2 Energy transfer in electrical systems

KEY QUESTIONS:

- What is an electric current?
- What is an electric circuit?
- Where does the energy come from in a circuit?
- What are components?
- How do we draw electric circuits?
- What effects can an electric current produce?
- Why does the element in a light bulb glow and the element in a kettle become hot?
- What is an electromagnet and are they useful to us?
- How do you plate metal rings and earrings in gold to produce jewellery?

In the last chapter we looked at static electricity. We are now going to focus on current electricity. You will already be familiar with some of the concepts and terminology about electricity from previous grades. This year we are going to revise some of these concepts and also extend our knowledge about electricity.

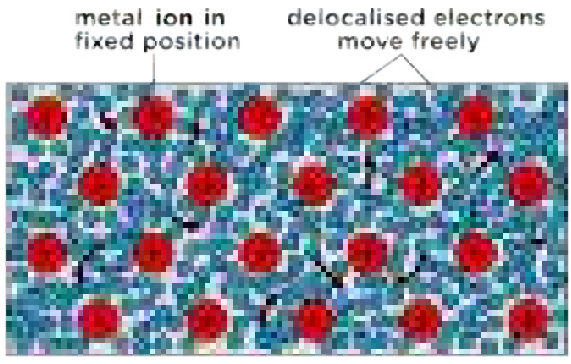
2.1 Circuits and current electricity

What is an electric current?

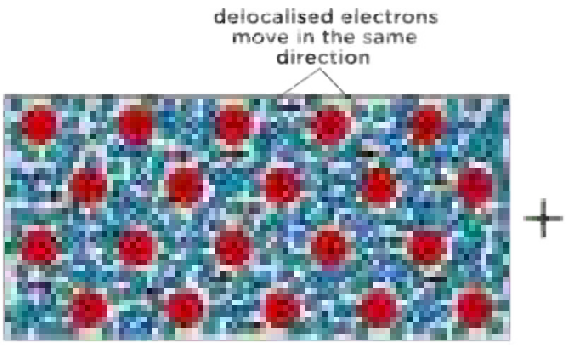
NEW WORDS

- delocalised
- component
- conductor
- electric circuit
- electric current
- qualitative
- resistor
- switch

An electric current is the movement of charge in a closed, conducting circuit. As we know from Chapter 1, and also from Matter and Materials, the electrons in an atom are arranged in the outer space around the central nucleus. We saw in the last chapter how electrons can be transferred between objects resulting in a charge on the object. In metals, the electrons are able to move freely within the metal. The electrons are not associated with a particular atom in the metal. We say electrons in a metal are **delocalised**. Have a look at the following diagram which shows this.



Conducting wire in an electric circuit is made of metal. If we supply it with a source of energy and a complete circuit, then the electrons will all move in the same general direction through the wire. This movement of electrons through a conductor is **electric current**.



TAKE NOTE

An ion is an atom that has a charge due to the loss or gain of electrons. Here the metal ions are positive as the electrons are delocalised.

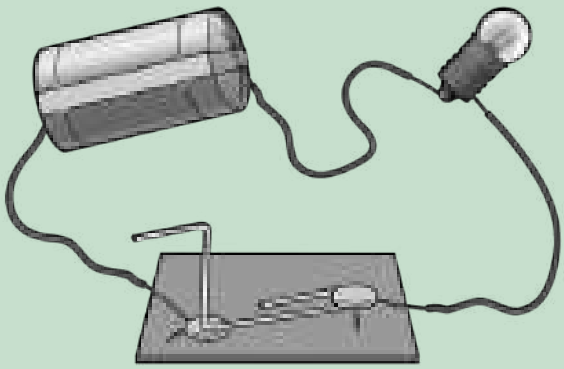
Do you remember what you learnt in Grade 6 and 7 about circuits? Let's revise briefly:

- An electric circuit needs a **source of energy** (a cell or battery).
- Cells have positive and negative terminals.
- A circuit is a **complete pathway** for electricity.
- The circuit must be **closed** in order for a device to work, such as a bulb which lights up.
- We can say that an electric circuit is a **closed system** which transfers electrical energy.
- A circuit is made up of various **components**, which we will look at in more detail.

ACTIVITY: A simple circuit

INSTRUCTIONS:

1. Look at the example of a simple circuit.
2. Answer the questions which follow.



QUESTIONS:

1. What are the parts that make up this system for transferring electrical energy?

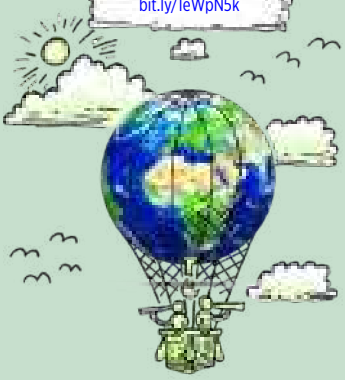
2. Do you think this is an open or closed circuit? Explain your answer.

3. Which part is providing the source of energy?

4. What is the conducting material?

VISIT

Electricity and circuits bit.ly/17ni2R4 and Revise a simple circuit. [video] bit.ly/1eWpN5k



5. What type of energy does the battery have?

6. What is this energy transferred to when the circuit is closed and the electrons **move** through the wires?

7. What is the output of this system?

8. In most systems, the input energy is more than the useful output energy as some of the input energy is transferred to wasted output energy. In this simple circuit with a light bulb, what is the wasted output energy?

NEW WORDS

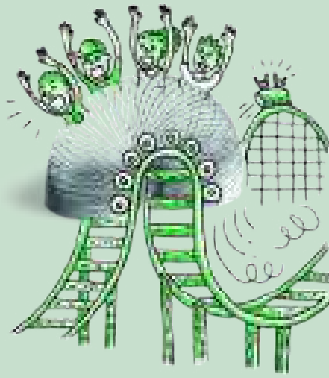
- ammeter
- cell

A complete circuit is a complete conducting pathway for electricity. It goes from one terminal of a cell along conducting material, through a device and back to the other terminal of the cell. Let's look at the components of a circuit.

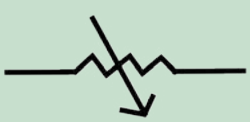
2.2 Components of a circuit

You are probably already familiar with the components of an electric circuit from previous grades. Do you remember that we have a specific way of drawing the components in a circuit in an electric circuit diagram? Each component has a different symbol.

ACTIVITY: Components in an electric circuit



Complete the following table. List the function of the component and draw the circuit symbol. The last two rows have been filled in for you as you may not yet know these symbols, but we will be using them in this chapter.

Component	Function	Symbol
Cell		
Torch bulb		
Open switch		
Closed switch		
Electrical wire		
Resistor	A component that opposes or inhibits electrical current in a circuit. It can also convert electrical energy to heat or light.	 or 
Variable resistor	A resistor whose resistance can be adjusted higher or lower.	

