Electricity and Magnetism: Teaching Approaches 03

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This is the 'Teaching Approaches', showing selected possible activities suitable for the classroom. To develop your expertise in the episode, work with the 'Physics Narrative' and the 'Teaching and Learning Issues'. Navigate to any part of the topic using the Topic Menu, or use the tabs below to stay within this episode.

Four approaches

Adding batteries to the circuit	class practical activity	• to confirm through practical activity that when an extra battery is added to a simple electric circuit, the current around the circuit increases in value so more energy is shifted per unit time in a bulb or other device • to encourage pupils to talk and think about the electric circuit model and teaching analogies and to account for these observations
From supermarket picture to electric circuit model	teacher presentation and class discussion	• to introduce the supermarket picture teaching analogy to the pupils • to make the link from the teaching analogy to the electric circuit model
Building circuits: Adding cells in series	software activity	• to develop the pupils' understanding of series circuits
Questions to probe understanding	three diagnostic questions	• to check the pupils' understanding of ideas developed in this episode • to help identify where further teaching and learning effort may be needed

Adding batteries to the circuit

Part 1: What happens on adding a battery?

What the activity is for

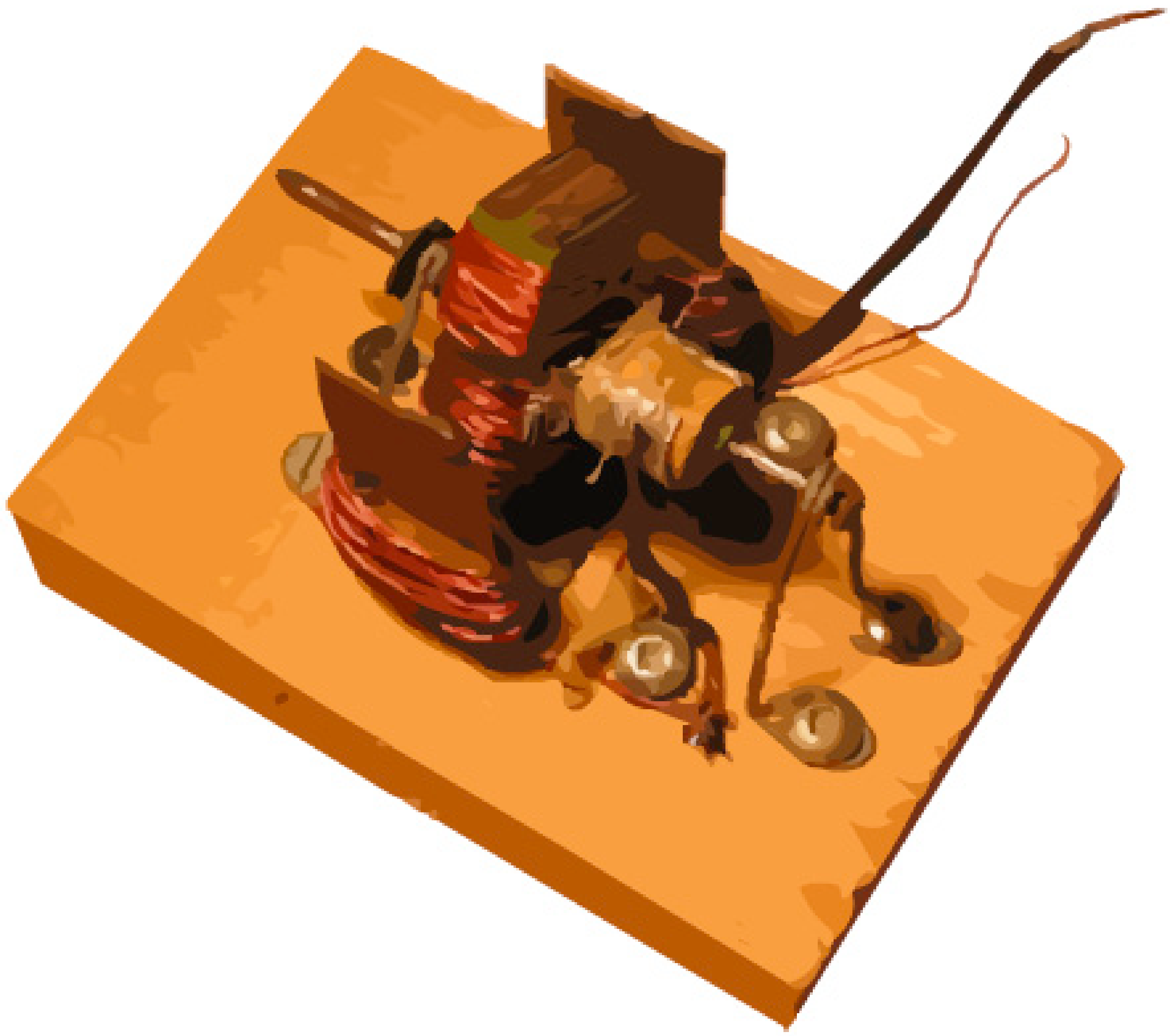
Throughout this practical activity, the pupils will establish that when an extra battery is added to a simple electric circuit, the current around the circuit increases in value and the bulb gets brighter; or the buzzer/bell sounds louder; or the motor turns more quickly.

What to prepare:

- batteries
- bulbs
- buzzers/bells/motors
- ammeters
- connecting leads
- support sheet: Adding batteries to the circuit

What happens during this activity

The pupils work in pairs to measure the current through the bulb circuit and buzzer/bell/ motor circuit with one, two and possibly three batteries and observe what happens.



