

# Electricity and Magnetism: Physics Narrative 03

## Contents

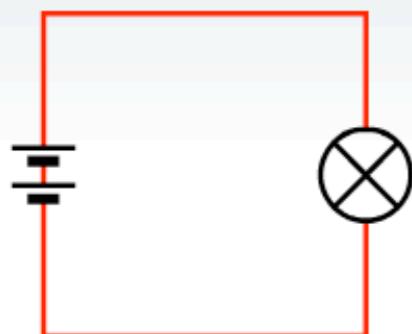
Adding to simple circuits .....	2
Adding batteries to the circuit.....	3
Thinking about the electric circuit model.....	5
Why is the bulb brighter? .....	6
Progress check: Adding batteries to the circuit.....	7
Adding a second lamp to the circuit.....	8
Why are the bulbs dimmer? .....	13
Progress check: Adding a second lamp to the circuit .....	14
Adding bulbs in parallel: What happens? .....	15
Explaining parallel circuits .....	17
Connections and circuits.....	21
Progress check: Adding bulbs in parallel.....	22

This is the 'Physics Narrative' for this episode, that explains the physics for teachers. To develop your expertise in the episode, work with the 'Teaching and Learning Issues' and the 'Teaching Approaches'. Navigate to any part of the topic using the Topic Menu, or use the tabs below to stay within this episode..

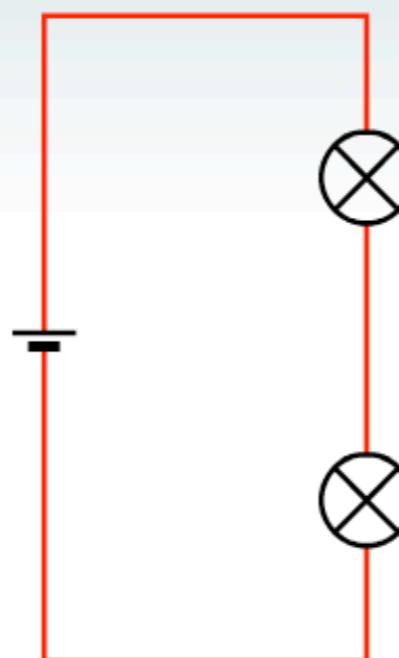
## Adding to simple circuits

There are three steps in this episode. In the first step an extra battery is added to the circuit. This is compared to the simple circuit studied up to this point. Then, this same simple circuit is compared to one where there are two bulbs in a single loop. Finally, the simple circuit is compared to one in which there are two bulbs, but each is on its own loop.

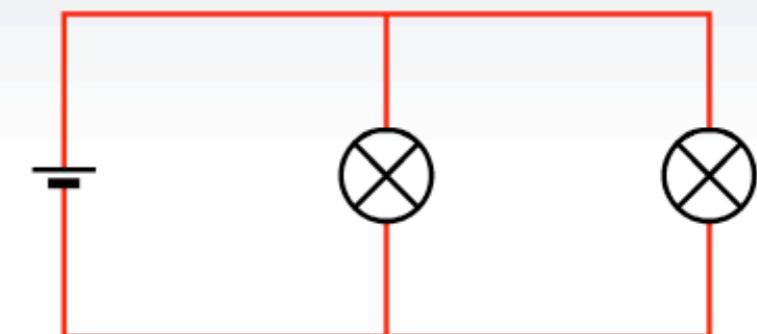
EXTRA BATTERY ADDED



TWO BULBS IN SERIES



TWO BULBS IN PARALLEL



## Adding batteries to the circuit

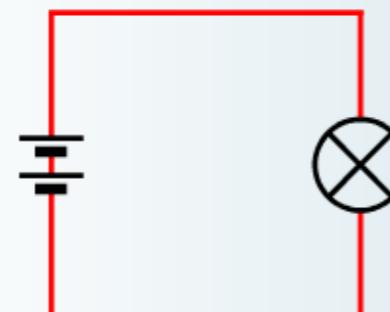
### Starting point: So what actually happens?

What happens when a second battery is added to the circuit so that we now have two batteries and one bulb?

When the circuit is completed, the bulb lights up and it is now brighter than normal. How can we explain this observation using the electric circuit model?

A simple series circuit: Two batteries, one bulb

Step on to see some other ways of drawing the same circuit.



When we draw circuits, we prefer to do it like this, keeping the batteries on one side, and the bulbs on the other.