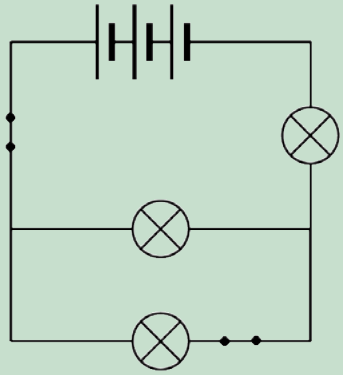
Let's now practice drawing some simple circuit diagrams. Draw the following circuit diagrams.

1. A closed circuit with one cell, two light bulbs and a switch.

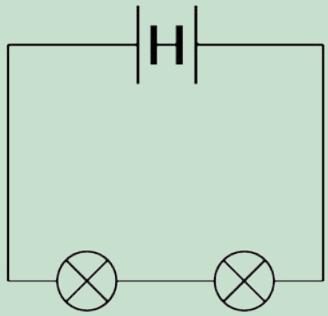
2. An open circuit with two cells, two light bulbs and a switch.

3. A closed circuit with 4 cells and one light bulb.

4. Look at the following circuit diagram. Identify the number of bulbs, switches and cells in this circuit.



5. What is wrong with the following circuit diagram? Does it represent a closed circuit? Explain your answer.



VISIT

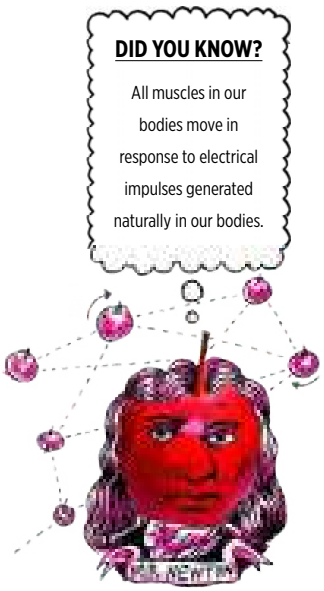
Build you own electric circuits with this simulation.

bit.ly/19eotZk

6. Why do you think it is useful to have a switch in a circuit?

7. Why are conducting wires made out of metal?

Let's take a closer look at the source of energy in electric circuits.



Cells

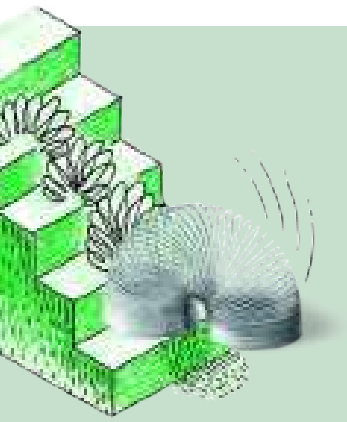
Electrical cells are the source of energy for the electric circuit. Where does that energy come from?

Inside the cell are a number of chemicals. These chemicals store **potential energy**. When a cell is in a complete circuit, the chemicals react with each other. As a result, electrons are given the potential energy they need to start moving through the circuit. When the electrons move they have both potential and kinetic energy. The **electric current** is the movement of electrons through the conducting wires.

Cells come in many different sizes. Different sized cells provide different amounts of energy to the electrical circuit. The types of cells you would use in toys, torches and other small appliances range in size from AAA, AA, C, D, and 9-volt sizes. AAA, AA, C and D cells usually have a rating of 1,5V, but the larger cells have a larger capacity. This means that the larger cells will last longer before going 'flat'. A cell goes flat when it is no longer able to supply energy through its chemical reactions.

When we buy cells in the shop they are usually referred to as batteries. This can be a bit confusing because a battery is really two or more cells connected together. So when we refer to a battery in circuit diagrams we need to draw two or more cells connected together.

Different sized batteries.



ACTIVITY: Recycling of batteries

Batteries which no longer work must not be thrown away in dustbins. They need to be recycled.

INSTRUCTIONS:

1. Work in small groups.
2. Find out why batteries should not be thrown away in normal dustbins. Write a paragraph to explain why.

3. Find out where you can recycle batteries in your community. Write down the details of the centre(s) closest to where you live.

Resistors

What are resistors? In order to work out what they are, let's first remind ourselves about conductors and insulators.

We are specifically looking at electricity so we can now talk about **electrical conductors and insulators**. An electrical conductor is a substance which allows electric charge to move through it. An insulator is a substance which does not allow electric charge to move through it.

Think back to our model of a metal wire and how the electrons are able to move through the wire. The metal wire is a conductor of electricity. Write down some materials which do not conduct electricity.

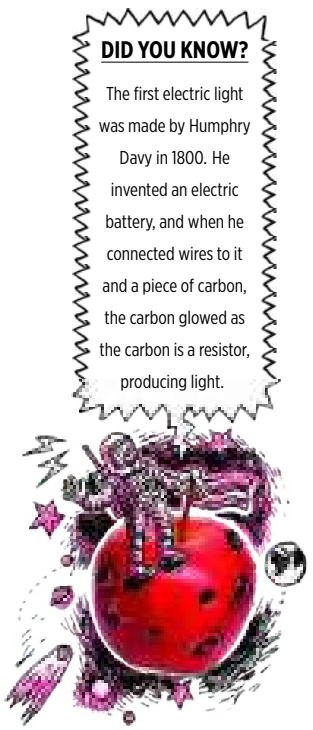
Why do you think most conducting wires are surrounded with plastic?

Resistors are a bit of both. They allow electrons to move through them, but do not make it easy. They are said to **resist** the movement of electrons. Resistors therefore influence the electric current in a circuit.

But, why would we want to resist the movement of electrons? Resistors can be extremely useful. Think about a kettle. If you look inside you will see a large metal coil.

Looking inside a kettle.

This metal coil is the heating element. If you plug in and switch on the kettle, the element heats up and heats the water. The element is a large resistor. When the electrons move through the resistor they expend a lot of energy in overcoming the resistance. This energy is transferred to the surroundings in the form of heat. This heat is useful to us as it heats our water.



A good example of where resistors are used is in light bulbs. Let's take a closer look at the different parts of a light bulb to see how it works.

ACTIVITY: Resistance in a light bulb

An incandescent light bulb.

MATERIALS:

- light bulb
- lamp

INSTRUCTIONS:

1. If you have light bulbs available, have a close look at the different parts, otherwise have a look at the photos provided here.
2. Read the information about how a light bulb works and identify the parts that have been numbered.
3. Answer the questions that follow.

