Electricity and Magnetism: Physics Narrative 02

Contents

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..

Start

Measuring electric currents

The point was made earlier that an electric current consists of electrons, or more generally charges, moving around a circuit. We now turn to considering how electric currents can be measured and how we can make sense of these measurements.

Measuring electric currents

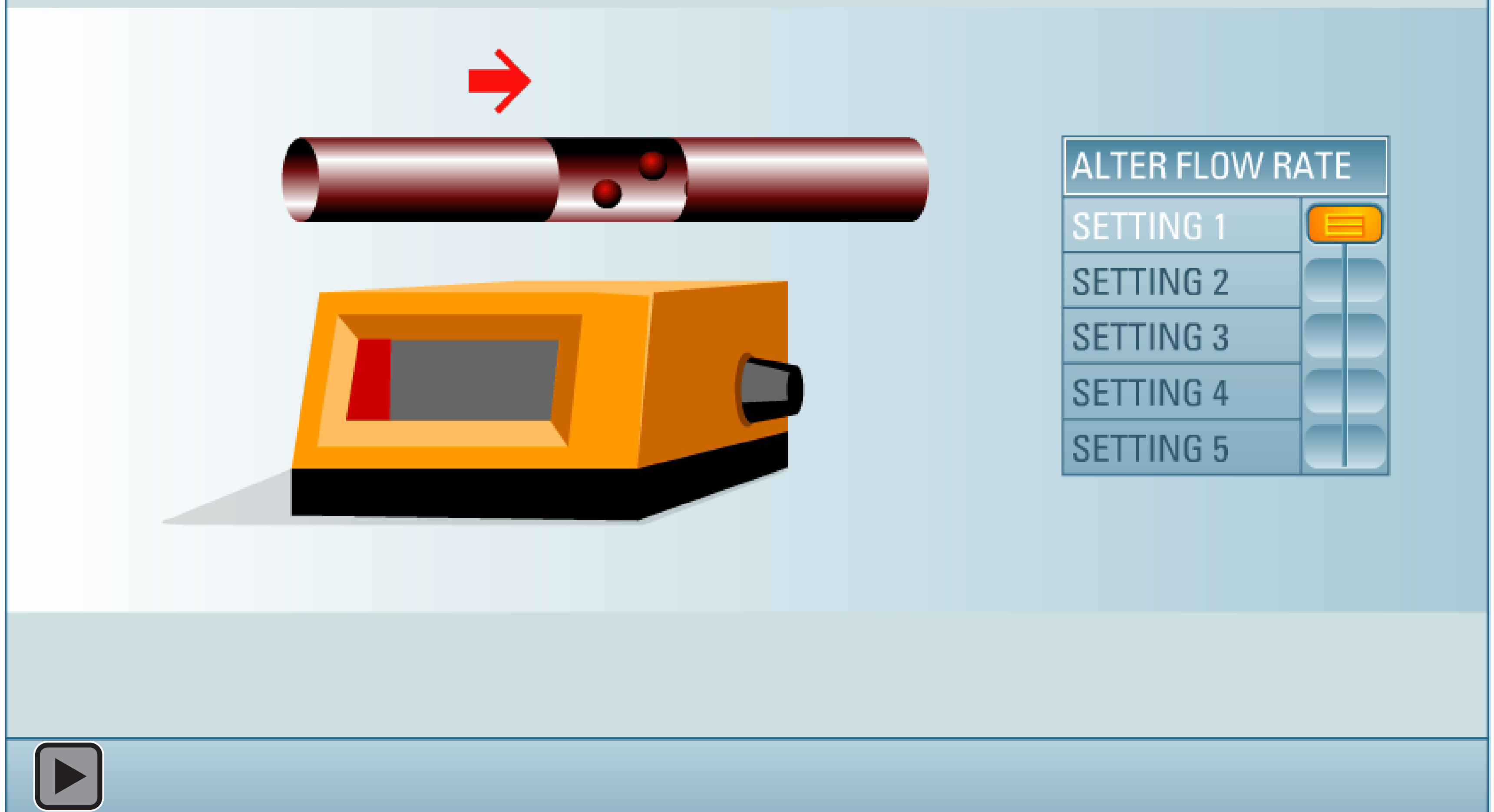
The electric current through a circuit is measured with an ammeter. To take the measurement, a gap is made in the circuit and the ammeter is connected into that gap, so that the charges moving around the circuit must pass through the meter.

What does the ammeter actually measure when it is connected in a circuit? You might visualise the working of an ammeter as counting charges as they move through the instrument, to see how many pass each second. The amount of charge passing per second is a measure of the electric current:

Lots of charges passing per second:	BIG current
Few charges passing per second:	SMALL current

Varying the flow alters the current

Use the stepper to alter the flow. See what happens to the current shown by the ammeter.



Measuring electric currents

In other words:

Electric current = amount of charge passing per second

Electric current = rate of flow of charge

Since the ammeter is connected directly into the circuit, it must have a low resistance so that it does not reduce the flow of charge which it is being used to measure.