STEP 1 of 2



## Adding batteries to the circuit

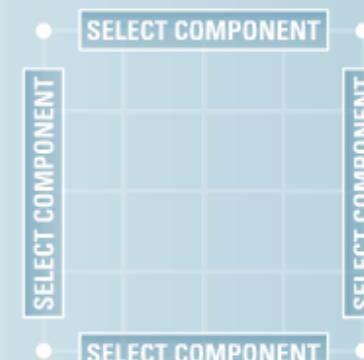
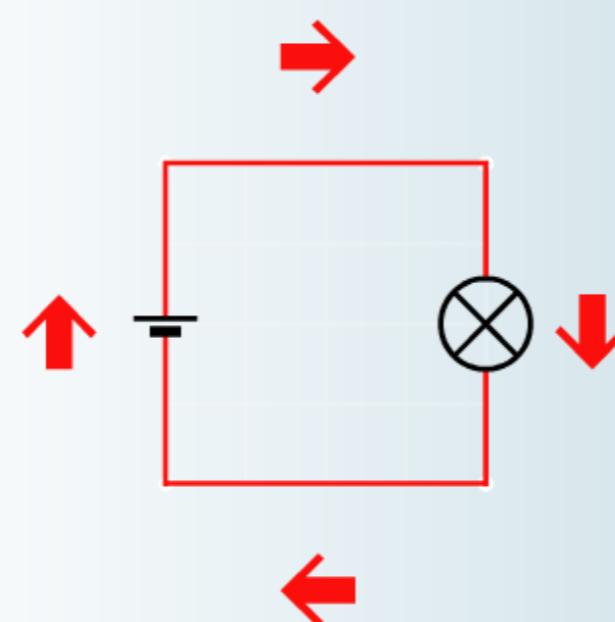
The first effect is simply that there is a larger current, adding more batteries increases the current.

Notice that the current is the same everywhere in the circuit.

### Increasing the current by adding cells

Build a circuit like this one, but where twice as much current passes through each part of the loop.

CHECK IT



## Thinking about the electric circuit model

Adding a second battery to the circuit has the effect of producing a bigger “push” from the two batteries acting together, moving the charges around the circuit more quickly. This means that more charges per second pass any point in the circuit and so the size of the electric current is increased. It is worth emphasising here that the number of charges moving around the circuit has neither been reduced nor increased. The same charges flow are made to flow at an increased rate by adding the extra battery.

### Why is the bulb brighter?

There are actually two effects that contribute to the bulb being brighter. The batteries maintain the greater flow of the charges, so that:

- the number of charges passing through the filament of the bulb per second increases
- each passing charge shifts more energy at the filament of the single bulb

The model to develop is one where adding the extra battery results in more charges arriving at the bulb per second, resulting in more energy shifted and a brighter bulb.

Adding cells speeds charges up

Use the switch to alter the number of cells. Then, drag the magnifying glass and use the other switches to change your view.

→

NUMBER OF CELLS  
1 CELL   
2 CELLS

WIRE SHOW   
HIDE

ATOMS SHOW   
HIDE

▶

## Why is the bulb brighter?

Find out more about the mechanism that makes the bulb brighter.

It is interesting to look in more detail at what happens in the circuit when an extra battery is added. Here is a model that is simple to describe, and quite plausible.

First of all, think about the charges as they are driven by the push of a single battery through the filament of the bulb. Each charge undergoes a stop-start motion as it moves through the array of fixed ions. Thus, a charge collides with an ion and the kinetic energy of the charge is transferred to that ion. The charge is then accelerated once again towards the terminal of the battery with the opposite charge and travels a short distance before colliding with the next ion. And so the stop-start motion continues.

With an extra battery, the positive terminal of the battery becomes more positively charged and the negative plate becomes more negatively charged, creating a greater force on the charges.

As a result:

- more charges pass through the filament each second
- each charge shifts more energy.

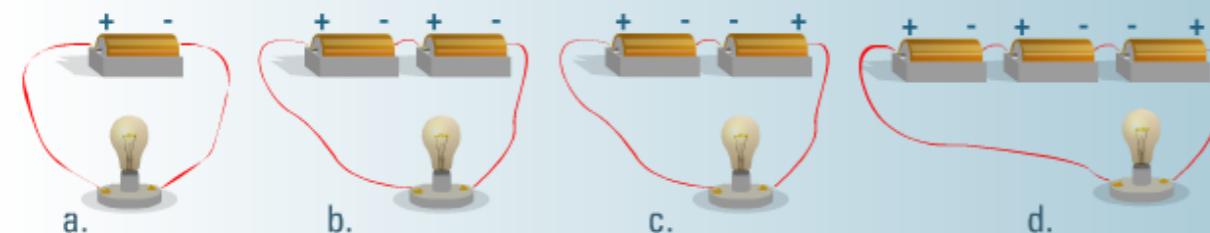
## Progress check: Adding batteries to the circuit

You can use the following questions to check your own understanding of this episode and your pupils' understanding.