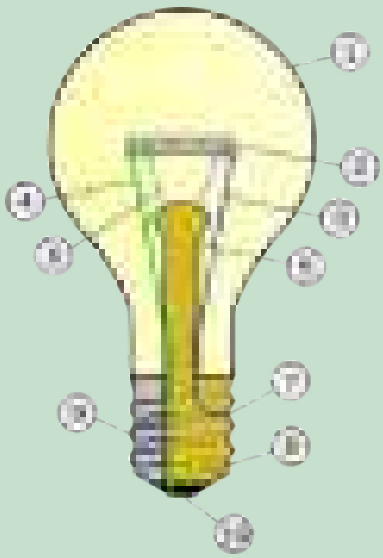


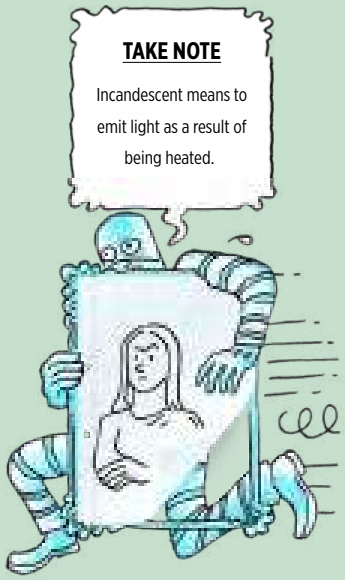
Diagram of the parts of a light bulb.

A light bulb consists of an air-tight enclosed glass case (number 1). At the base of the bulb are two metal contacts (numbers 7 and 10), which connect to the ends of an electrical circuit. The metal contacts are attached to two stiff wires, (numbers 3 and 4).

These wires are attached to a thin metal filament. Have a look at a light bulb. Can you identify the filament? This is number 2 in the diagram. The filament is made from tungsten wire. This is an element with high resistance.

QUESTIONS:

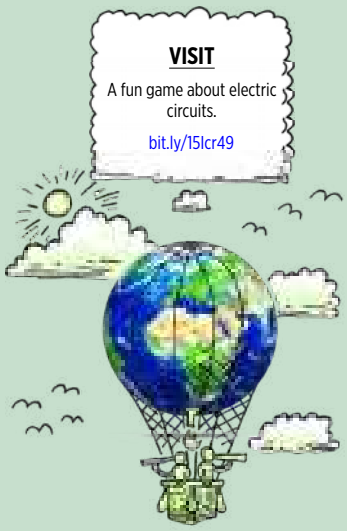
1. When the electrons move through the filament they experience high resistance. This means that they transfer a lot of their energy to the filament when they pass through. The energy is transferred to the surroundings in the form of heat and bright light. Describe the transfer of energy in this light bulb.



2. What is the useful energy output and what is the wasted energy output in this light bulb?

3. Can you see the filament is coiled? Why do you think this is so? Discuss this with your class and teacher.

4. The filament is mounted on a glass stem (number 5). There are two small support wires to hold the filament up (number 6). Why do you think the stem is made of glass?

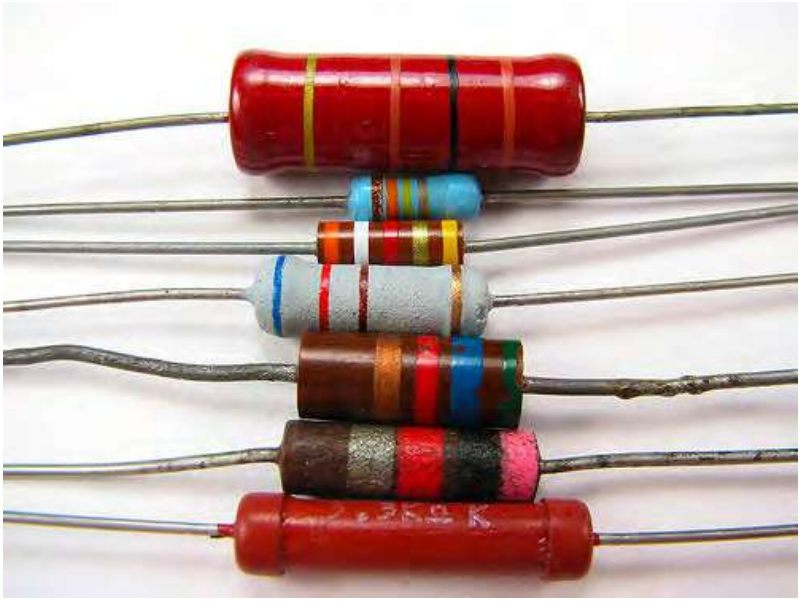


5. The inside of the base of the bulb is made from an insulating material.This is the yellow part labeled number 8. On the outside of this is a metal conducting cap to which the wire is attached at number 7. Why is the wire attached at 7 making contact with the metal conducting cap?

6. If you have a lamp in the classroom, screw the bulb into the lamp and turn it on to observe the filament glow and also getting hot.

The amount of resistance a substance offers to the circuit is measured in ohms (Ω). If we want to use resistors to control the current flow, then we need to know the amount of resistance. There are some common resistors shown in the

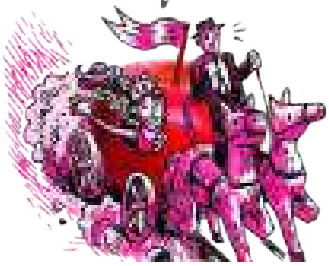
photo.



Some common resistors.

DID YOU KNOW?

The inventor, Thomas Edison, experimented with thousands of different resistor materials until he eventually found the right material so that the bulb would glow for over 1500 hours.



Can you see that there are different coloured bands on the resistors? This isn't just to make them look pleasing to the eye. The coloured bands are actually a code that tells us the resistance of the resistor. We also get resistors where we can adjust the resistance ourselves. This is called a variable resistor. You have already seen the symbol for drawing a resistor in a circuit diagram. Draw a circuit diagram in the space below with two bulbs, two cells, an open switch and a resistor.

NEW WORDS

- variable
- fuse
- electromagnet
- electric current

An electric current can have various effects. Let's find out more about what these are.

2.3 Effects of an electric current

We are going to look at the effects of an electric current, and specifically how we use these effects. An electric current can:

- generate heat in a resistor;
- generate a magnetic field; and

- cause a chemical reaction in a solution.

Heating effect

As electrons move through a resistor they encounter resistance and they transfer some of their energy to the resistor itself. We saw this in the last section where we looked at the filament in a light bulb and the element in a kettle.