Adding batteries to the circuit

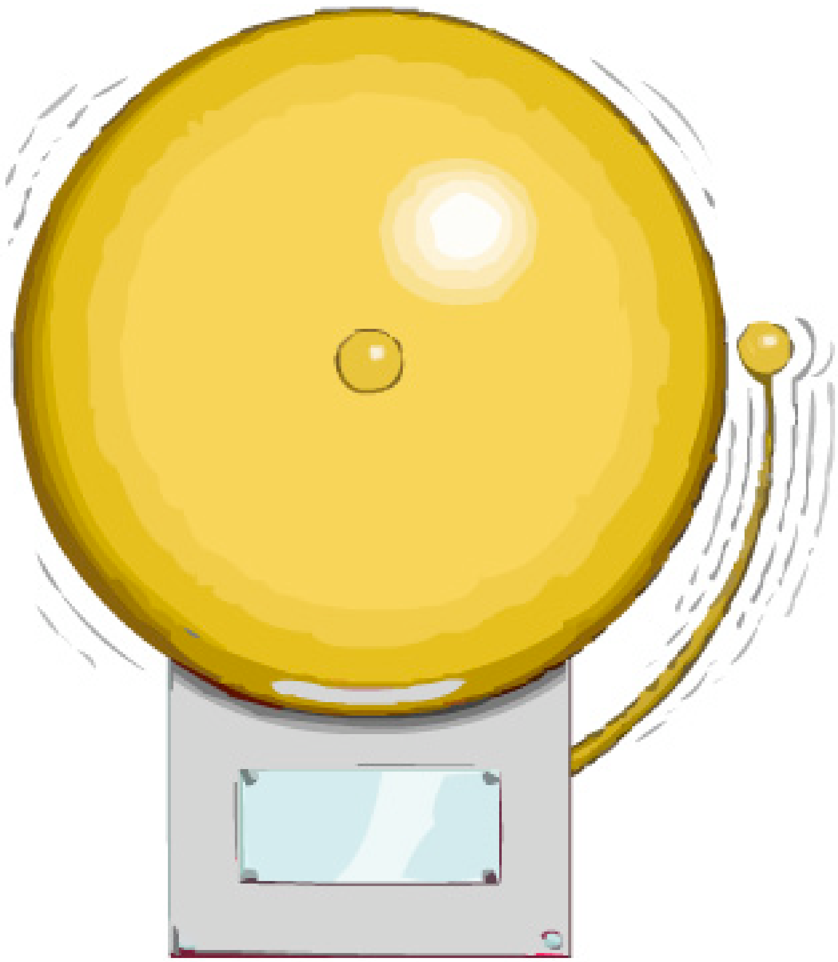
Part 2: How to explain what happens

What the activity is for

The pupils are encouraged to talk and think about the electric circuit model and a teaching analogy to account for what they have found with the various electric circuits.

What happens during this activity

The pupils work in pairs to talk through their ideas to explain why the bulb is brighter (the buzzer/bell louder) and the current is bigger when a second cell is added. Pairs then report back during class discussion.



Moving from one to two batteries

When moving from one to two batteries in a circuit, pupils often anticipate (sensibly) that the current will double in strength. What happens in practice is that the current certainly increases, but not to the extent of doubling. The reason for this is that as the current through the bulb increases, the filament heats up more and its resistance increases. The increased thermal agitation of the atoms of the filament makes it harder for the charges to pass.

From supermarket picture to electric circuit model

What the activity is for

The supermarket picture is presented as a teaching analogy, which provides a way of helping pupils develop an understanding of abstract concepts (such as energy, charge and current) by relating them directly to familiar everyday objects (such as supermarket delivery vans).

Part 1: To introduce the supermarket analogy to the pupils

What to prepare:

- supermarket picture OHT to assemble
- supermarket picture stick-in-sheet

What happens during this activity

The pupils might be asked to imagine that a new supermarket has just opened, and that it is so busy a special system of delivering bread from the nearby bakery has been set up with a chain of delivery vans. The following features should be talked through as the supermarket picture is introduced and developed:

- Individual delivery vans are loaded with bread at the bakery.
- The vans deliver the bread to the supermarket where they are sold (and dispersed to the shoppers).
- After leaving the supermarket, each empty van returns to the bakery to collect more bread.
- The chain of vans is set in motion by the bakery manager.
- As soon as the vans are set in motion, bread is delivered to the supermarket.
- All the vans move at the same speed (nose to tail).
- If the vans are sped up, more bread is delivered to the supermarket in a given time.
- If more bread is loaded onto each van, more bread is delivered to the supermarket in a given time.

These key features should be further explored through discussion. It is crucially important that the pupils understand the details of the teaching analogy. All pupils are provided with a stick-in-sheet of the supermarket picture.

Going back to a previous point, it is important to recognise that the last pair of bullets must happen together: Increasing the number of bakeries will both increase the amount of bread loaded onto each van and send the vans moving around more quickly.

From supermarket picture to electric circuit model

Part 2: To make the link between the supermarket picture to the electrical circuit model

What to prepare:

- stick-in-sheet
- support sheet: Supermarkets and electric circuits

What happens during this activity

The pupils are now invited to think back to a simple electric circuit and to suggest how the supermarket picture might be similar. First of all ask the pupils to talk with the person next to them to decide which parts of the supermarket picture link to which parts of the electric circuit model.

Take feedback and run through the key points

- The battery is an energy store (just like the bakery provides bread).
- The energy is transferred as the charges move around the circuit (just like the bread is carried around by the vans).
- The charges are part of the atoms which are already there in the wires (just like the waiting delivery vans).
- The flow of charges is called an electric current (just like the line of moving vans).
- The energy is transferred by the charges to the bulb and the charges then continue around the circuit (like the bread carried by the vans is sold in the supermarket and the vans then continue around to the bakery where they collect more bread). This idea of the charges/vans carrying something for half the circuit might be seen as a weak point of the picture: not representing the electric circuit model very well.

All pupils are provided with a stick-in-sheet of the electric circuit model.
The pupils work on these new ideas by completing (possibly for homework) the support sheet: Supermarkets and electric circuits

Models and pictures

When using the teaching analogy in class, we find it very helpful to talk about it as the supermarket picture and to avoid calling it the supermarket model. This helps distinguish between the supermarket picture (the teaching analogy) and the electric circuit model (the scientific model the pupils are beginning to understand).

