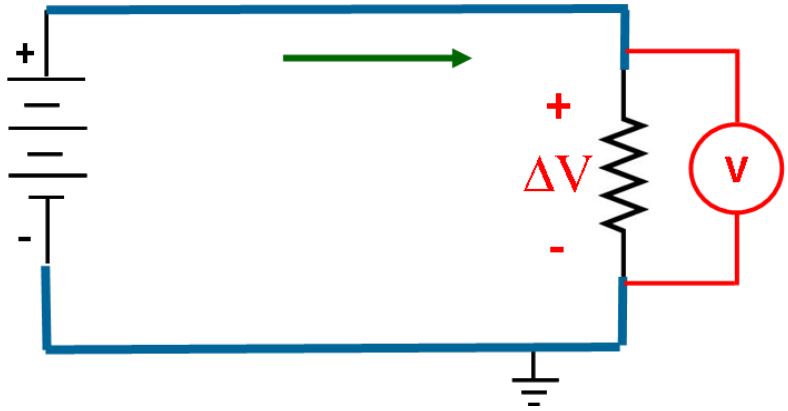
Measuring Current and Voltage

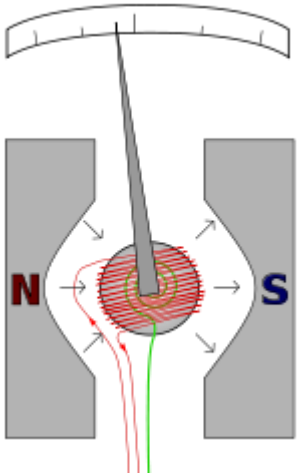
When we measure the voltage between two points in a circuit, when we measure a resistor or when we measure the current flowing through a wire, we must **sense** the parameter to be measured **truly.** Also, we must be careful not to **affect** the parameter being measured.

- **Ohmmeters** : measure resistance.
- **Voltmeters** : sense the voltage difference between two points.
- **Ammeters**: measure the current flowing through a wire.

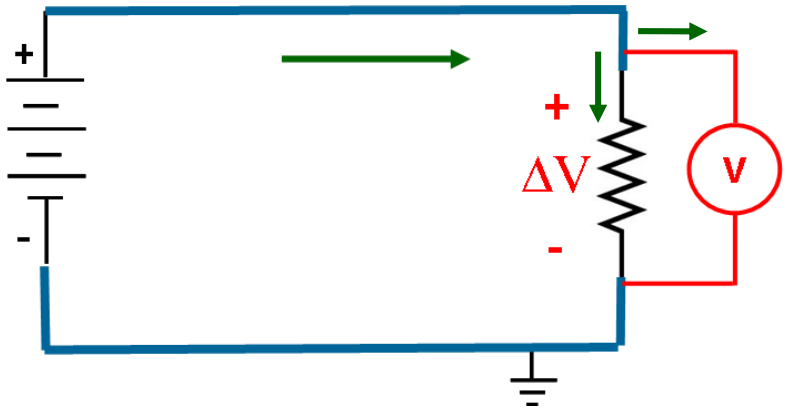
Voltmeters

Voltmeters are connected in "parallel" with the thing to be connected. This means the voltage across the **measurand** and the **voltmeter** is the same.