### Electric Current

Question: 1 of 3

The bulbs in these circuits are all identical. The batteries are also identical, but look carefully at the + and - markings on them.



a) In which circuit is the bulb brightest?

- a. b. c. d.

b) In which circuit is the bulb dimmest?

- a. b. c. d.

c) In 2 of the circuits, the bulbs are the same brightness. Which 2 are these?

- b&c a&d c&d a&b



Explain your answer (self check):

Explain your answer (self check):

Explain your answer (self check):



Once you are happy with your answer click 'check it' to continue

CHECK IT

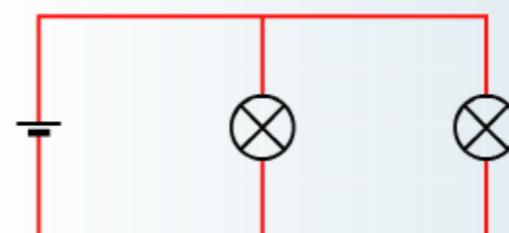
## Adding a second lamp to the circuit

What happens when a second bulb is added to the circuit, so that we now have one battery and two bulbs in series, in a single loop?

When the circuit is completed, both bulbs light up. However, this time they are not as bright as the single bulb; they are now equally dim. How can we explain this observation using the electric circuit model?

A simple parallel circuit: Two bulbs, one battery

Step on in order to see some other ways of drawing the same circuit.



When we draw circuits, we prefer to do it like this, keeping the batteries on one side and the bulbs on the other.



## Adding a second lamp to the circuit

### What happens to the electric current?

The effect of adding a second bulb in series is to increase the overall resistance of the circuit. The resistance previously provided by the thin filament wire of just one bulb is now doubled due to the presence of two.

This increase in resistance reduces the drift of charges around the whole circuit. Fewer charges per second pass any point in the circuit so the size of the electric current is reduced.

It is worth emphasising here that the total number of charges moving around the circuit has neither been reduced nor increased. The charges are simply made to flow at a lower rate all around the circuit by adding resistance.

Adding bulbs slows charges

Use the switch to alter the number of bulbs. Then, drag the magnifying glass and use the other switches to change your view.

NUMBER OF BULBS

1 BULB	<input checked="" type="checkbox"/>
2 BULBS	<input type="checkbox"/>

WIRE

SHOW	<input checked="" type="checkbox"/>
HIDE	<input type="checkbox"/>

ATOMS

SHOW	<input checked="" type="checkbox"/>
HIDE	<input type="checkbox"/>

PLAY

## Adding a second lamp to the circuit

### What about the energy?

Given that there are now two equal resistances in the circuit, and bearing in mind the rule introduced earlier in episode 1 (that energy is shifted wherever there is an electric current in a resistance) the energy from the battery is shared equally between the two bulbs. We can imagine that as the charges travel around the circuit, equal amounts of energy are shifted to the stores associated with the surroundings as the charges pass through each filament.

Adding bulbs slows charges

Use the switch to alter the number of bulbs. Then, drag the magnifying glass and use the other switches to change your view.

NUMBER OF BULBS

1 BULB      2 BULBS

WIRE

SHOW

HIDE

ATOMS

SHOW

HIDE

PLAY

## Adding a second lamp to the circuit

### Why are the bulbs dimmer?

The basic reason that the bulbs are now dimmer is that adding the extra bulb increases the resistance and reduces the current everywhere in the whole circuit.

As a result fewer charges per second pass through each bulb and each charge shifts less energy as it passes through the filament.