Building circuits: Adding cells in series

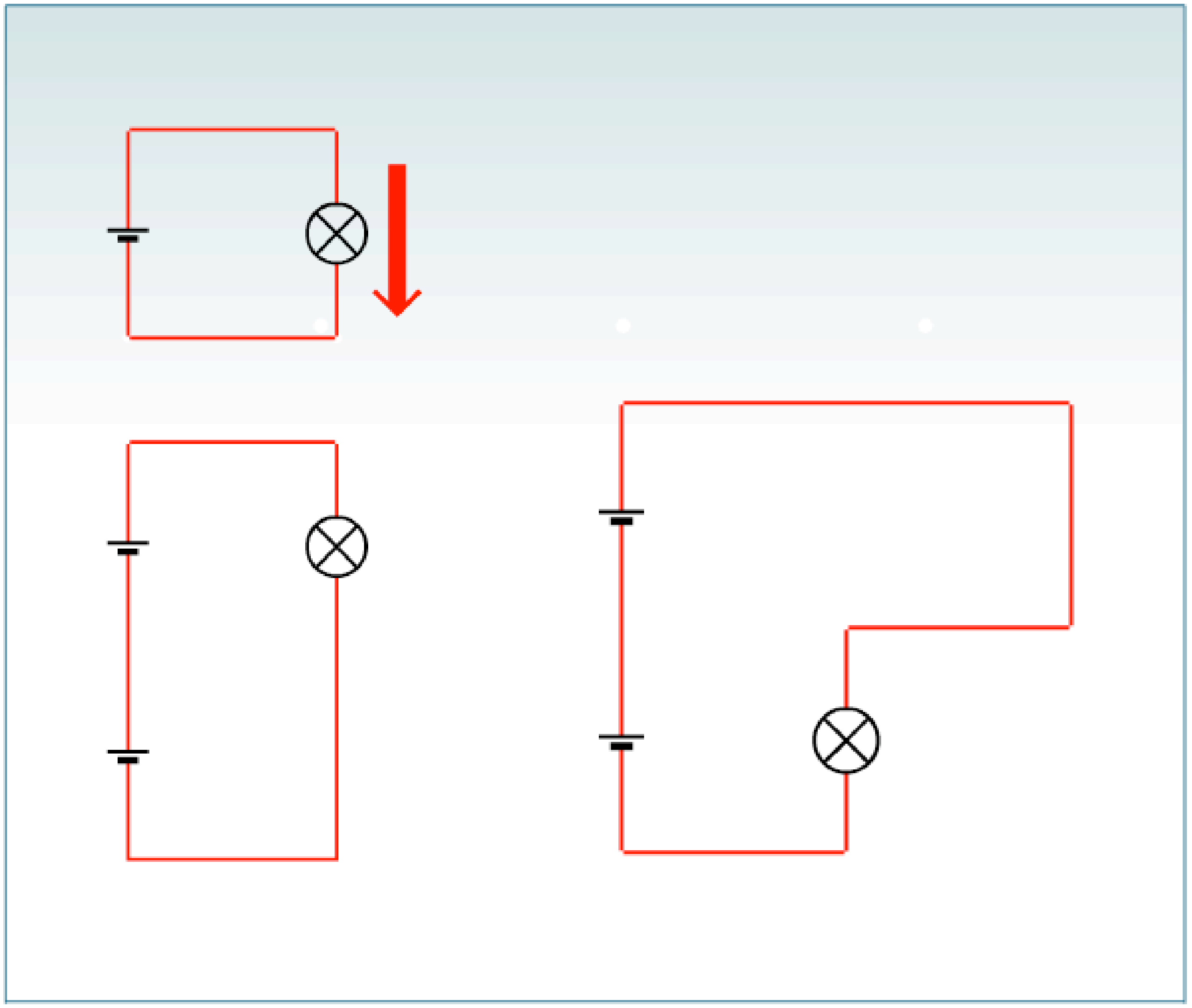
Here you will want to concentrate on the two aspects of adding cells to the circuits, as experienced by the resistive elements in the circuit:

- more current in through the components
- the energy shifted/second increases as the current increases

Other changes follow from this, and you may want to use the energy and charge flow descriptions as well, although these should not be central at this point. The whole circuit is important here, so we suggest building one or two simple ones, showing how the labels might be used, and then providing a few challenges to construct with the class as a way of fixing the behaviour of the circuit elements in their minds.

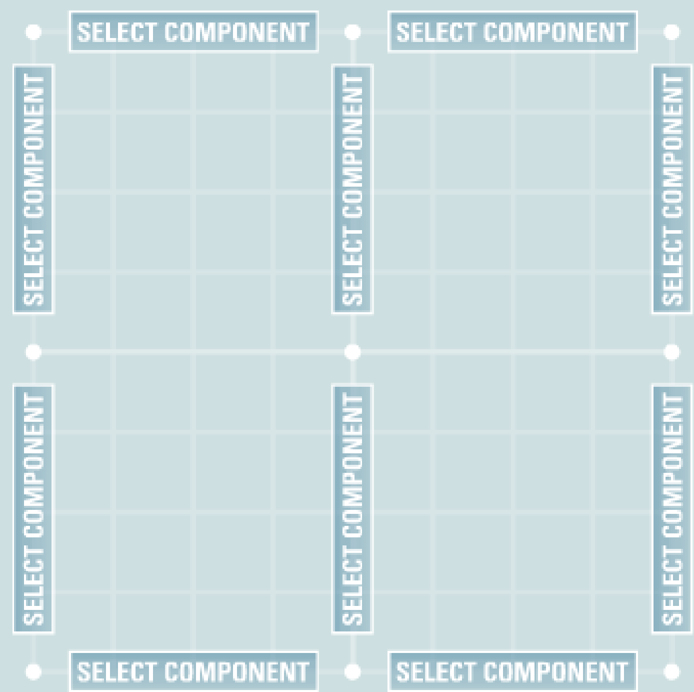
On the right are some circuits you might try.

For these circuits, we suggest that you use a mixture of current and potential difference labels, and consider the necessary changes to these labels as the number of batteries is increased.



Building circuits: Adding cells in series

Building circuits with multiple cells



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STEP 1 of 3

Questions to probe understanding

What the activity is for

The diagnostic questions can be used to check the pupils' understanding of key ideas introduced in this episode.

What to prepare:

- open and print the questions, provided as pdfs

What happens during this activity

The questions might be used for homework or as the basis for discussion in class.

Commentary and answers

Check 1: Which way around?

This question targets the point that the direction that individual cells are connected in influences their effect on the circuit. Both cells need to be pointing in the same direction to provide a greater push on the charges, and to shift more energy to the charges as they pass through the battery.

- Circuit (b) is the brightest; the batteries are pointing in the same direction.
- Circuit (c) is the dimmest; the bulb will not light at all.
- Circuits (a) and (d) are of the same brightness; in circuit (d) two of the batteries are connected in the same direction, whilst the third is facing in the opposite direction.

Check 2: Remove battery

This question probes the way in which the current changes when the number of batteries in a circuit is reduced. When one of the batteries is removed, the current through the bulb gets less (but is not zero) because one battery exerts a smaller push on the charges.

Check 3: Add battery

This question probes the way in which the bulb brightness changes when the number of batteries in a circuit is increased. When an extra battery is added the bulb gets brighter because the extra battery pushes a bigger current around the circuit, and with the extra battery more energy is shifted by the charges .