Voltmeters

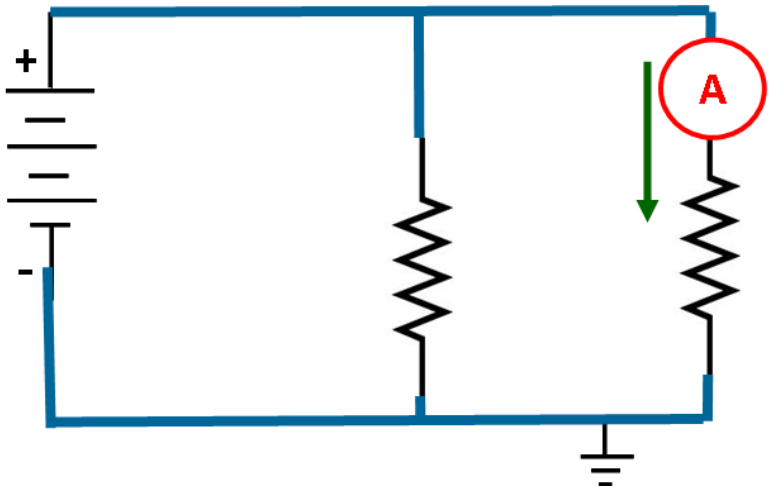


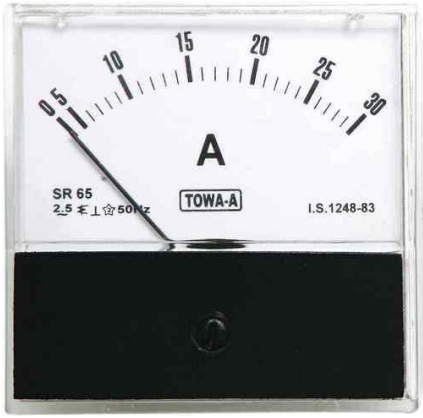
Voltmeters are connected in parallel, so that means some additional current will flow into the voltmeter. This will pull more current from the battery (or other parts of the circuit). **This will affect the operation of the circuit.**

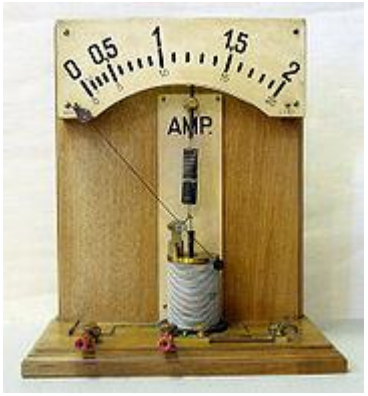
How can we minimise this effect?

Ammeters

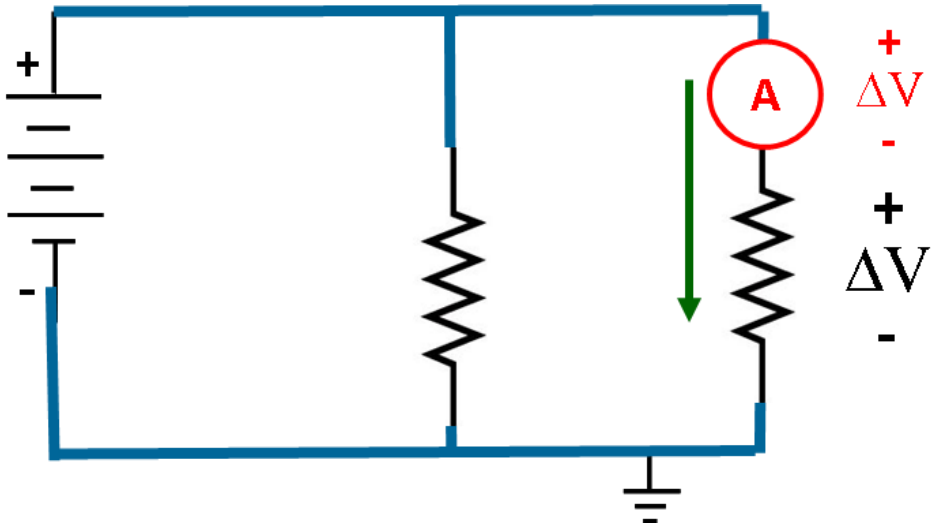
Ammeters are connected in "**series**" with the thing to be connected. This means that the same current will flow through the ammeter as through the point in the circuit that you are measuring.