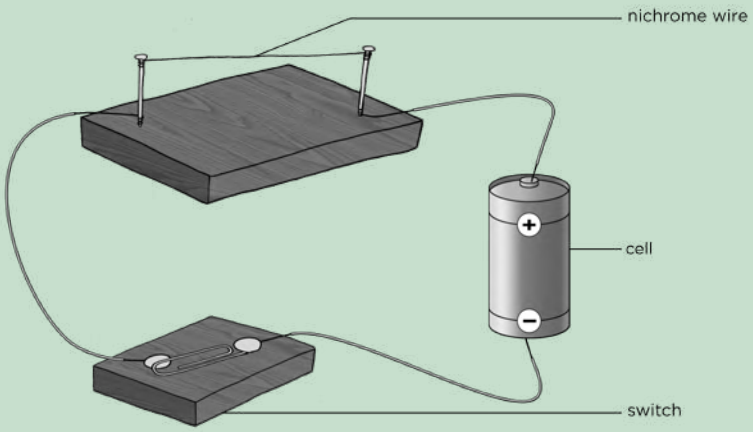
ACTIVITY: Heating a wire in a circuit

MATERIALS:

- 1,5 V cell
- conducting wires
- switch
- block of wood
- 2 nails
- hammer
- 10 cm of nichrome wire

INSTRUCTIONS:

1. Hammer the two nails into the block of wood and attach the nichrome wire between the nails.
2. Build the following circuit and keep the switch open.



3. Feel the nichrome wire. Is it hot or cold?

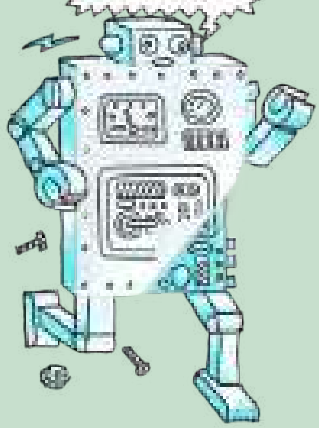
_____

4. Close the switch. Leave it on for a minute.
5. Open the switch again.
6. Feel the wire, briefly. Is it hot or cold?

_____

TAKE NOTE

You can easily make your own switch by sticking two metal drawing pins into a piece of wood with a metal paper clip in between, as shown in the diagram.



QUESTIONS:

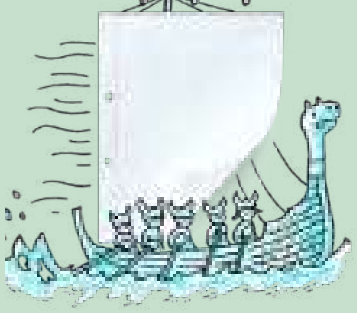
1. When you felt the nichrome wire after the circuit had been on for a while, you felt an increase in **temperature** in your skin as **thermal energy,** which was transferred from the wire to your skin. Explain the heating effect of the electric current in the resistance wire.

2. List 2 useful applications of the heating effect of an electric current.

3. Choose one of the applications you listed in question 2 and explain how the heating effect of the electric current is used.

TAKE NOTE

Remember that heat and temperature are not the same thing. Temperature is a measure of how hot or cold something is (measured in ^{o}C) whereas heat is the transfer of thermal energy from a hotter object to a colder object (measured in J).



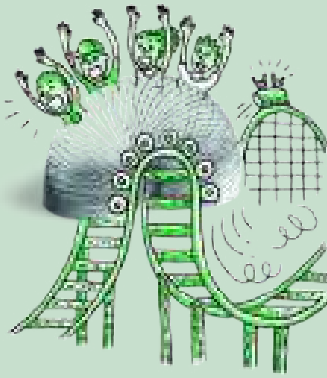
4. Look at the following photo of a toaster.

An electric toaster.

Can you see the glowing filament inside? Why does the element glow?

So now we know that an electric current can cause objects to heat up. Let's look at a useful application of the heating effect.

ACTIVITY: Melting metal

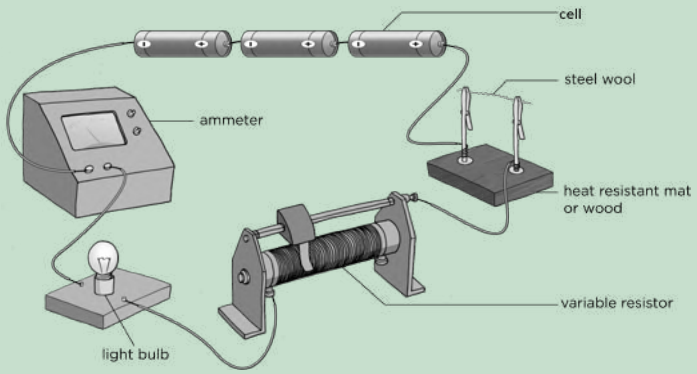


MATERIALS:

- three 1,5 V cells
- copper conducting wires with crocodile clips
- steel wool
- heat resistant mat or piece of wood
- torch light bulb
- variable resistor
- ammeter

INSTRUCTIONS

1. Set up a circuit according to the following picture.



2. Twist a few strands of steel wool into a wire.
3. Use the steel wool to complete the circuit.
4. Set the variable resistor to its highest resistance.
5. Close the switch. What do you observe?

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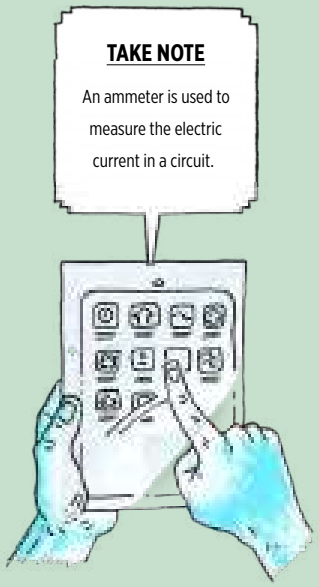
6. Take note of the reading on the ammeter which measures the current in the circuit.
7. Open the switch.
8. Set the variable resistance to its lowest resistance.
9. Close the switch. What do you observe?



QUESTIONS:

1. Draw a circuit diagram for your circuit.

This is the symbol for an ammeter.

2. Why is the light bulb included in the circuit?

3. When you decreased the resistance, what happened to the current? In other words, what happened to the reading on the ammeter?

4. What do you think happens to the electric current when the steel wool has burnt? Explain your answer.

In this activity, we just demonstrated how a **fuse** works. The steel wool acted as a fuse. When the current was too high, the steel wool melted and prevented any further current in the circuit.

What are fuses?