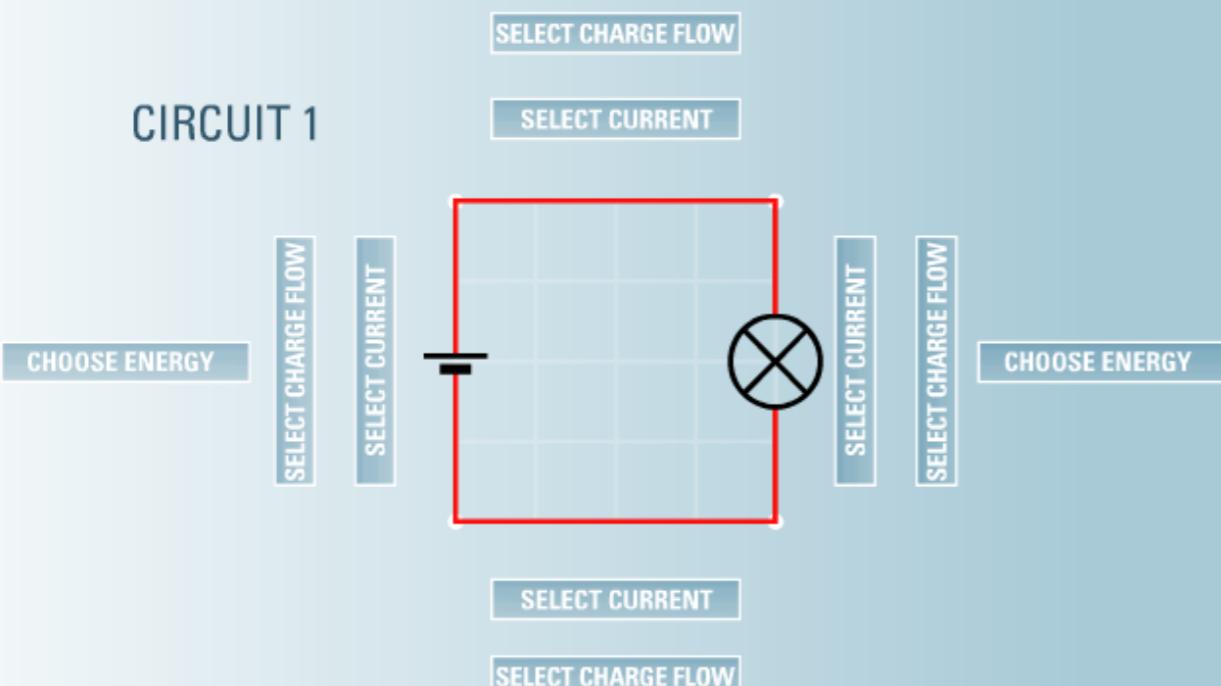


## Adding a second lamp to the circuit

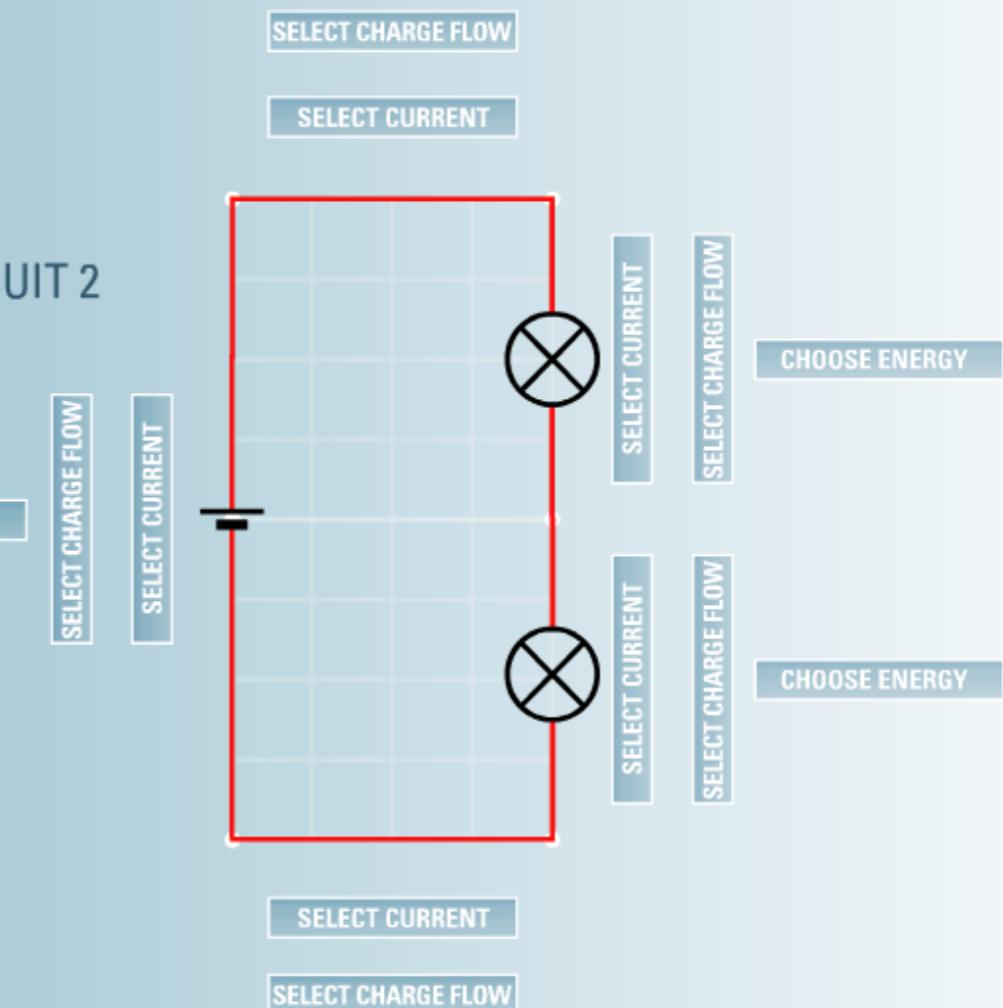
### Accounting for dimness

Describe these two circuits in a way that could provide a basis for accounting for the dimness of the lamps.