Three approaches to adding bulbs

Adding bulbs to the circuit	class practical activity	• to confirm, through practical activity, that when an extra identical bulb is added to a simple electric circuit, the current around the circuit decreases and the bulbs become equally dim • to encourage pupils to talk and think about the electric circuit model and teaching analogies, and to account for these observations
Building and describing series circuits	software based activities	• to allow pupils to show and develop their understanding of series circuits
Testing understanding: Adding lamps in series	four diagnostic questions	• to check the pupils' understanding of ideas developed in this episode • to help identify where further teaching and learning effort may be needed

Adding bulbs to the circuit

Part 1: What happens on adding a bulb?

What the activity is for

Through practical activity, the pupils establish that when an extra bulb is added to a simple electric circuit, the current around the circuit decreases in strength and the bulb gets dimmer.

What to prepare:

- batteries
- bulbs
- ammeters
- connecting leads
- support sheet: Adding bulbs to the circuit

What happens during this activity

The pupils work in pairs to measure the current through the circuit with one, two and possibly three bulbs and observe what happens.

Part 2: How to explain what happens

What the activity is for

The pupils are encouraged to talk and think about the electric circuit model and teaching analogy to account for what they have found with the various electric circuits.

What happens during this activity

The pupils first of all work in pairs to talk through their ideas to explain why the bulbs are dimmer and the current smaller when a second bulb is added. Pairs then report back in during class discussion.

Building and describing series circuits

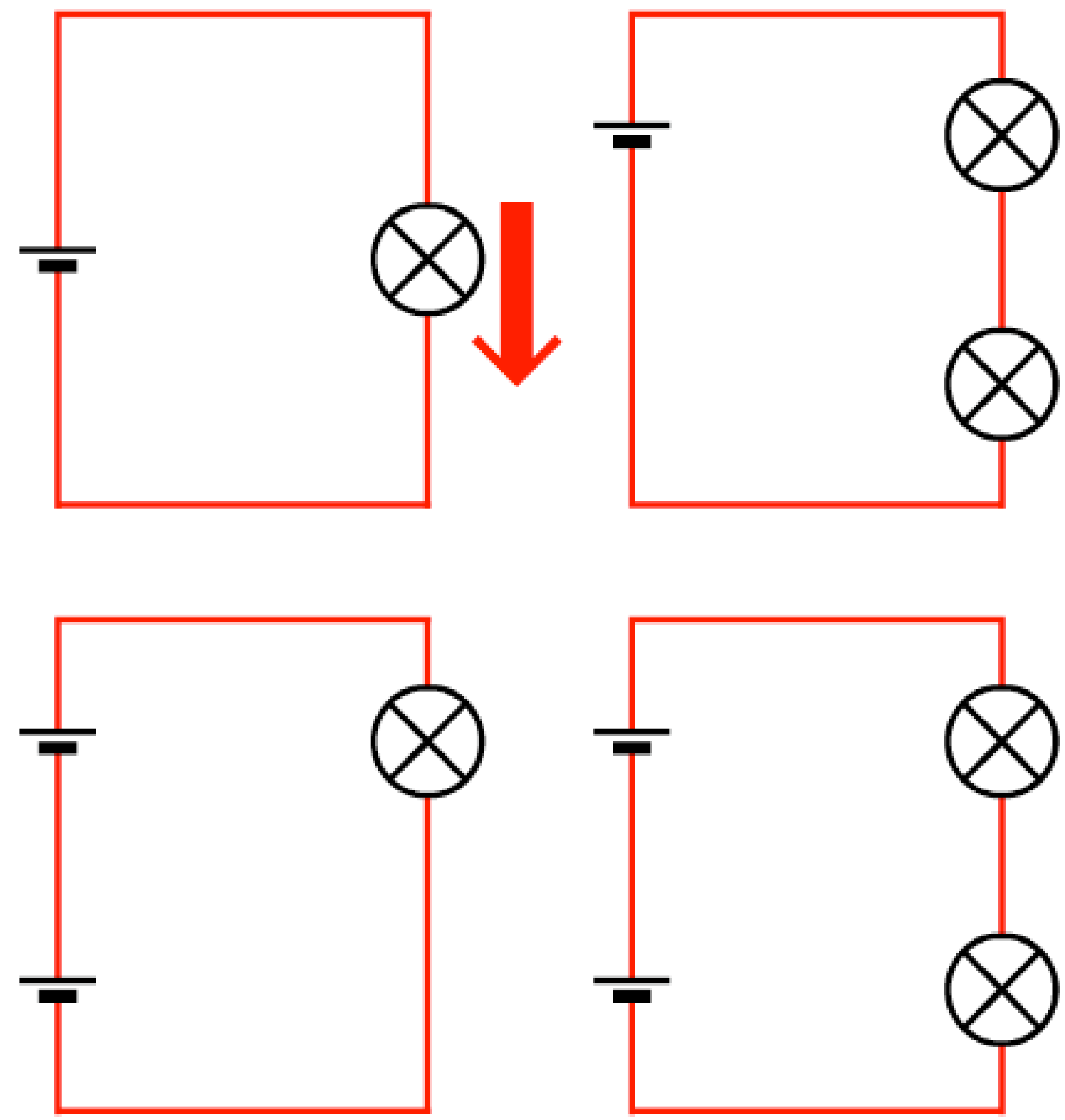
Here you will want to concentrate on what is happening in the resistive elements of the circuit when bulbs are added to the circuits:

- less current in the components
- more current in through the components.
- the energy shifted/second decreases as the current decreases

(You might want to assume that doubling the number of bulbs in the circuit halves these quantities, as a first approximation.)

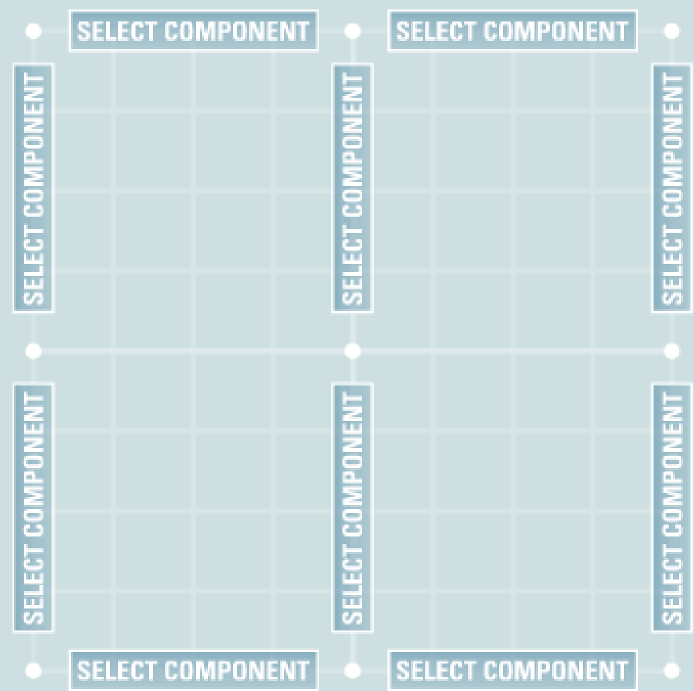
Other changes follow from this, and you may want to use the energy and charge flow descriptions as well, although these should not be central at this point. The whole circuit is important here, so we suggest building one or two simple ones, showing how the labels might be used and then providing a few challenges to construct with the class as a way of fixing the behaviour of the circuit elements in their minds.