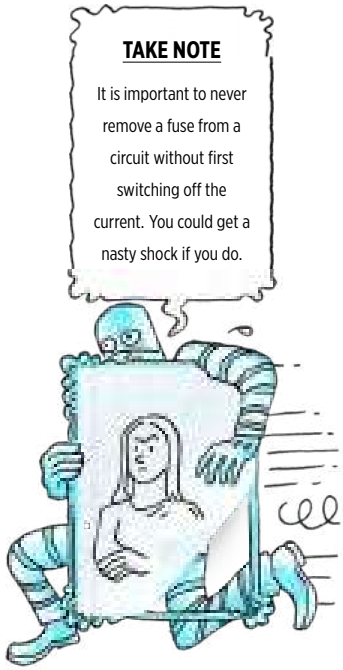
The heating effect of an electric current can be dangerous. If a circuit overheats it could cause a fire. To avoid overheating, circuits often contain a fuse. Fuses contain a low resistance wire made of a metal with a low melting point. Therefore, the piece of wire melt if it gets too hot, just like the steel wool in our activity.

An example of a fuse. Can you see the low melting point wire inside?

Different circuits need different strength currents and so we need different types of fuses. Some fuses can only handle a little bit of heat, some can handle a lot. We choose the fuse that suits the safety needs of our circuit. If the circuit overheats, the fuse will melt and break the circuit to reduce the danger of fire as well as protect electronic equipment.

How did you draw the fuse that we made using steel wool in the last activity? The conventional symbol for drawing a fuse in a circuit diagram is shown here:

A fuse.

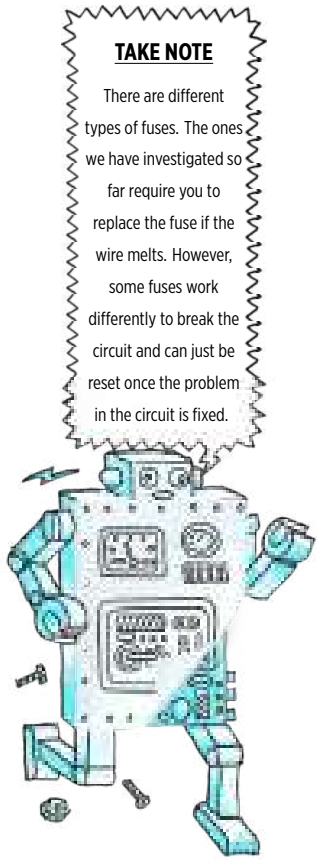


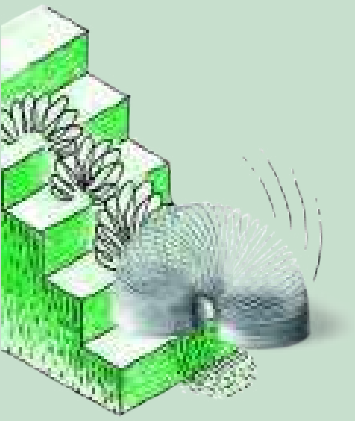
What is a short circuit?

Have you ever heard that something broke because it **short circuited**? A short circuit happens when another, easier path is accidently made in an electric circuit. What do we mean by *easier*?

We mean that the path offers very little resistance to the electric current. As there is so little resistance the current flows along the short circuit and doesn't pass through the main circuit. Short circuits can be dangerous and cause a lot of damage to appliances.

Have you ever had a piece of toast get stuck in a toaster? It's a real nuisance. Lots of people are tempted to use their butter knife to unhook the bread. Don't be tempted. Your knife is a conductor and can act as a short circuit. All the electric current will flow through your knife and, because you are touching it, through you. What would be the safe way to unhook your toast?





ACTIVITY: How are fuses used in everyday circuits?

INSTRUCTIONS:

1. Find out about common household appliances which use fuses. Choose one of these appliances on which to focus your research.
2. Write a short paragraph describing the appliance and explaining why a fuse is necessary for that appliance.

Most modern homes have **circuit breakers** instead of fuses. A circuit breaker is similar to a fuse in that it is designed to protect an electric circuit from damage, due to overload or a short circuit, by stopping the current flow. However, unlike a fuse which melts and must then be replaced, a circuit breaker can be reset to start operating again. This can be done manually or take place automatically.

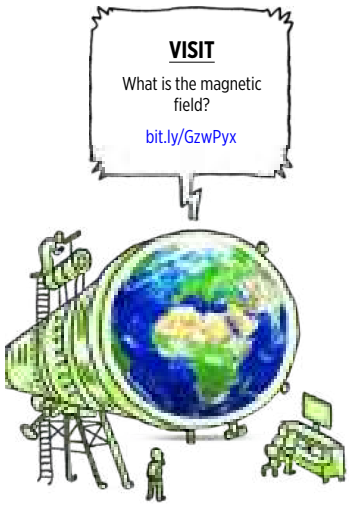
Magnetic effect

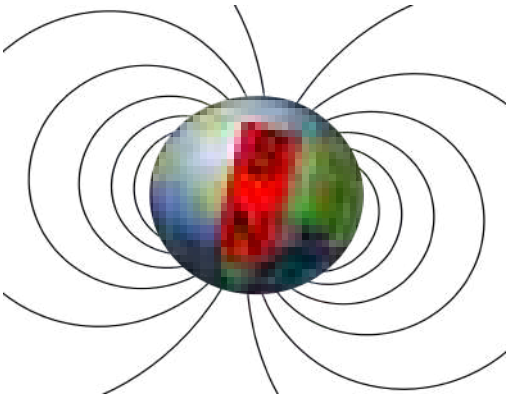
Before we look at how a current produces a magnetic field, let us first learn more about magnets. A magnet is a piece of material which produces a magnetic field. A magnet has a north pole and a south pole. Opposite poles will attract each other and the same poles will repel each other. A magnet has a magnetic field around it.

A bar magnet.

Did you know that the Earth is like a bar magnet with a North and a South Pole?

The Earth has a magnetic field. This is why we can use compasses to tell direction. A plotting compass has a needle with a small magnet. The needle points to magnetic north because the small magnet is attracted to the opposite magnetic pole and can be used to determine direction.





Earth has a magnetic field, as though there is a big bar magnet running through the core, with its South Pole under Earth's magnetic North pole.

A compass with the needle pointing North.

ACTIVITY: Playing with plotting compasses and magnets

MATERIALS:

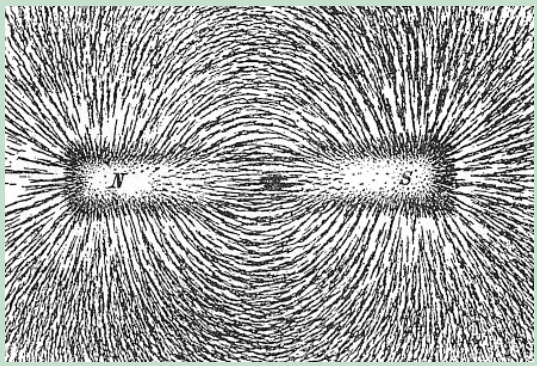
- plotting compasses
- bar magnets
- piece of white paper
- iron filings

INSTRUCTIONS:

1. Hold the plotting compass in your hand. The north end of the needle should point to magnetic north.
2. Put the bar magnet flat on the desk. Make sure you know which end is north and which is south. If you are not sure, ask your teacher.
3. Put plotting compasses in a circle around the bar magnet.