Time, charge and current

Click on a term to make it the subject of the relationship.
Unlock a pair of variables, then drag one to see how the other varies.

$$\text{current} = \frac{\text{charge}}{\text{time}}$$

Measuring electric currents

To increase the size of the electric current,

either

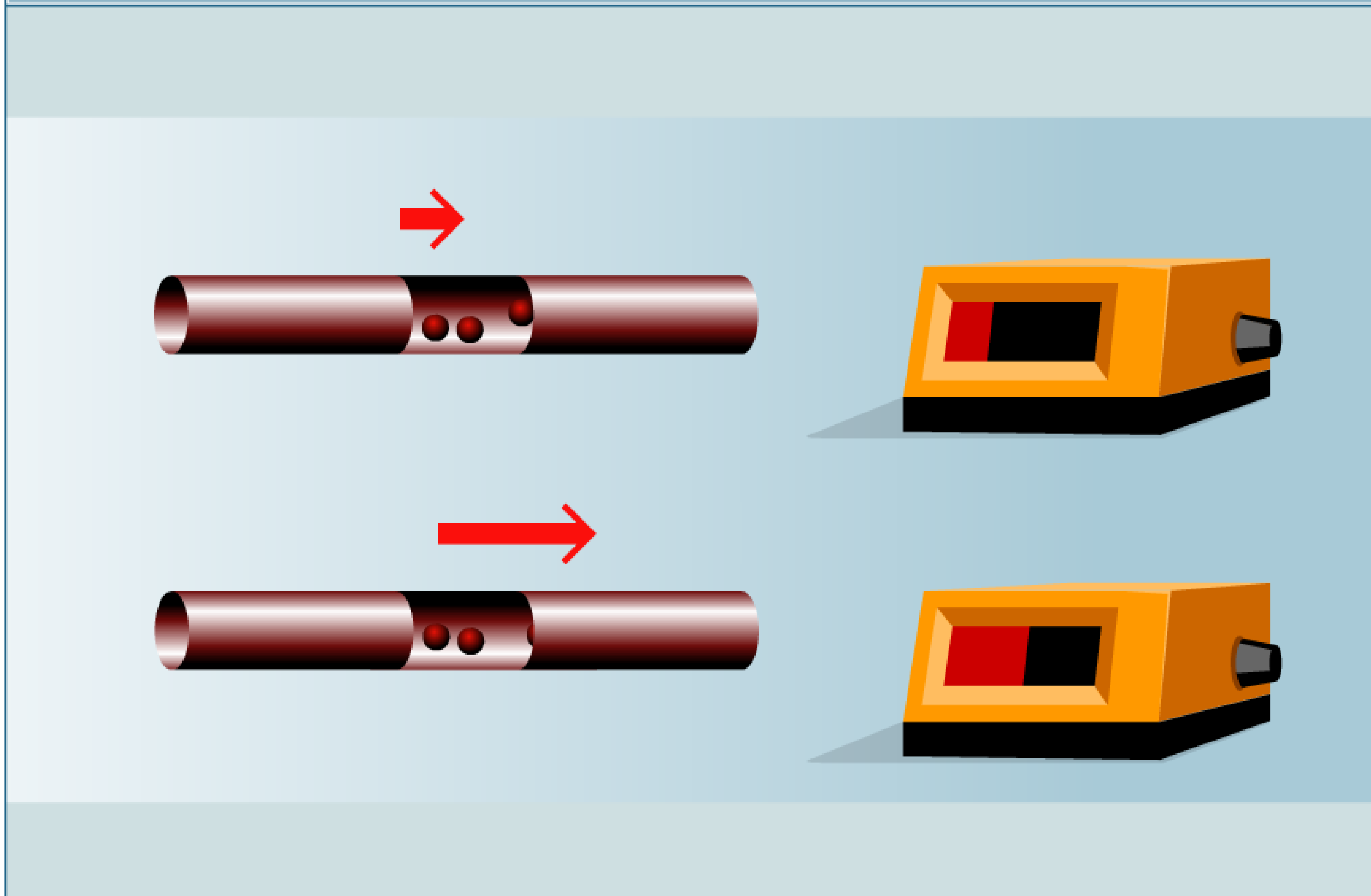
- more charges must be set in motion,

or

- the charges must be made to travel more quickly around the circuit.

Both of these actions result in more charges passing any point in a circuit each second and thus produce a bigger electric current. In episode 3, you will see how the electric current can be increased.