Some circuits that you might try are shown. For these circuits, we suggest that you use a mixture of current and potential difference labels, and consider the necessary changes to these labels as the number of bulbs is increased.



Building and describing series circuits

Building circuits with multiple cells



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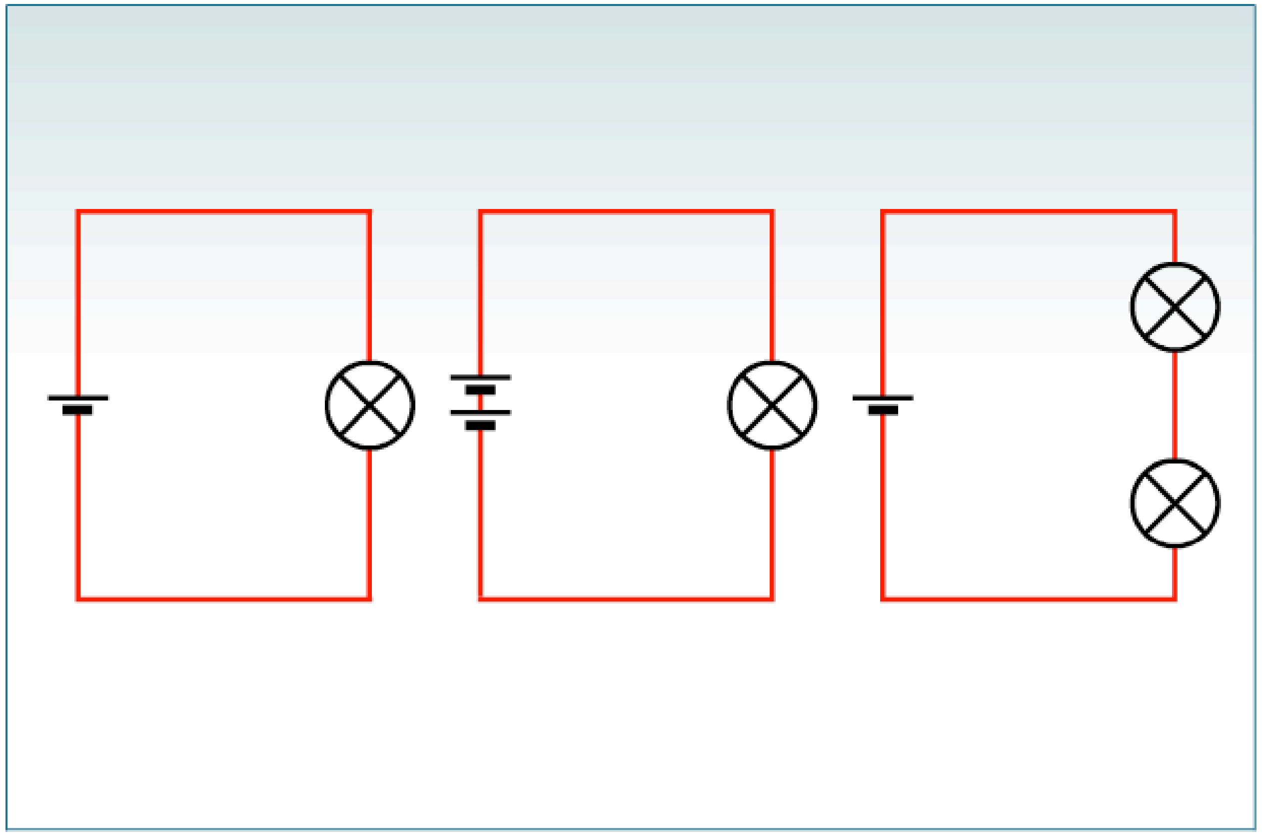
STEP 1 of 3

Building and describing series circuits

Alternatively, you might seek to reinforce knowledge about the behaviour of charge flow by, for example, setting a question similar to the following:

“How can you picture the flow of charges in all of these circuits to give a fair comparison?”



Testing understanding: Adding lamps in series

What the activity is for

The diagnostic questions can be used to check the pupils' understanding of key ideas introduced in this episode.

What to prepare:

- these four sets of questions.

What happens during this activity

The questions might be used for homework or as the basis for discussion in class.

What happens to the current?

This question probes the effect on the electric current of adding a bulb to a circuit. When the extra bulb is added:

a. The current in the circuit gets less, but not zero.
b. The battery cannot push as big a current through two bulbs.

We find that many pupils incorrectly select the fifth option to explain what happens ("the current is shared between the two bulbs, so each gets half"). While it is acceptable to say that the energy is shared, it does not make sense to say that the current is shared. This answer suggests that these pupils may not have separated in their minds the two distinct ideas of current and energy.

Both ammeters

This question probes the effect on the electric current of adding resistance to a circuit. When the large resistance is placed in the circuit:

a. The reading on ammeter A1 gets smaller.
b. The reading on ammeter A2 gets smaller.
c. This is because increasing the resistance makes the current smaller everywhere in the circuit.

Two bulbs

This question probes the effect on bulb brightness of adding a second bulb to a circuit. When the extra bulb is added:

a. Both bulbs are lit with the same brightness.
b. Energy is shared equally between the two bulbs as the charges pass around the circuit and the electric current is reduced all round the circuit.

Bright and dim

This question probes the pupils' understanding of what happens in a circuit with two non-identical bulbs when the current is reversed.

a. The bulbs are the same as before. Bulb 1 is bright. Bulb 2 is dim.
b. After turning the battery around, the current is the same (but reversed in direction) and energy is shared between the two bulbs as in the original circuit.

Some pupils may think that when the current is reversed, the brightness of the bulbs also changes over. Some pupils will be interested to talk through why bulb 1 is brighter (it must have a bigger resistance, so the rate of energy transfer is bigger in bulb 1).