Draw what you see.

4. Next, place a white sheet of paper over the bar magnet and sprinkle iron filings over the sheet of paper over the magnet.
Observe what happens to the iron filings. Did you see something similar to what is shown in the photograph below? Describe what you see.



Iron filings on a piece of paper over a bar magnet.

So now we know that there is a magnetic field around a magnet and that plotting compasses and iron filings can be used to visualise that field. Is there anything else that has a magnetic field around it?

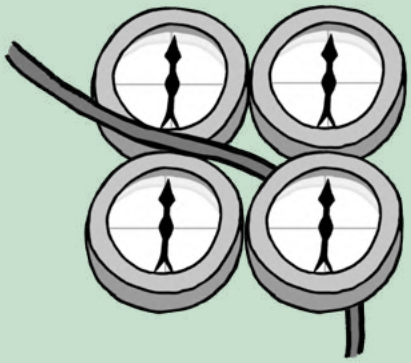
ACTIVITY: Magnetic field around a conductor

MATERIALS:

- plotting compasses
- three 1,5 V cells
- insulated copper conducting wires
- switch

INSTRUCTIONS:

1. Construct a circuit which contains the batteries, copper wires and the switch.
2. Put the plotting compasses on either side of the conducting wire as shown in the diagram, as well as below and above the conducting wire.



Plotting compasses placed around a conducting wire.

3. Keep the switch open. What do you notice about the needles of the plotting compasses?

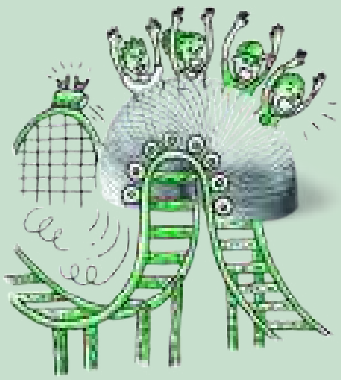
_____

4. Close the switch and observe what happens to the needles.
5. Draw a picture of the wire and plotting compasses in the space below:
6. What does the pattern of the compasses tell us?

_____

We saw from our first activity that plotting compasses react to magnetic fields. The plotting compasses changed direction when the current was switched on. This means there is a magnetic field around the wire. Was it there when the current was switched off? No, it was not. That means that the presence of the electric current in the wire must have produced a magnetic field.

The magnetic effect of an electric current has many useful applications.



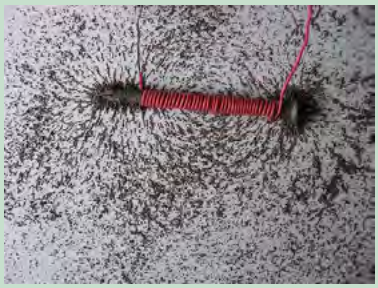
ACTIVITY: Making an electromagnet

MATERIALS:

- one iron nail (approximately 15 cm long)
- 3 metres of 22 gauge insulated copper wire
- two D cell batteries
- paper clips
- iron filings

INSTRUCTIONS:

1. Wrap the insulated copper wire tightly around the nail. Make sure that you wrap the wire in the same direction.
2. Strip some of the insulation off each end of the insulated copper wire.
3. Attach the ends of the insulated copper wire to the terminals of the battery.
4. Hold the wrapped nail above the paper clips.
5. Disconnect the wire from the battery.
6. Hold the wrapped nail above the paper clips.
7. If you have iron filings, place some on a piece of paper around the electromagnet you have made and observe the magnetic field.



The magnetic field around an electromagnet.

QUESTIONS:

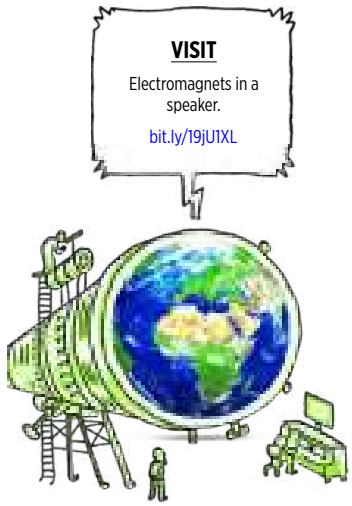
1. What happened when you held the nail over the paper clips?

2. Why were the paper clips attracted to the nail?

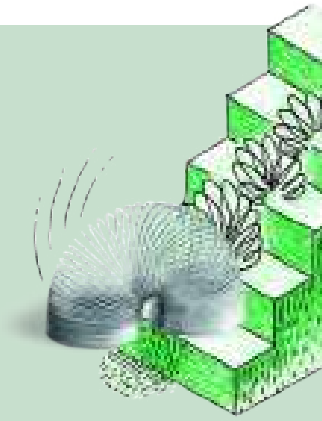
3. Did the disconnected nail attract the paper clips? Why?

Electromagnets can be used in all sorts of practical applications, including speaker and electric bells, as you can see in the photo.

An electromagnet in a bell.



ACTIVITY: Research the use of electromagnets



INSTRUCTIONS:

1. Work in groups of 2 or 3.
2. Research one of the following applications of the magnetic effect of an electric current to explain how the device works:
   a) speakers
   b) electric bells
   c) telephones
   d) magnetic trains
   e) industrial lifters and separators
3. Write a short paragraph showing what you've learnt. Remember to note down from where you got your information.
4. Share your paragraph with the rest of the class.

Chemical effect

The last effect of an electric current that we are going to look at is how an electric current can cause a chemical reaction in a solution.

ACTIVITY: Electrolysis

You might already have done this activity in Matter and Materials when we investigated the decomposition of copper chloride. We are going to perform it again, this time focussing on the effects of an electric current.

MATERIALS

- 250 ml beaker
- 2 carbon electrodes
- sandpaper
- 3 copper conducting wires (with crocodile clips)
- copper chloride solution
- torch bulb
- power pack

INSTRUCTIONS

1. Sand down the electrodes with the sandpaper to make sure they are clean.
2. Connect the conducting wire from one electrode to the torch bulb and another wire from the torch bulb to the negative terminal of the power source.
3. Connect the crocodile clip from the second electrode to the positive terminal of the power source.
4. Pour 100 ml copper chloride solution into the beaker.
5. Put the electrodes into the beaker. Make sure that they do not touch each other.
6. Look at the electrodes. What do you observe?