CIRCUIT 1



CIRCUIT 2



## Why are the bulbs dimmer?

Find out more about the mechanism that makes the bulb dimmer.

It is interesting to look in more detail at what happens in the circuit when an extra bulb is added.

First of all, think about the charges as they are driven by the push of a single battery through the filament of the bulb. Each charge undergoes a stop-start motion as it moves through the array of fixed ions. Thus, a charge collides with an ion and the kinetic energy of the charge is transferred to that ion. The charge is then accelerated once again towards the terminal of the battery with the opposite charge and travels a short distance before colliding with the next ion. And so the stop-start motion continues.

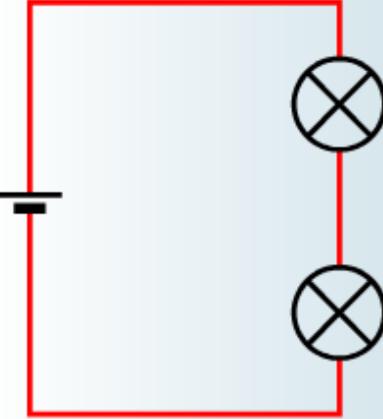
With an extra bulb, the total resistance in the circuit is increased so the charges move around more slowly. This results in:

- a decrease in the number of charges passing through the filament each second
- less energetic collisions with the fixed ions (each charge loses less kinetic energy and each ion gains less energy) in both bulbs

So, both bulbs in the circuit become dimmer as a result of the second bulb being added because fewer charges per second pass through each bulb and the collisions between charges and lattice ions are less energetic.

## Progress check: Adding a second lamp to the circuit

You can use the following questions to check your own understanding of this episode and your pupils' understanding.

What happens to the current?		Question: 1 of 4
This circuit consists of a battery and a bulb. The bulb is lit. 	a) What happens to the current in the circuit? (tick one box)  <input type="checkbox"/> It gets bigger <input type="checkbox"/> It stays the same <input type="checkbox"/> It gets smaller but not zero <input type="checkbox"/> It drops to zero	a) How would you explain this? (tick all the correct statements)  <input type="checkbox"/> The battery is not strong enough to push any current through two bulbs <input type="checkbox"/> The battery cannot push as big a current through two bulbs <input type="checkbox"/> It is the same battery so it supplies the same current <input type="checkbox"/> Two bulbs need more current than one on its own <input type="checkbox"/> The current is shared between the two bulbs, so each gets half
A second identical bulb is added. 	<p>Once you are happy with your answer click "check it" to continue</p> <p><b>CHECK IT</b></p>	

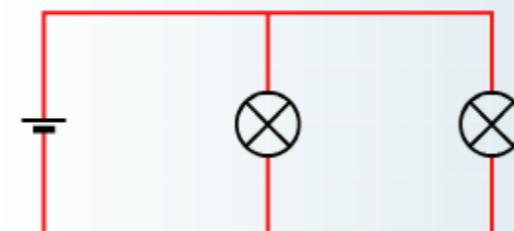
## Adding bulbs in parallel: What happens?

### Starting point: So what actually happens?

What happens when a second bulb is connected in parallel with the first?

A simple parallel circuit: Two bulbs, one battery

Step on in order to see some other ways of drawing the same circuit.



When we draw circuits, we prefer to do it like this, keeping the batteries on one side and the bulbs on the other.



## Adding bulbs in parallel: What happens?

When the circuit is completed, both bulbs light up, and each is of normal brightness (the same as with one battery and one bulb). When first encountered, this effect can seem a bit surprising, almost as if something is being gained for nothing.

Just by connecting the bulbs in parallel, they both shine with normal brightness. How can we explain this observation using the electric circuit model?

Energy shifted in a parallel circuit

Drag the extra loop to make a parallel circuit.