Activities for parallel circuits

Understanding parallel circuits	teacher demonstration	• to talk through the idea that a parallel circuit can be thought of in terms of two loops • to establish that when a second bulb is added in parallel, the current through the battery increases • to help pupils recognise that the increased current in the battery involves energy being shifted by battery and bulbs at a greater rate
Measuring currents in a parallel circuit	class activity	• to allow pupils to build a simple parallel circuit and take current measurements at various points around the circuit • to enable pupils to strengthen their understanding of parallel circuits through practical measurements
Building and describing circuits with parallel connections	class software based activity	• to allow pupils to show and develop their understanding of parallel circuits
Testing an understanding of parallel circuits	three diagnostic questions	• to check the pupils' understanding of ideas developed in this episode • to help identify where further teaching and learning effort may be needed

Understanding parallel circuits

What the activity is for

This demonstration activity offers a way of helping pupils come to understand how parallel circuits work.

What to prepare:

- 12 volt/24 watt bulbs
- 12 volt direct current power supply
- demonstration ammeter with a large, easy to read display

Equipment tip: Using 12 volt/24 watt car headlamp bulbs, a 12 volt lab-pack supply and a demonstration analogue meter (0-5 ampere direct current) you are likely to measure currents of 1.4 ampere in each loop.

What happens during this activity

Part 1: Lighting two bulbs from one electrical supply

To start with, the teacher gathers the pupils around and, by way of review, demonstrates the familiar points that:

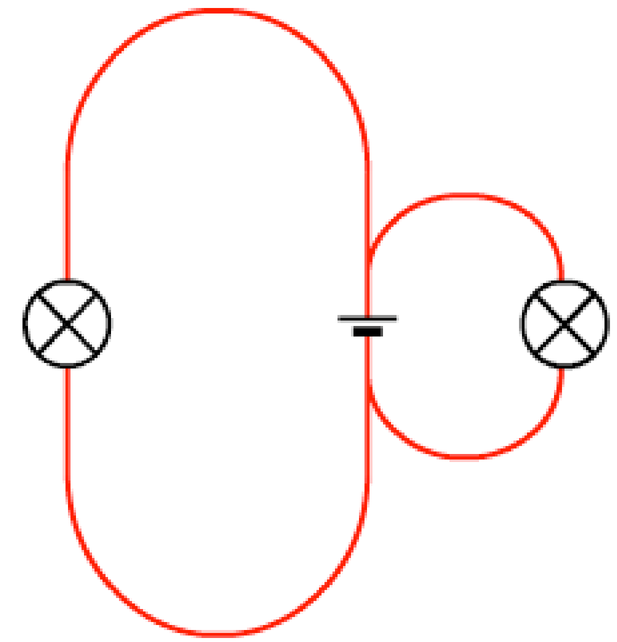
- one bulb connected to the supply is of normal brightness,

whilst

- two identical bulbs connected in series are equally dim.

Then poses the question: “How might you connect two bulbs to one supply such that both bulbs are of normal brightness?”

Pupils are likely to suggest: “Just connect up each bulb to the battery to make two circuits” (and if they don’t, you might offer: “Here’s an easy way to do it”).



Connect up the circuit and switch on. Both bulbs light to equal, normal brightness. At this point, with the bulbs there in front of the pupils’ eyes, you should draw attention to the apparently odd nature of this circuit.

Understanding parallel circuits

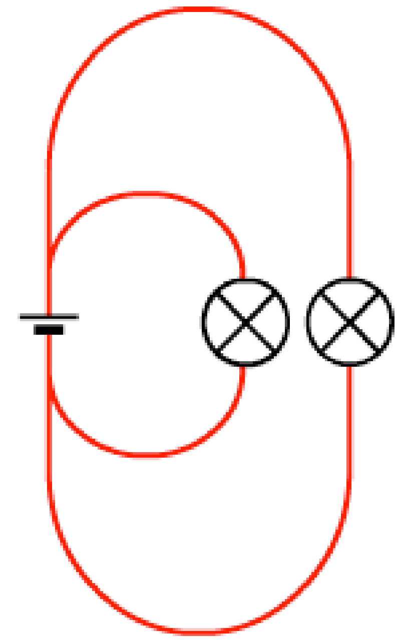
So! Both bulbs light to normal brightness. I haven't added more batteries or anything else like that and yet we get two bulbs lit, twice the energy out. How can that be? It's the Yorkshire-man's dream: Summat for nowt! What's going on here?

As a starting point to finding out what's going on, suggest measuring the currents in each of the circuit loops:

Well, let's look at the currents in each of these loops. The big loop to the left and the small loop to the right.

Part 2: Seeing parallel circuits as two loops

The next step is to re-organise the circuit so that it begins to look more like the standard parallel circuit format:



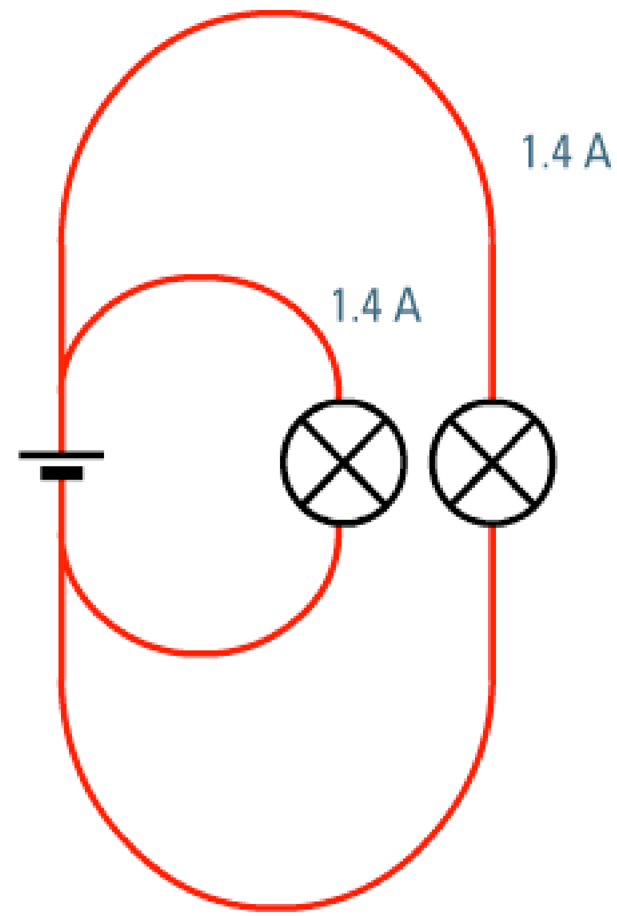
Suppose I just lift this big loop across so that it fits around the small loop.