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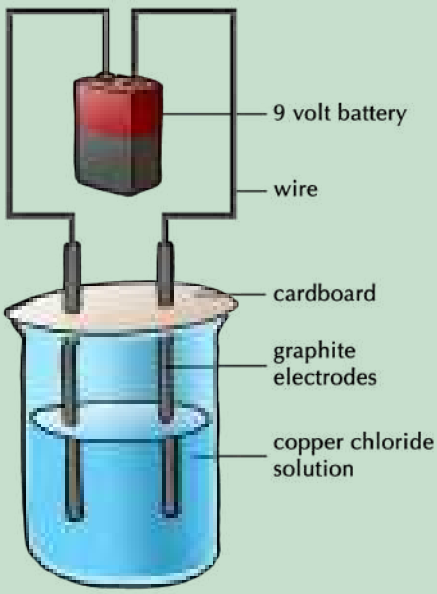
7. Turn on the power source. Leave it on for a few minutes.



The setup might look something like this, which you have seen before. You might also have a light bulb connected in the circuit.

QUESTIONS

1. When you switch on the power source, does the torch bulb glow?

2. What do you observe happening at the two different electrodes?

3. Can you smell anything? What do you think this is?

4. What is happening to the copper chloride solution when the electric current is passed through it?

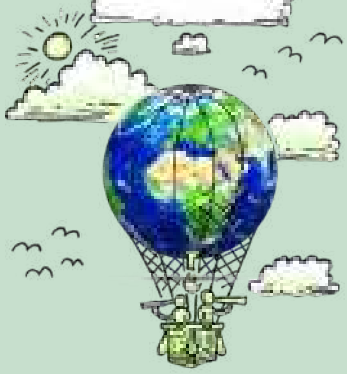
5. If you switch off the power source, what happens?

6. What is causing the separation of the copper chloride?

7. Why is it important that you do not let the carbon electrodes touch each other while the current is flowing?

VISIT

Learn more about silver refining through electrolysis. bit.ly/1fZQ5SW and the process of electroplating (video) bit.ly/GzH851



NEW WORDS

- electrolysis
- electrodes
- electroplating

The separation of the copper chloride means that an electric current can cause chemical reactions to occur. There are many ways in which we can harness this chemical effect for practical uses.

Electrolysis is the breaking down of a substance into its component elements by passing an electric current through a liquid or solution. We can also use electrolysis to purify substances.

Impure copper can be purified using electrolysis. Instead of using carbon electrodes in a copper sulphate solution we can use copper electrodes. If one of the copper electrodes is pure copper and the other is impure copper, then the impure electrode will break down and deposit pure copper on to the already pure copper electrode.

One of the most important uses of electrolysis is **electroplating**.

Electrolysis is used to electroplate metals. In the last activity, one of the carbon electrodes was coated with an even layer of pure copper. We say that the carbon electrode was electroplated with copper.

Why do we electroplate? An example is in the making of jewellery where an inexpensive metal is made into a ring, for example, and then coated with gold by electroplating. This makes it less expensive than if it were made from pure gold. Iron rusts easily and so it is useful to coat it with a layer of a zinc to protect it from corrosion. Many car parts, bathroom taps and wheel rims are electroplated with chromium.

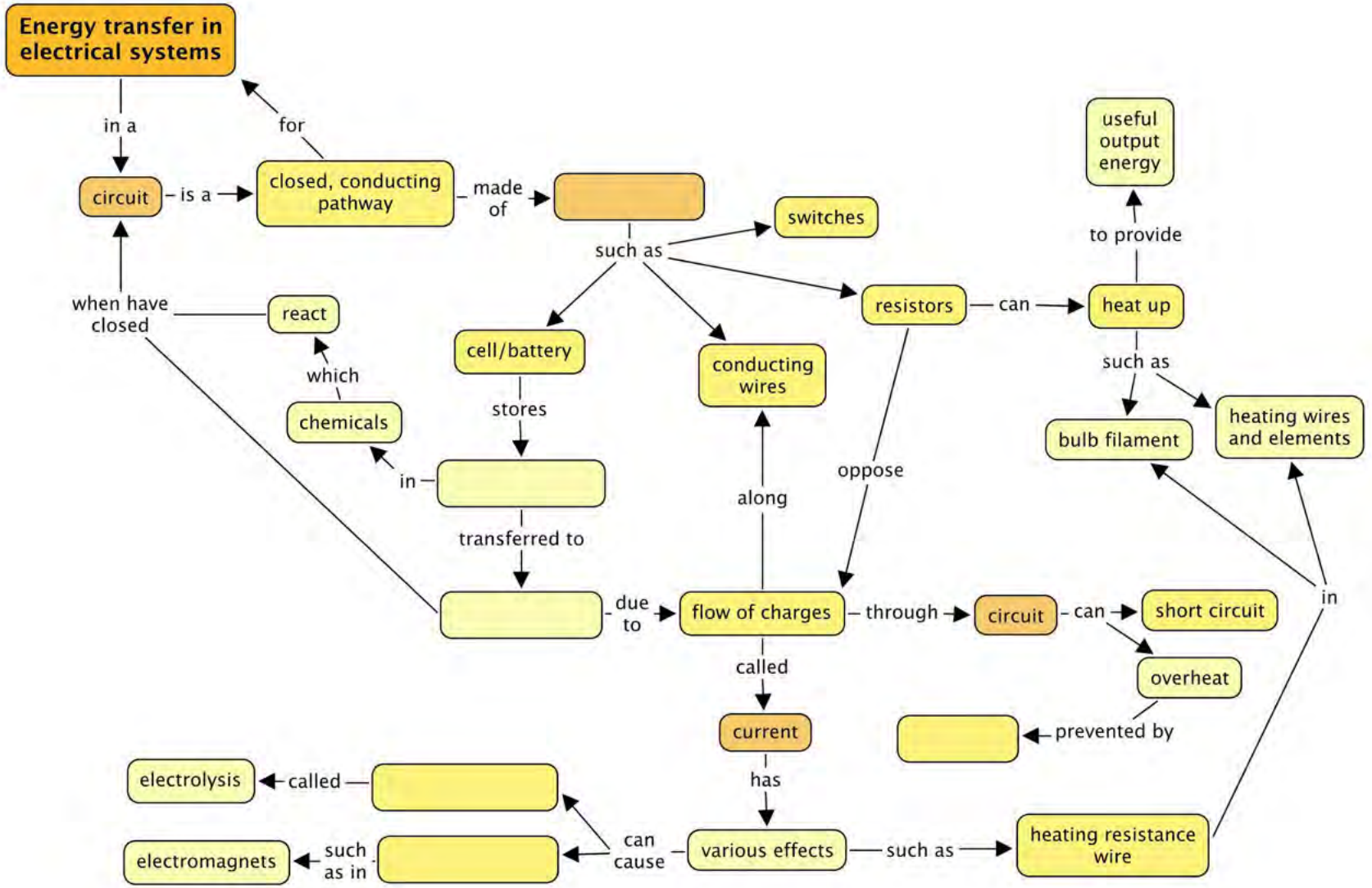
SUMMARY:

Key Concepts

- A circuit is a system for transferring electrical energy.
- For a circuit to function there must be a complete, unbroken pathway for the electrons to follow, a source of energy (cell or cells) and a load (lightbulb or any other resistor).
- We use symbols to represent components of an electric circuit so that everyone can interpret the diagrams.
- A resistor is a component in a circuit which resists the movement of electrons through the circuit.
- An electric current can heat a resistance wire. This heating effect is used in many everyday appliances, such as kettles and irons.
- An electric current causes a magnetic field. This magnetic effect is used in electromagnets.
- An electric current can cause a chemical reaction in solutions. This is called electrolysis, and is used to electroplate objects.