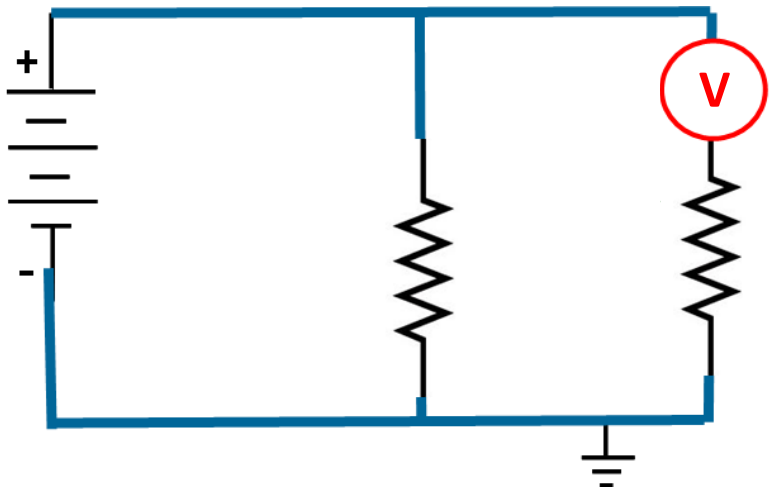
Ammeters

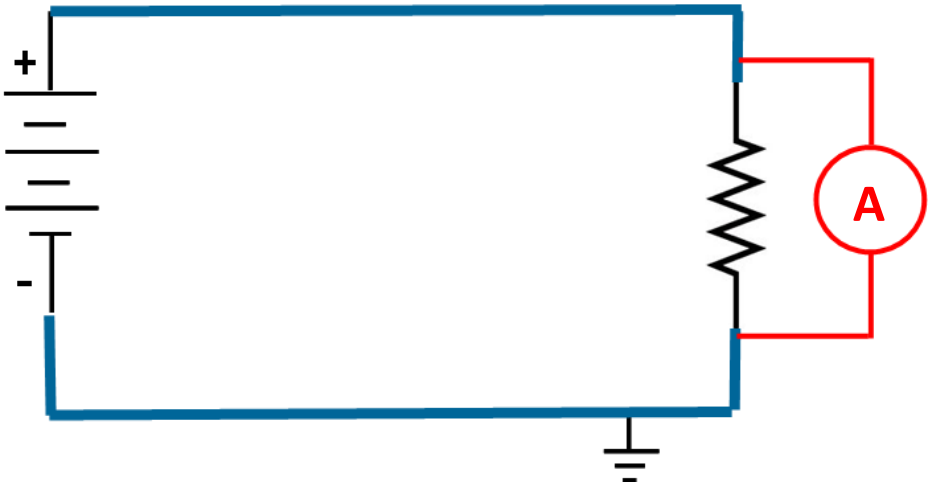


Ammeters are connected in series so that means the current will flow through the ammeter. But all devices have some resistance and this means that a small voltage drop will appear across the ammeter. **This affects the circuit behaviour.**

How can we minimise this effect?

What will happen???





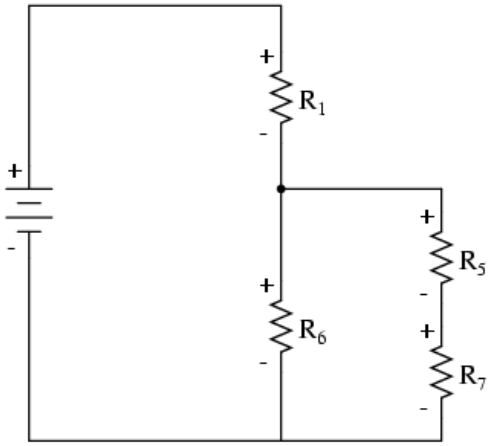
Drawing schematics and circuits

Schematic is the term for the diagram that represents an electrical circuit.

1) Wires in schematics are deemed to be ideal.

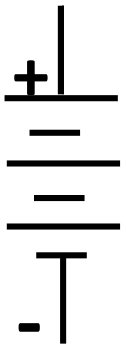
2) It should not matter how the schematic is drawn, but it does.