The diagram illustrates a circuit transformation. On the left, a single horizontal wire segment with two orange arrows pointing right contains a battery symbol (-) and a light bulb symbol (circle with an X). A dashed rectangular frame labeled "DRAG ME" surrounds the entire circuit. On the right, the circuit has been modified: the original wire segment is now a vertical dashed line, and a new horizontal wire segment has been added to the right, connecting the light bulb to the positive terminal of the battery. This creates a parallel circuit where current can flow through both the bulb and the battery. A play button icon is located at the bottom left of the frame.

## Explaining parallel circuits

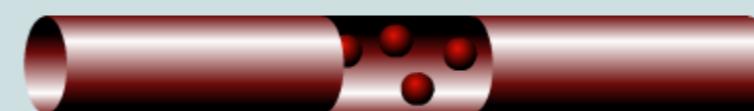
### What happens to the electric current?

Adding a second bulb in parallel to the first sets up a second circuit loop in which charges can be set in motion. Not only do we have the loop of charges passing through the first bulb, but we also have a second loop of charges through the second bulb. The number of charges passing through the battery each second is thus doubled, with half of the charges moving on to pass through the bulb in the first loop, and the other half through the bulb in the second loop.

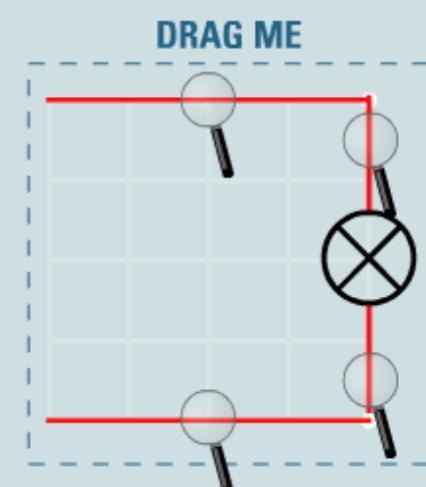
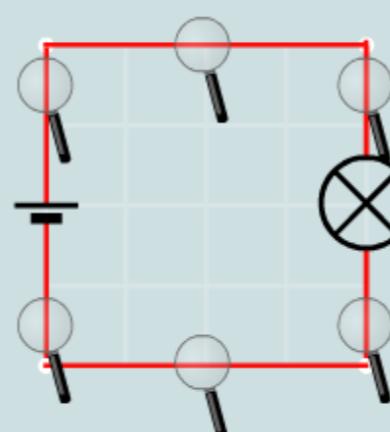
In other words, the current through the battery is double that with one battery and one bulb, whilst the current through each bulb is the same as in a circuit with one battery and one bulb.

Altering the circuit affects the flow of charge

Drag the extra loop to make a parallel circuit.



Click on a magnifying glass to get a close up model.



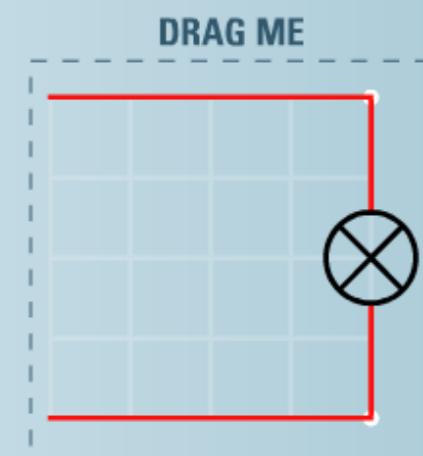
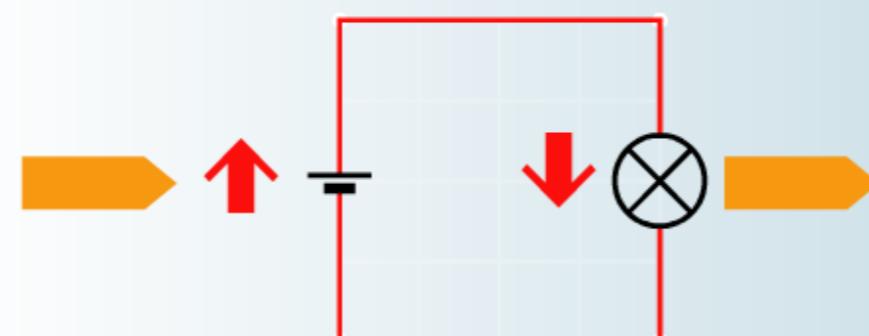
## Explaining parallel circuits

### What about the energy?

In each loop of the circuit, the charges are set into motion by the battery and shift energy to the stores associated with the surroundings as they pass through the filament.

#### Energy and current in a parallel circuit

Drag the extra loop to make a parallel circuit.