Understanding parallel circuits

We have a current of 1.4 ampere in the small circuit coming from the supply, and 1.4 ampere in the big circuit, also coming from the supply. What, do you think, will be the total current from the supply?

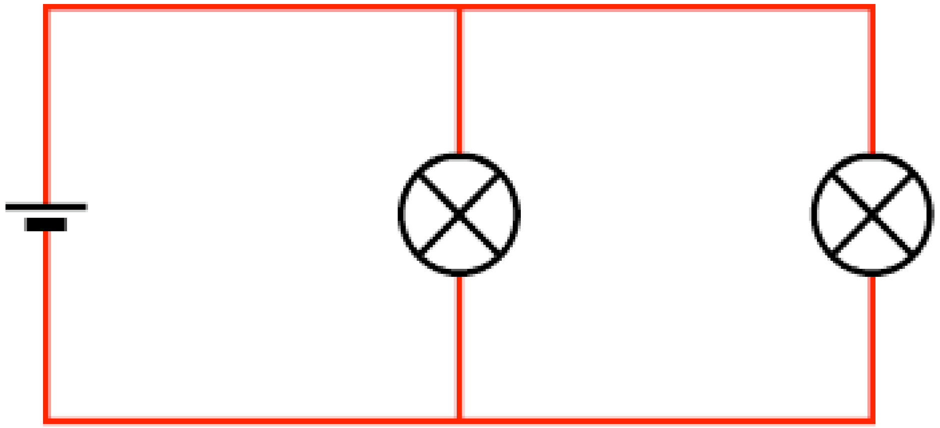
The easiest way to measure the total current through the supply is to use two additional leads, from and to the supply, and to connect these to both loops. Measure the current through each of the two leads to the supply:

So, the current from the battery here is 2.8 ampere and back to the battery here is 2.8 ampere.



Understanding parallel circuits

The demonstration circuit now looks like the standard circuit diagram format for parallel circuits:



All that remains is to piece the explanation together.

OK, so with one battery and one bulb, we can picture the charges moving through the battery around to the bulb and energy is transferred by each charge. When a second bulb is added in parallel, an extra loop is provided around which the charges move. The number of charges passing through the battery each second is therefore doubled, and the same amount of energy is transferred by each charge. So with the second loop the charges carry energy away from the battery at twice the rate and the battery will flatten more quickly.

Careful with your language!

Here it would be very easy to say “a current of 1.4 ampere flows from the supply” or “a current of 1.4 A is drawn from the supply”. Once again these words imply that the current originates in the battery. It is better to say something like: “There is a current of 1.4 ampere in the big loop and in the supply.”

Measuring currents in a parallel circuit

What the activity is for

This practical activity offers pupils the opportunity to build a simple parallel circuit and to take current measurements at various points around the circuit. The intention is to enable pupils to strengthen their understanding of how parallel circuits work.

What to prepare:

- batteries
- bulbs
- ammeters
- connecting leads

What happens during this activity

Pupils work in pairs to build a parallel circuit and to measure the current through the leads to and from the battery and through each of the bulbs.

Building and describing circuits with parallel connections

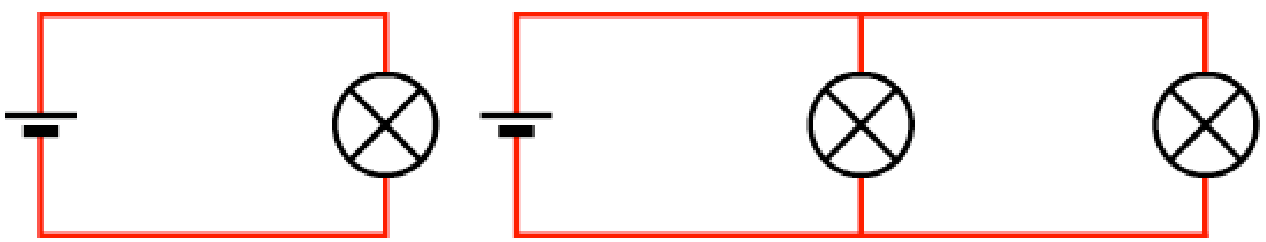
Here you will want to concentrate on the follow two aspects of adding bulbs in parallel:

- There is more current in the battery.
- The energy shifted by each bulb remains constant, so long as there is only one bulb in each loop.

(You might want to assume simple proportionalities, as a first approximation.)

Other changes follow from this, and you may want to use the energy and charge flow descriptions as well, although these should not be central at this point. The whole circuit is important here, so we suggest building one or two simple ones, showing how the labels might be used, and then providing a few challenges to construct with the class as a way of fixing the behaviour of the circuit elements in their minds.

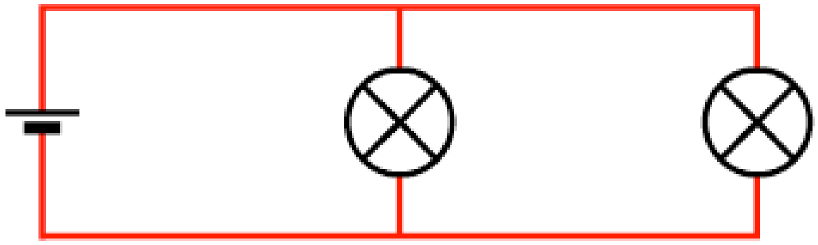
Some circuits that you might try:



For these circuits, we suggest that you use a mixture of current and potential difference labels, and compare the resultant changes to these labels as the number of loops is increased.

Alternatively you might want to set some circuits that bring together some of the challenges through this topic. For example, one could ask the pupils to build a circuit that flattens the battery twice as quickly as this one:

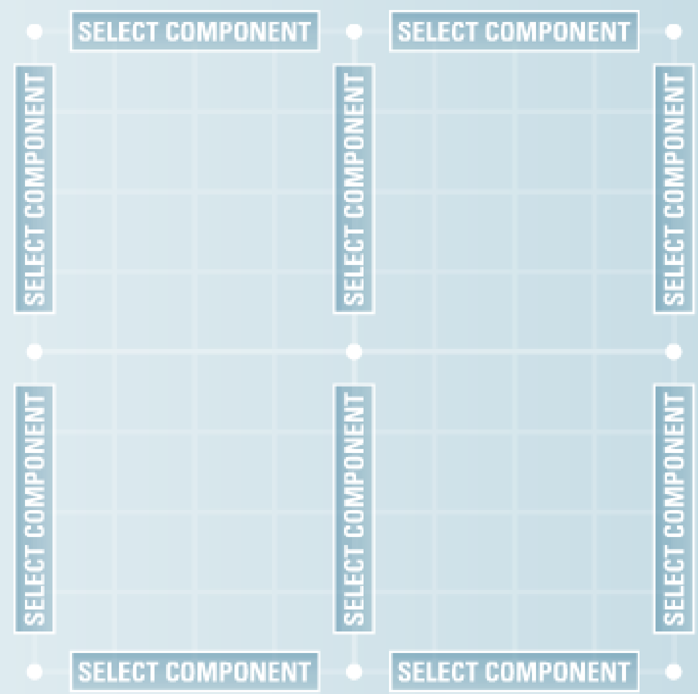
Which should yield a circuit like this:



You can then use the labels to demonstrate this as an answer.