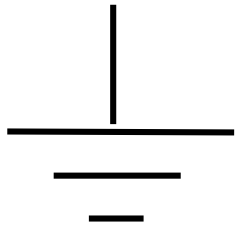
3) It is good practice to draw a schematic to enhance understanding as much as possible – *there are some guidelines on good practice*.

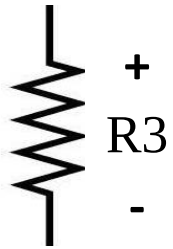


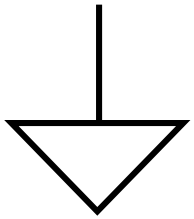
Drawing schematics and circuits

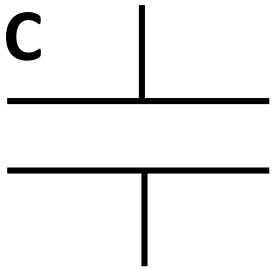
Use the right symbols, give them labels (R1, C3, X2)

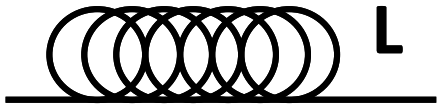








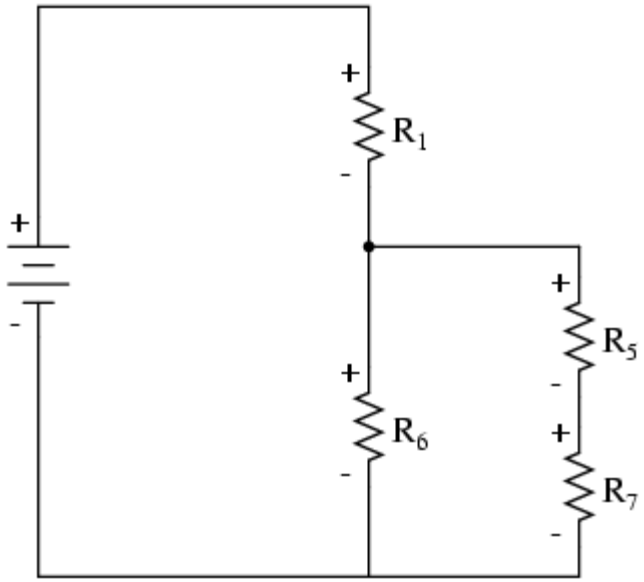




Drawing schematics and circuits

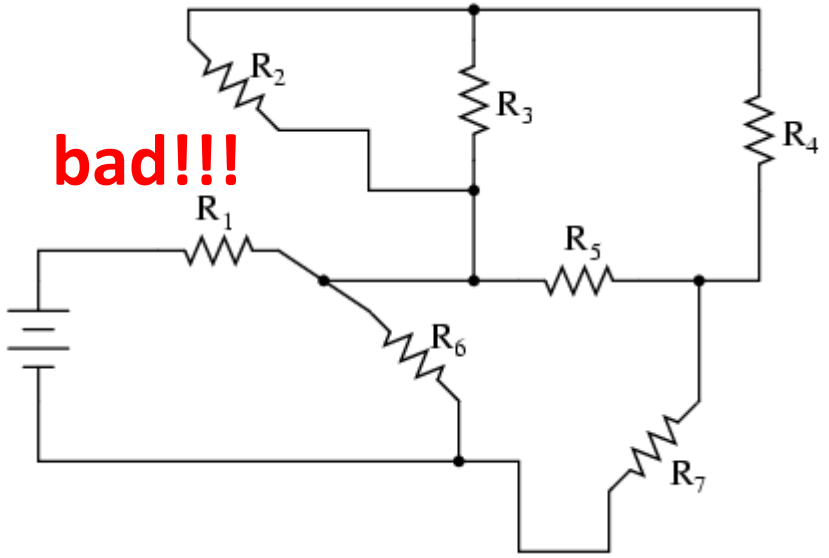
Try to use a vertical/horizontal drawing plan, **not one with random orientations.**

Space the elements well apart, keep it visually simple!



good

bad!!!