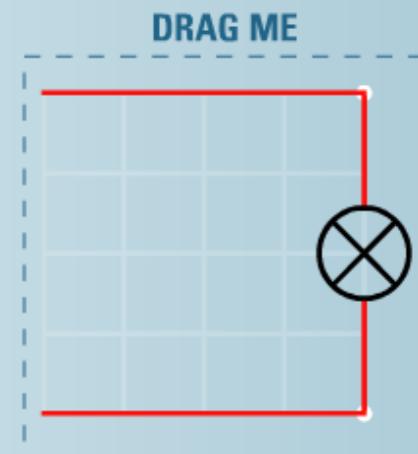
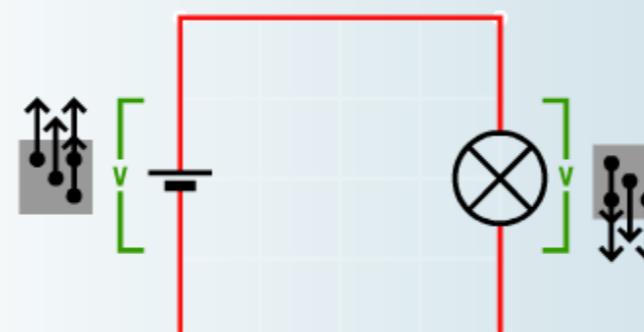
## Explaining parallel circuits

### Why are both bulbs of normal brightness?

When a second bulb is added in parallel the electric current through each bulb is the same as the circuit with one battery and one bulb. This means that all of the energy shifted by each charge as it passes through one or the other of the bulbs results in glowing at that bulb only, and so both bulbs are of normal brightness.

### Charge flow and energy per charge in parallel circuits

Drag the extra loop to make a parallel circuit.



## Explaining parallel circuits

### Something for nothing?

Connecting bulbs in parallel does not contradict the law of conservation of energy, even though at first sight this might appear to be the case! The good news is that we have two bulbs of normal brightness. The bad news is that the energy of the chemical store of the battery is shifted to the thermal stores of the surroundings twice as quickly as with one bulb.

The electric circuit model reinforces this result as the electric current through the battery (the flow of charges shifting the energy energy) is doubled as the second bulb is added in parallel.

Energy shifted in a parallel circuit

Drag the extra loop to make a parallel circuit.

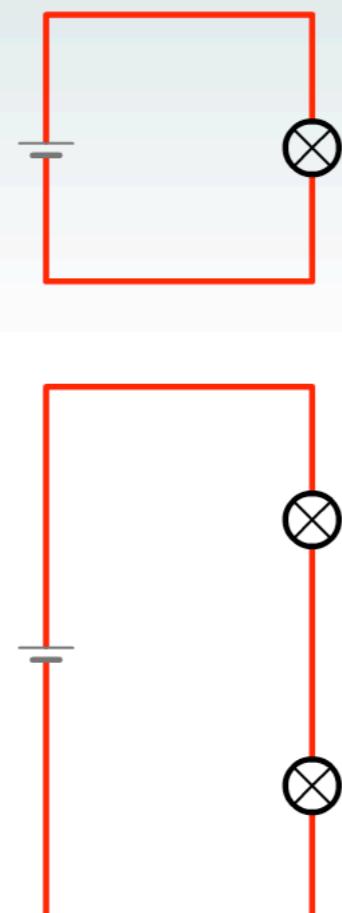
DRAG ME

▶

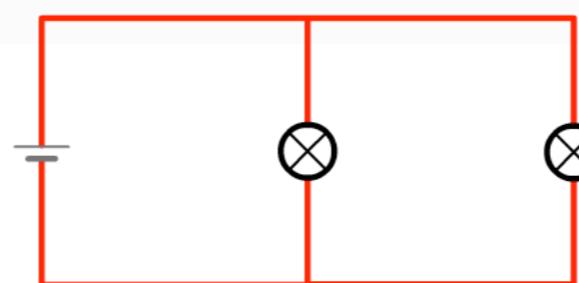
## Connections and circuits

Here you can find out the limits to dividing all circuits into two kinds: series and parallel.

Only series connections:  
series circuits

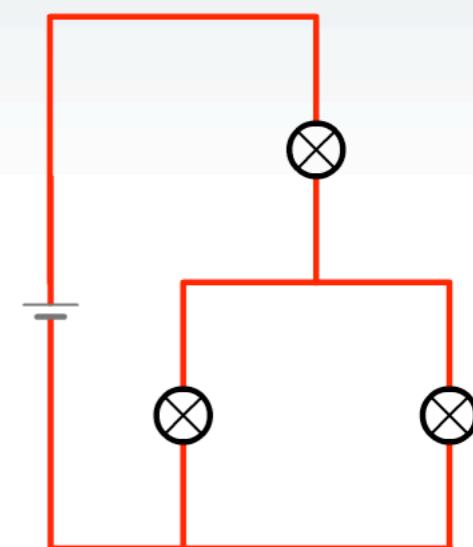


Only parallel connections:  
parallel circuits



Only in the very simplest cases are circuits either series or parallel. For more precision, you might refer to series connections or parallel connections. Later on, pupils may well meet circuits where things are connected in both series and parallel in the same circuit. But for very simple circuits you can use the terms series circuits and parallel circuits without causing too much confusion.