Double the current in the same wire



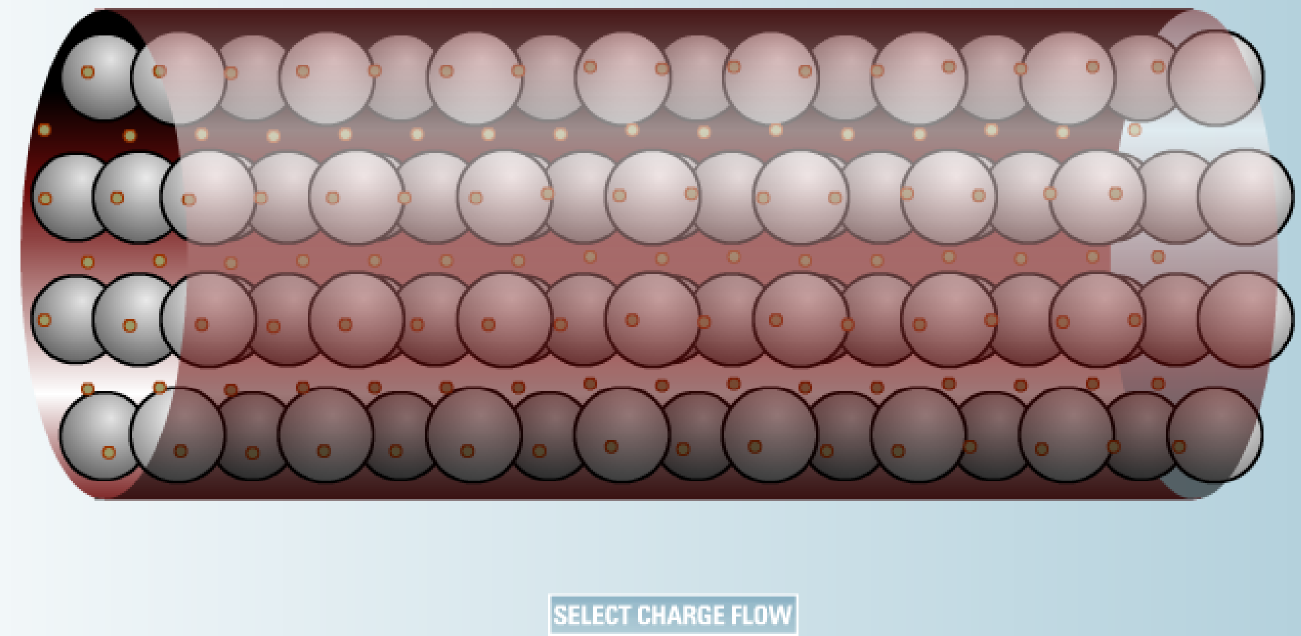
STEP 1 of 2

Measuring electric currents

Here you can alter the number of charges in the wire - done in practice by changing the material the wire is made from, or altering the rate at which these charges flow down the wire. Either of these actions changes the current.

Altering the charge flow rate in a charge carrying wire

Alter the charge flow using the charge pop-up.



Introducing the ampere

When an ammeter is used to measure the size of an electric current, the reading from the meter is in units of ampere. A steady electric current of 1.0 ampere means that one coulomb of charge is passing per second.

What does this mean? How many electrons make up one coulomb's worth of charge? Since the charge on one electron is 1.6×10^{-19} coulomb, then there must be about 6×10^{18} electrons (6 million, million, million!) in one coulomb of charge.

When thinking about electric currents, the image is thus one of huge numbers of electrons drifting around the circuit at a rather sedate pace!

Units: Electric Current

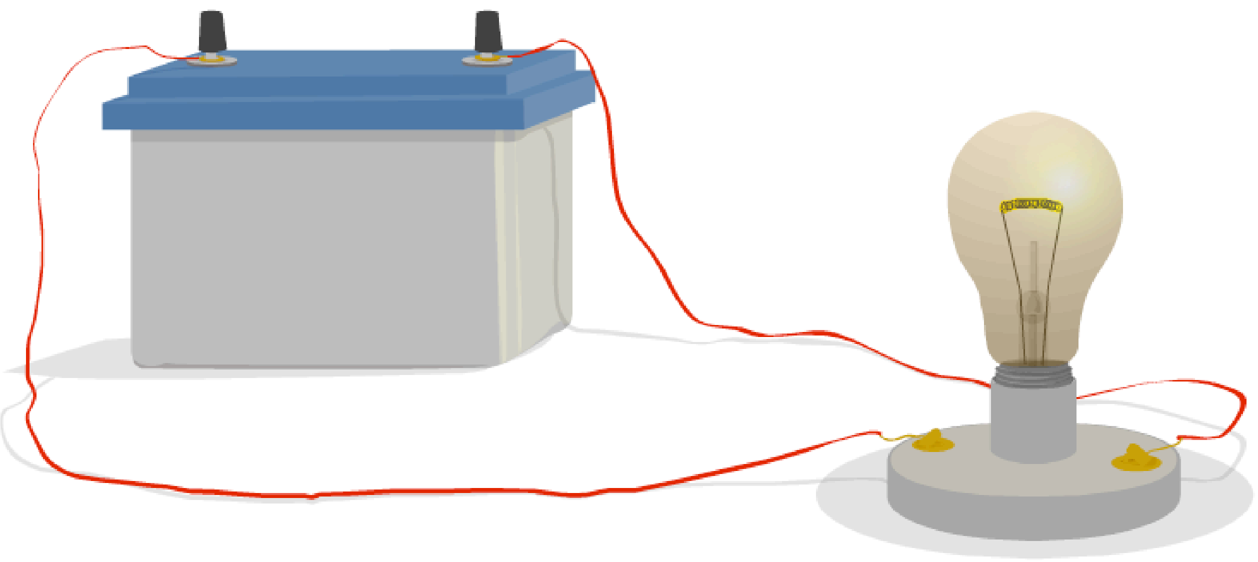
- The unit of electric current is the ampere.
- The symbol for the ampere is: A.