Difficult to follow which is series/parallel

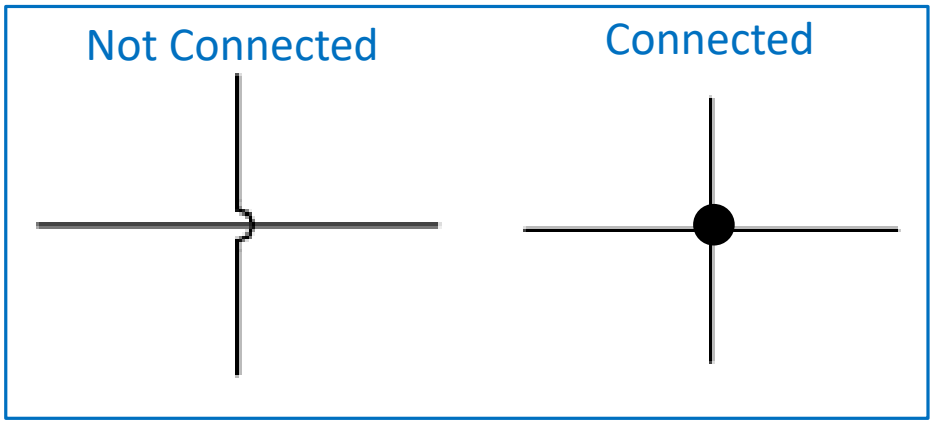
Drawing schematics and circuits

We can only show a 2D image on paper. Reality is often more complicated than that, so:

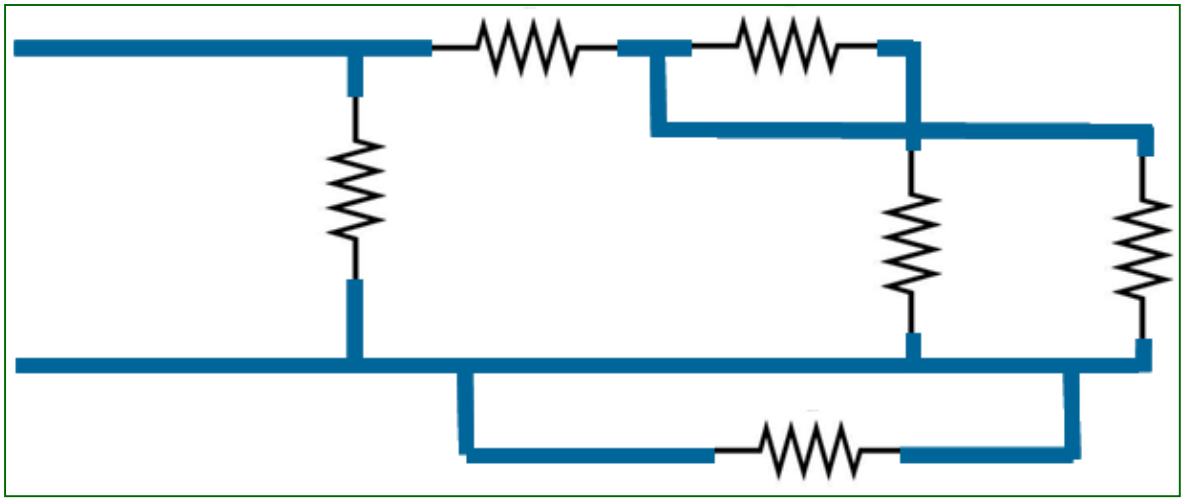
- If two wires are connected, show it with a **solid dot**! Two crossing wires are often assumed to be connected, but best to be sure.

- If two wires are passing each other but not connected, a dot is not used and where possible, a bridge is shown. It is best to **minimise cross-overs** where possible.