Both parallel and series connections :  
complicated!



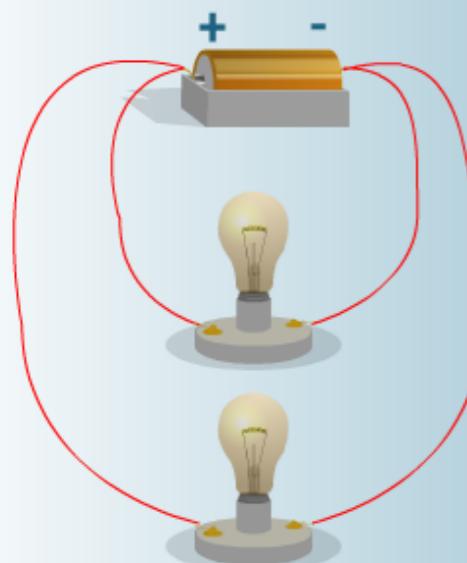
## Progress check: Adding bulbs in parallel

You can use the following questions to check your own understanding of this episode and your pupils' understanding.

Same circuit?

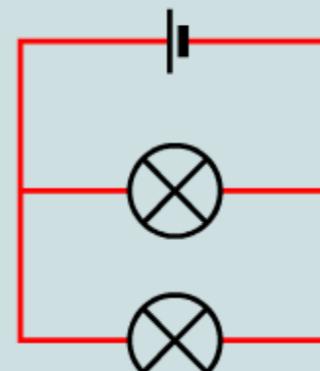
Question: 1 of 3

1. This electric circuit is set up on the bench:

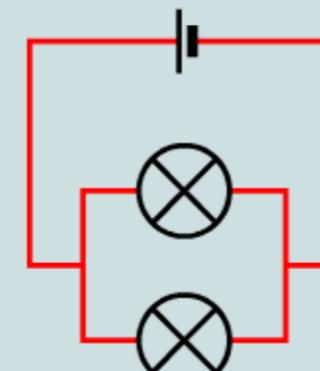


Five pupils are asked to draw its circuit diagram. Their drawings are shown on the right. For each, tick if you think it shows the connections in the circuit correctly.

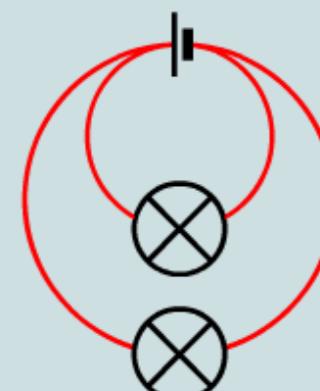
a



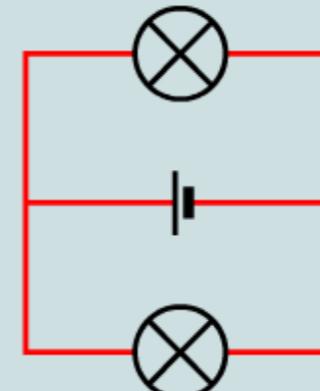
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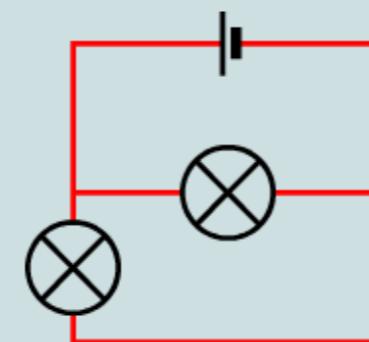
c



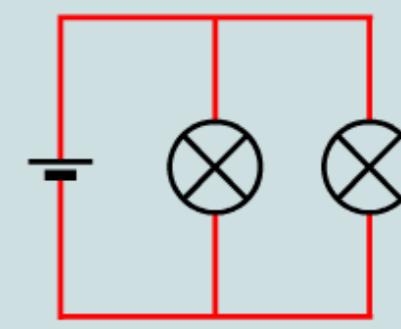
d



e



f



Once you are happy with your answer click "check it" to continue

CHECK IT