Electrons drifting at a sedate pace

Find out more about the connection between the immediate turning of the light and the slow motion of the charges.

In episode 1, the point was made that on completing a circuit the charges drift round at a speed of about 1 cm per minute. It is interesting to think about the BIG circuit in relation to this fact. When the BIG circuit is completed, the bulb appears to light immediately. This being the case, it is obvious that this is not achieved by charges travelling out from the battery to the bulb to make it light. If the BIG circuit runs from the front of the lab to the back, the bulb might then take 10 hours to light up! What happens, of course, is that as the circuit is completed, all of the charges in the circuit (including those in the filament of the bulb) start moving together and the filament heats up “instantly”.

As outlined in episode 1, the rope loop teaching analogy offers a convincing view of this effect.



Conservation of electric currents: They really don't get used up!

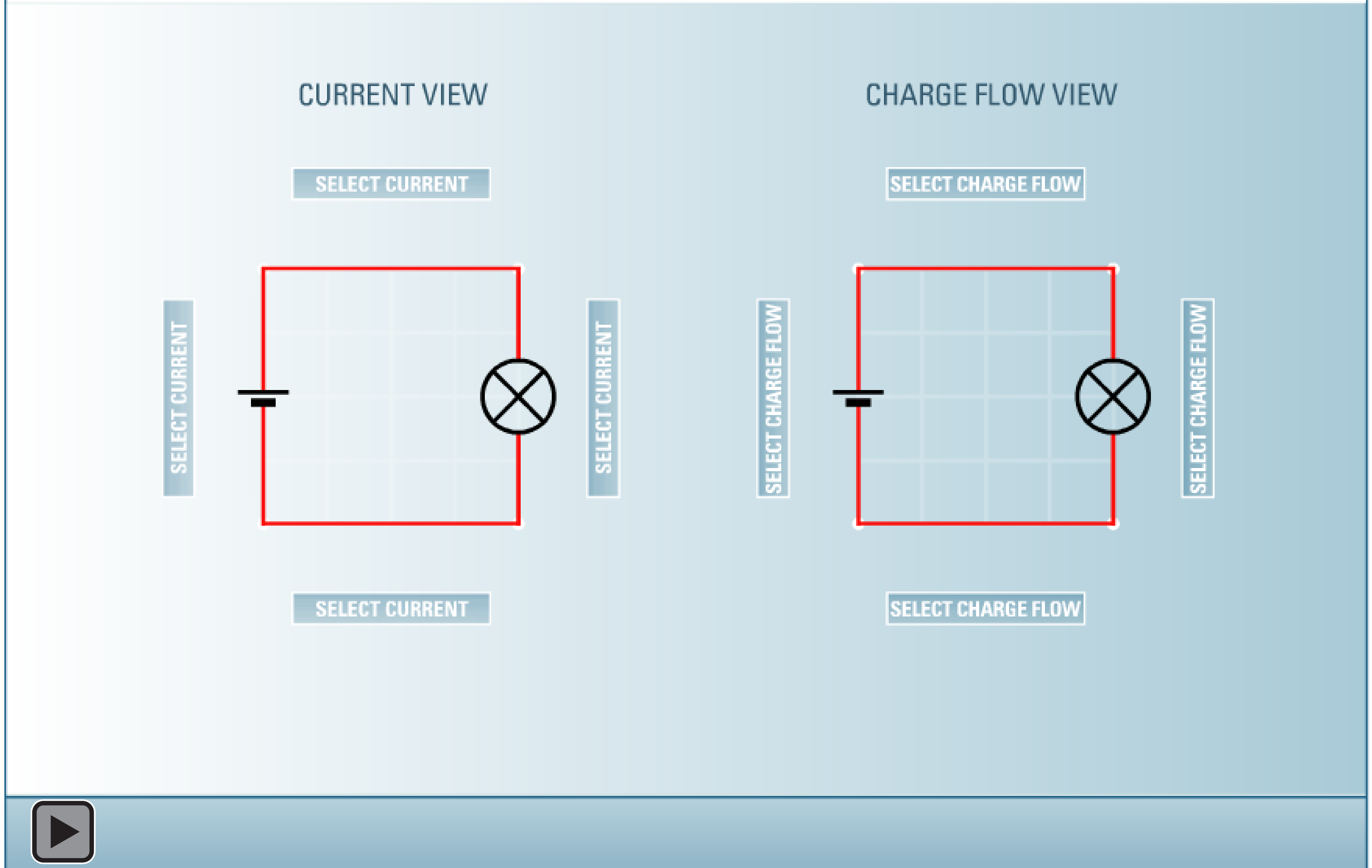
The point has already been made that electric currents do not get used up. In a simple circuit with one battery and one bulb, the size of the electric current is the same all around the circuit.