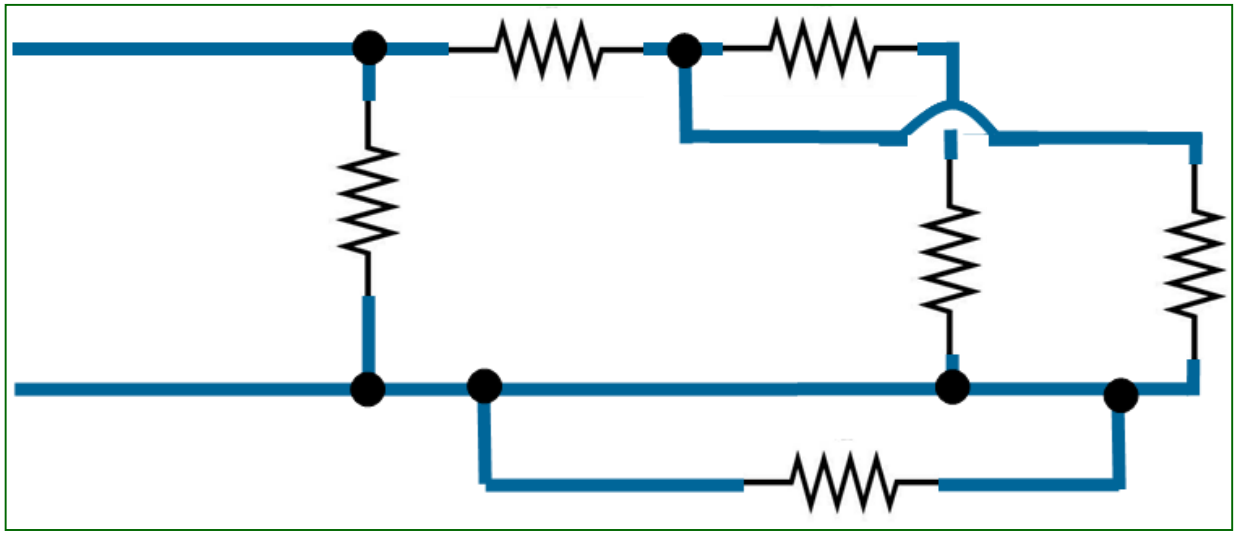
Connections are the most important thing in a circuit. Please try to make them as clear as possible.



Drawing schematics and circuits



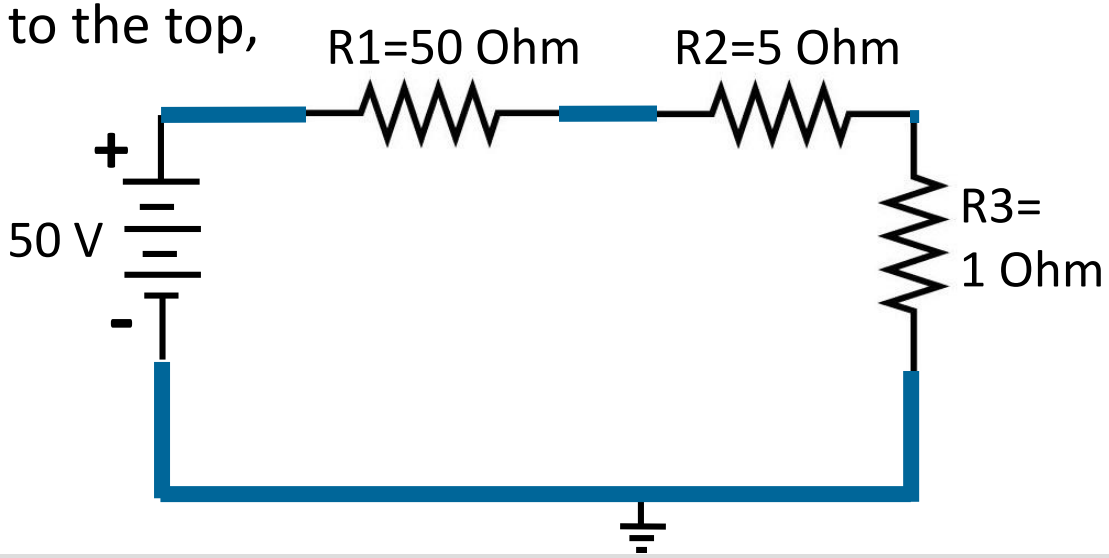
Is the bottom clearer?