Concept Map

Complete the concept map to summarise what you have learned about electric circuits and the effects of an electric current in this chapter.


Energy transfer in electrical systems
in a
for
circuit
is a
closed, conducting pathway
made of
such as
switches
useful output energy
to provide
resistors
can
heat up
when have closed
react
which
chemicals
in
cell/battery
stores
conducting wires
such as
bulb filament
heating wires and elements
transferred to
along
oppose
due to
flow of charges
through
circuit
can
short circuit
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such as in
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various effects
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heating resistance wire
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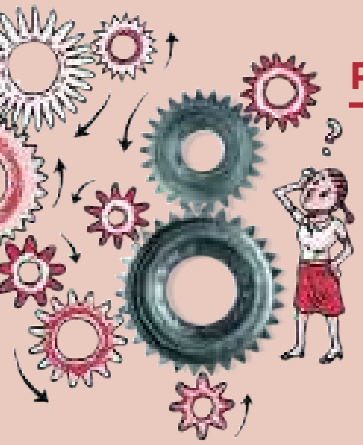


REVISION:

1. Write your own definition for an electric circuit. [2 marks]

2. What type of energy does a battery have? [1 mark]

3. When a battery is connected to a circuit, it causes an electric current in the circuit. Explain what an electric current is and why it is possible in metals. Use the word 'delocalised' in your explanation. [3 marks]

4. List 3 materials which conduct electricity. [3 marks]

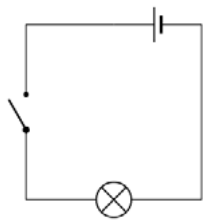
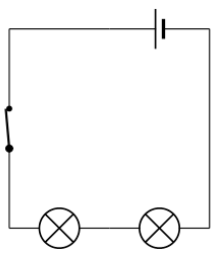
5. List 3 materials that do not conduct electricity. [3 marks]

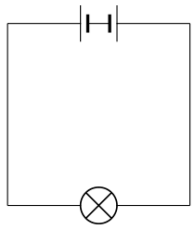
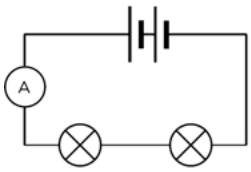
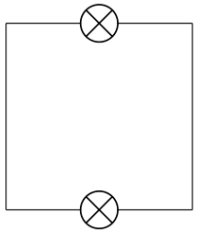
6. You have a battery, insulated copper conducting wires and a light bulb. Draw a setup which would allow you to test whether the materials you listed in questions 1 and 2 are conductors or not. [4 marks]

7. Draw the symbols for the following components. [6 marks]

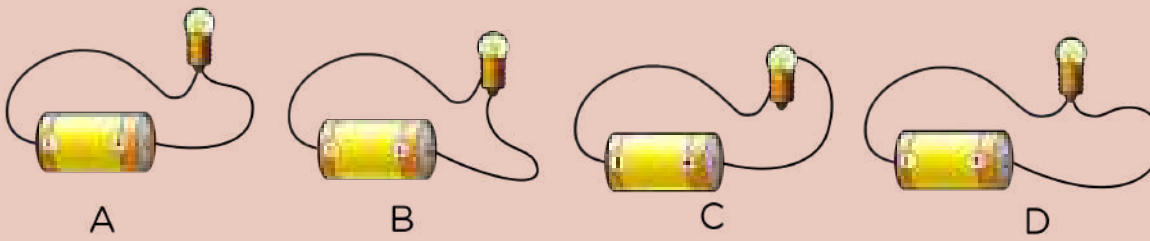
A cell	A light bulb
A conducting wire	An open switch
A resistor	A variable resistor

8. Look at the circuits below. If the bulb(s) will glow, place a tick next to the picture and explain why it will glow. If the bulb(s) will not glow, place a cross next to the picture and explain why it will not glow. [10 marks]

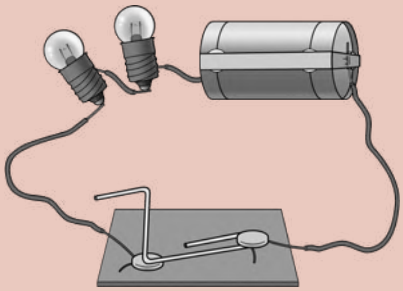
Circuit	Glow/Not Glow	Explanation
		
		

Circuit	Glow/Not Glow	Explanation
		
		
		

9. Which of the following setups shows the correct way to connect a light bulb to a battery? Explain your answer. [2 marks]



10. Draw a circuit diagram to illustrate the following circuit: (3 marks)

Image	Circuit diagram
	

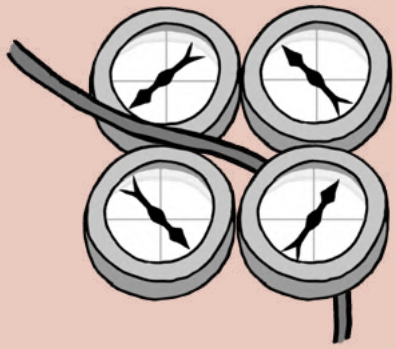
11. An electrician wants to replace a faulty fuse with a normal piece of conducting wire. Should you let him? Why or why not? [3 marks]

12. A child, while inserting an electric plug into the socket, did not see that there was a thin piece of aluminium foil stuck between the pins of the plug. When he turned the switch on, he noticed a spark at the plug, and at the same time, the lights went out. What could have happened to cause the spark and to make the lights go out? [4 marks]

13. What is the benefit of using a circuit breaker rather than a fuse? [2 marks]

14. Look at the following photo of a light bulb. Label the filament and explain why it glows. [4 marks]

15. You place some plotting compasses around an electric wire and observe the following.



a) Is there are current in the conducting wire? [1 mark]

b) Explain your answer. [2 marks]

16. Give two advantages of electroplating iron metal. [2 marks]

Total [55 marks]

Curious? Discover the possibilities with a magnifying glass.