If it is 0.75 ampere before the bulb, it is 0.75 ampere after the bulb and 0.75 ampere through the battery and bulb.

In other words, 0.75 coulomb of charge pass each point in the circuit every second. There are no "side-paths" down which the charges can pass and the charges themselves cannot just disappear.

Same current everywhere

Add to the diagrams to show the two views of electricity moving around the circuit: current and charge flow.



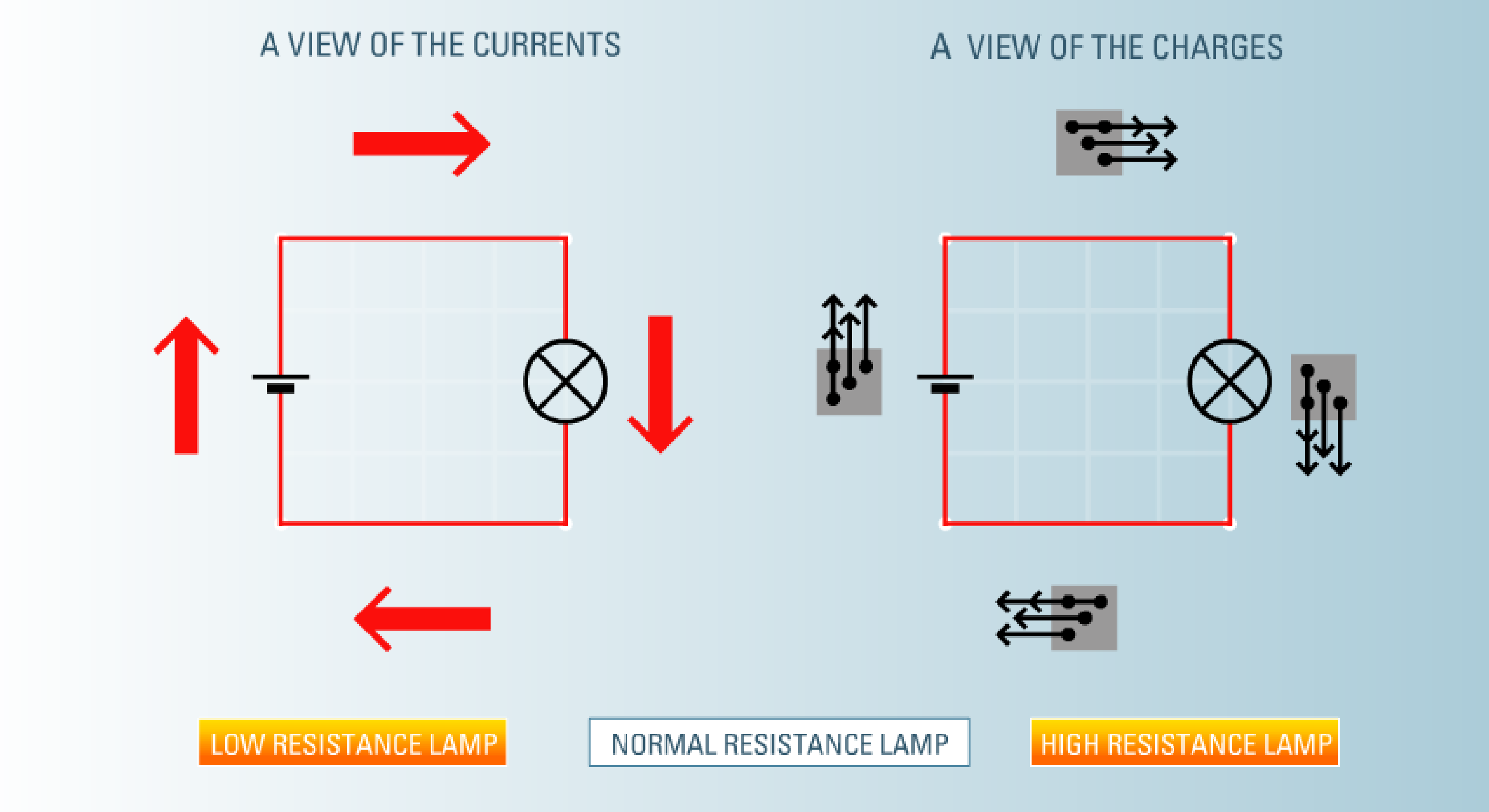
Conservation of electric currents: They really don't get used up!