Building and describing circuits with parallel connections

Building circuits with multiple lamps in parallel



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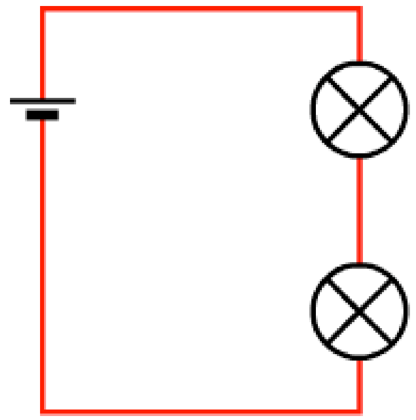
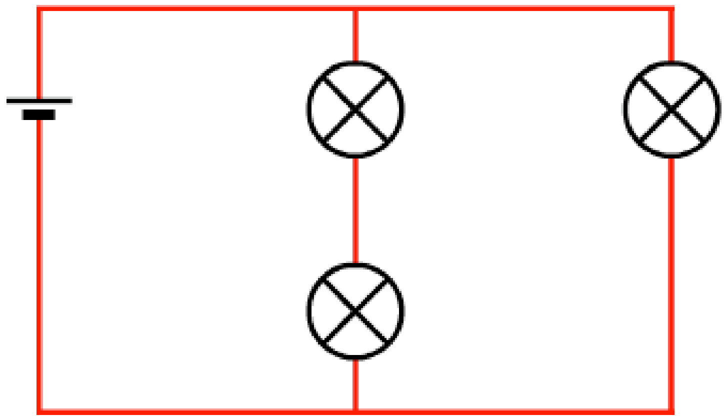
STEP 1 of 2

Building and describing circuits with parallel connections

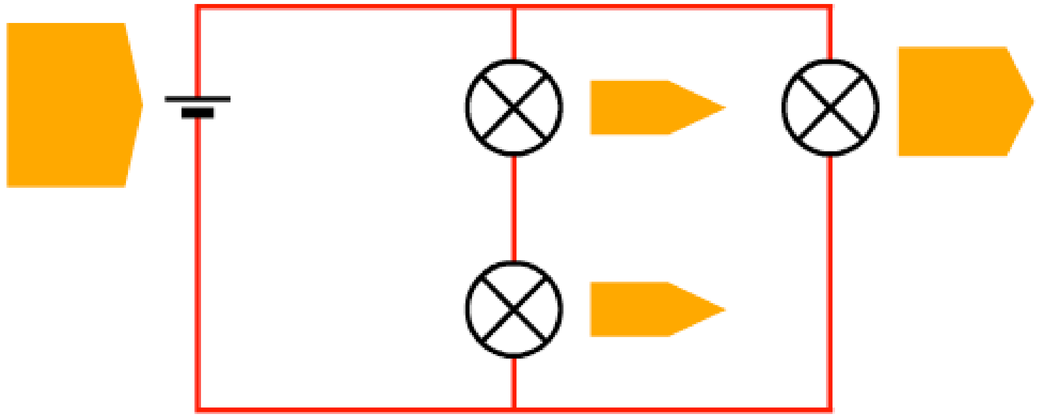
You could also ask for a circuit that flattens the battery at half the rate of the first one, giving:



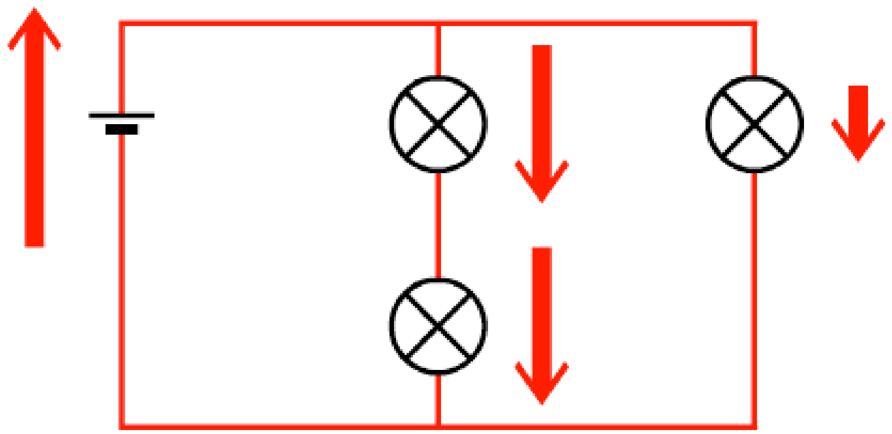
Again, use the labels to provide a set of reasons for this being a solution. Much greater complexities are possible, for example: “Build a circuit where three lamps are not all equally bright.”



To develop this: “Now add arrows to show the amounts of energy shifted by the bulbs and by the cell.”



And, even further: “Now add arrows to show how much current there is in each bulb and in the cell.”



So there are lots of possibilities for discussion foci here. You will need to choose wisely, with the abilities and interests of your class in mind.

Testing an understanding of parallel circuits

What the activity is for

The diagnostic questions can be used to check the pupils' understanding of key ideas introduced in this episode.

What to prepare:

- copies of the questions on the support sheets

What happens during this activity

The questions might be used for homework or as the basis for discussion in class.

Same circuit?

This question is designed to probe pupils' ability to recognise equivalent ways of drawing a circuit with two parallel branches. In fact, all of the circuit diagrams are correct representations.

Identical resistors

This question probes understanding about the relative sizes of the electric current at different points in a parallel circuit.

a. The current at c is the same size as the current at b.
b. The current at d is the same size as the current at b.
c. The current at a is bigger than the current at b.
d. The current at e is the same size as the current at a.

Ammeter readings

This question probes whether pupils can apply their understanding of electric current to a parallel circuit.

Circuit a: A1 = 0.3 ampere
Circuit b: A1 = 0.5 ampere A3 = 0.3 ampere