Drawing schematics and circuits

Rules

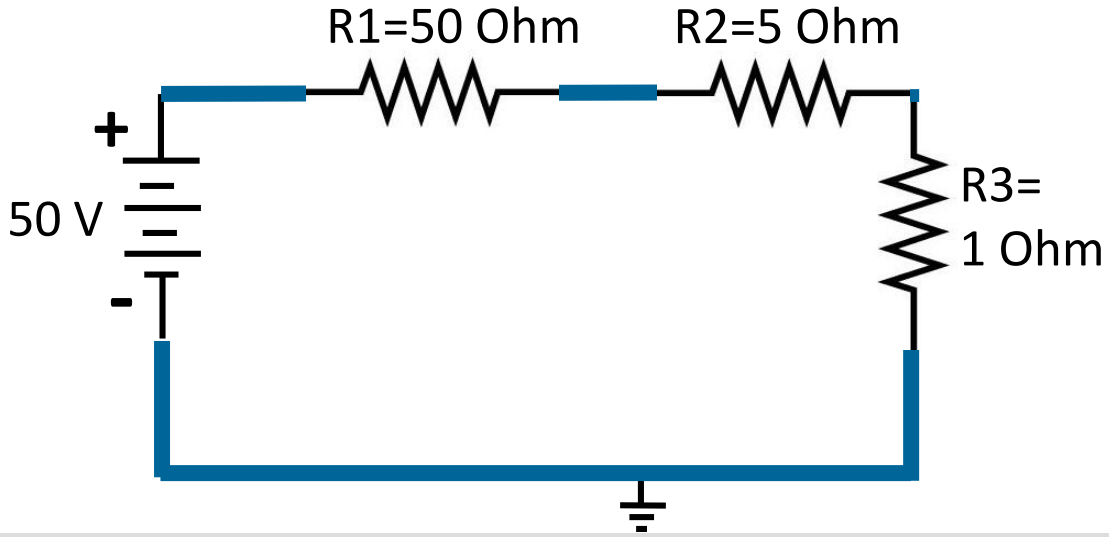
- **Always note the voltage supplies and earth** on the schematic.
- **Place the battery/power source to the left hand side** of the schematic (not always possible).
- Try to place parallel and series circuit elements and sections of circuits in **vertical/horizontal modular forms**.
- **Place** the positive voltage to the top, ground to the bottom.



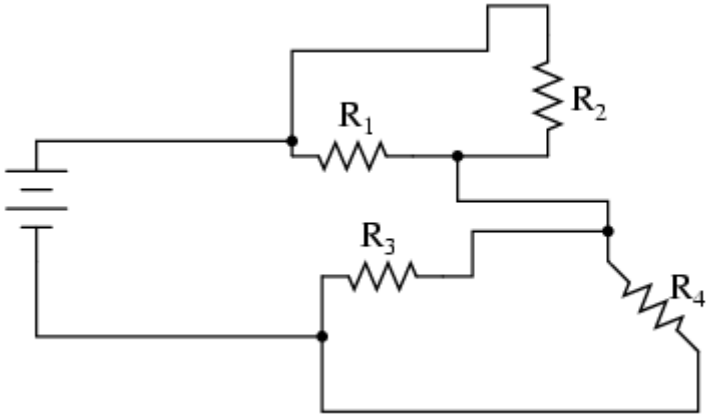
Drawing schematics and circuits

Rules

- **Mark wire connections clearly**, and label them.
- **Wires connect** and bend at right angles (90^{o}).
- **Use correct symbols** and appropriately **label** components (try to list component values on the schematic if space permits).



Redrawing circuits…



Redrawing circuits…