We can picture a steady and continuous flow of charge around the whole circuit. The rate of flow (the current) for the whole of the circuit with a given battery is fixed by the size of the bulb's resistance. If that resistance is reduced somehow, then the flow of charge increases everywhere in the circuit. This is exactly equivalent to the current increasing in each part of the circuit.

In episode 3, we build on these ideas by considering what happens when changes are made to our simple circuit, and how we can use the electric circuit model to both predict and explain what happens.

Swapping bulbs

Use the buttons to set the resistance of the bulbs. Note the changes in current and charge flow.



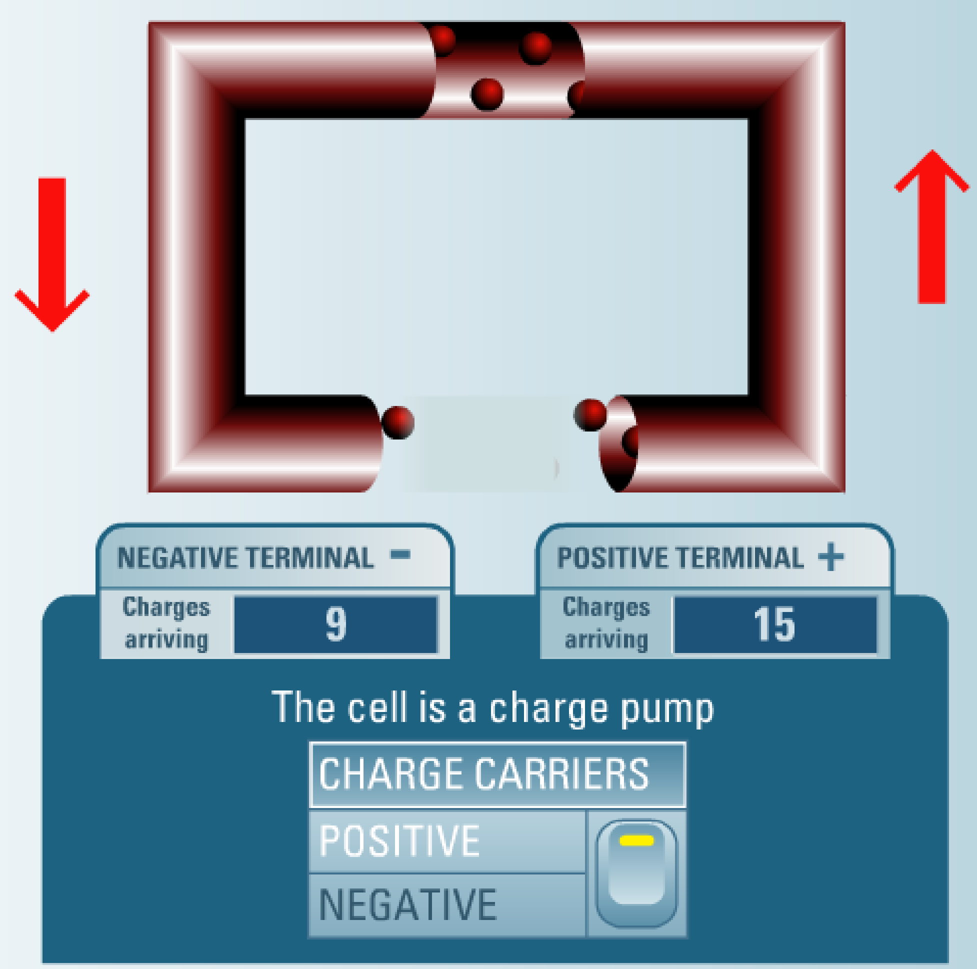
The direction of the electric current

Scientists agree to use a convention which shows the direction of the electric current in a circuit as being from the positive terminal of the battery towards the negative terminal. This is in the opposite direction to the actual flow of electrons. How did this odd state of affairs come about?

The answer is that the convention was established before it was known that electrons move through the wires of a circuit. In truth, however, the current direction convention is not important for understanding electric circuits and we shall not refer to any further it in this topic.

Flow and direction

Use the switch to alter what moves in the conductor.

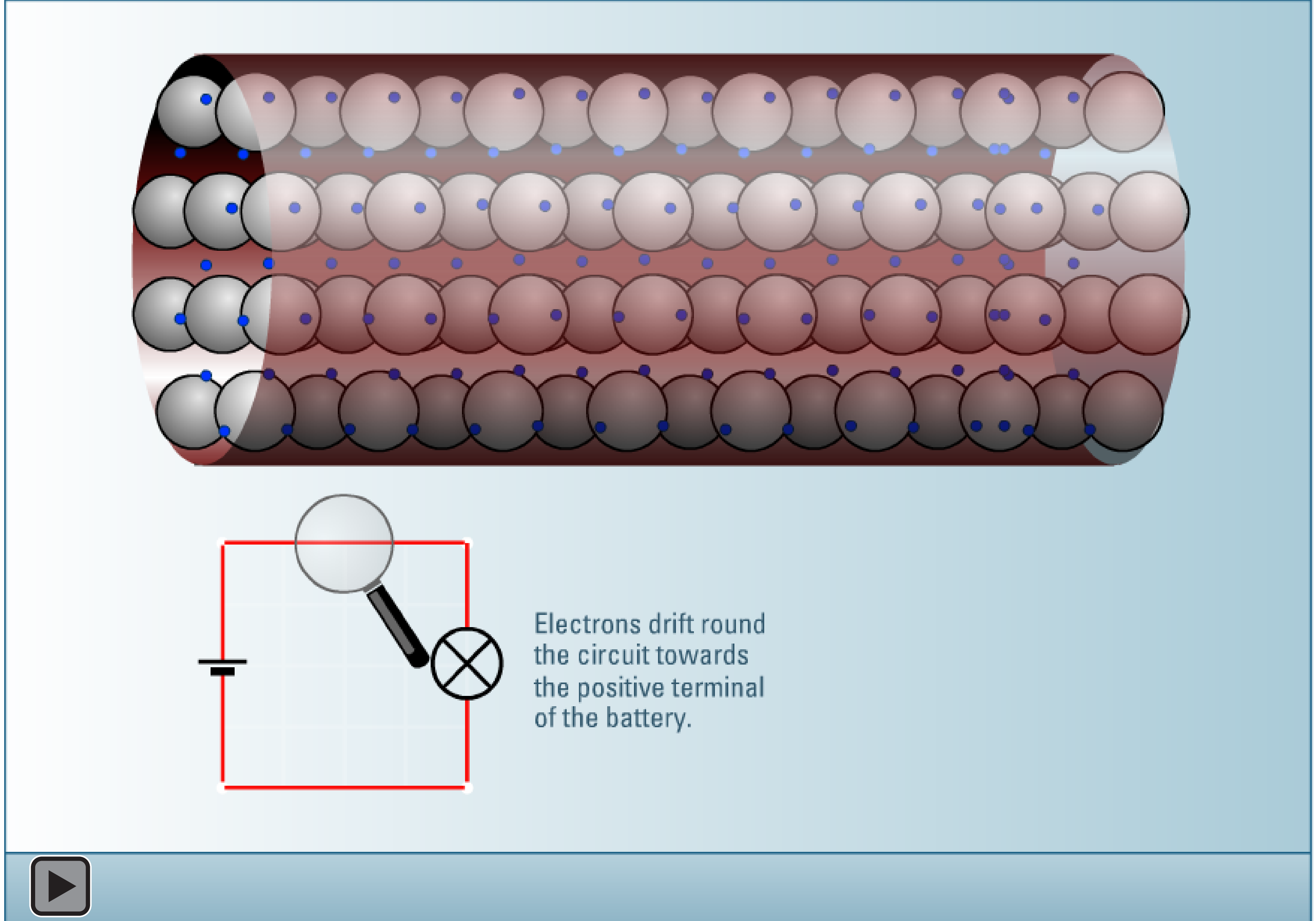


History and the electric current convention

Read more about which way the charges actually move - and find out whether it is important at this level.

In the metal conducting materials that we use to make electric circuits, it is the negative charges (the electrons) that are physically able to move around:

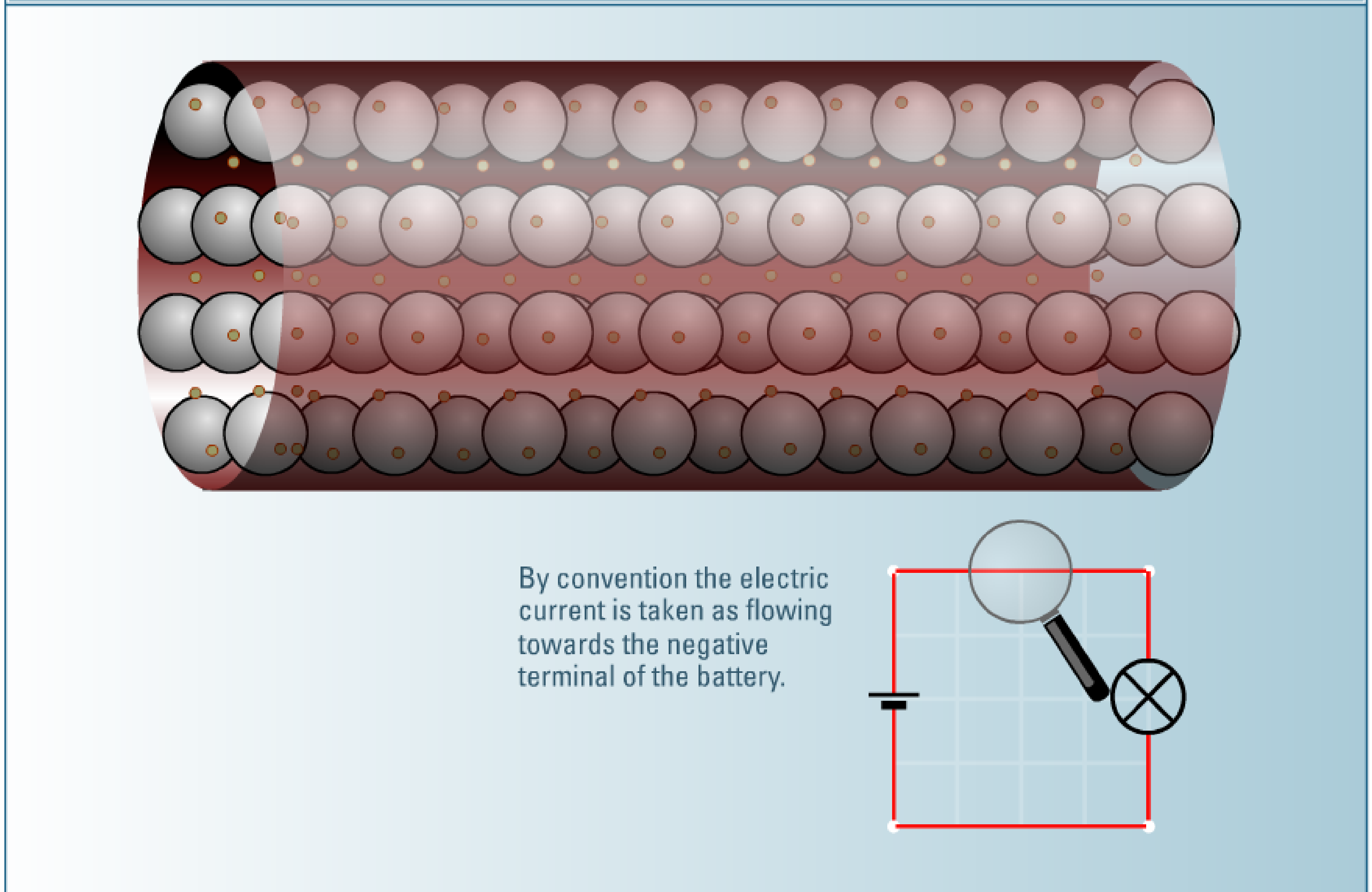
Electrons drift



History and the electric current convention

By convention, however, the electric current is taken as flowing in the opposite direction towards the negative terminal.

Conventional charges drift



History and the electric current convention

Why should it be that the conventional electric current is taken as being in the opposite direction to the motion of the electrons? The answer is that the convention arose historically.

Early experiments by William Gilbert (1544-1603), physician to Queen Elizabeth I, investigated electrical charging by friction of many substances. By comparing, for example, glass rubbed with silk and ebony rubbed with wool, Gilbert concluded that there were only two types of charge and that charges of the same kind repelled, whereas opposites attracted. He called those produced by the action of friction on fur as "positive" and those by friction on rubber as "negative".

It was noted in later experiments that when charged objects were brought into contact with the Earth through a conductor, a small charge flowed for a short time. When cells were invented, it was observed that a cell's carbon electrode behaved in a similar way to fur, and a silver electrode in a similar way to rubber. Thus, an "excess of electric fluid" (positive charge) appeared to be transferred from the positive carbon electrode (anode) to the negative silver electrode (cathode).

The idea of positively charged flow remained in favour until the work of Joseph John Thomson (1856-1940). In a study of the flow of electricity through gases, (technology used today in neon signs), Thomson isolated a beam of negatively charged particles of much smaller mass than atoms. These originated at the negative terminal (cathode) in his gas tube and Thomson realised his cathode rays were composed of negatively charged electrons. This fundamental particle, the electron, was soon associated with all atoms and shown to be responsible for both static charging and electrical currents.

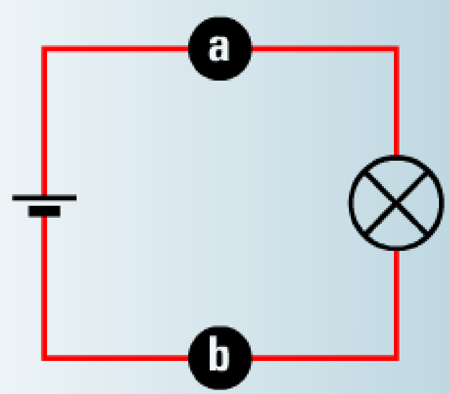
By this time, however, the convention had been established that electric current moved from the positive terminal (e.g. carbon electrode) to the negative terminal (e.g. silver electrode) of a cell. This flow of charge is a conventional current. In most wires, negative electrons flow in the opposite direction to this conventional current.

Check your progress

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

Electric current points

1. In this circuit, the bulb is lit.



a) What can you say about the electric current at points a and b? *(tick one box)*

- The electric current at **a** is bigger than at **b**
- The electric current at **b** is bigger than at **a**
- The electric current is the same size at **a** and **b**

b) How would you explain this? (tick one box)

- The current is the same all round the circuit
- Some of the current is used up by the bulb
- All of the current is used up by the bulb

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

CHECK IT