Electromagnets
Voltage and resistance *and* Current

Ideas you have met before

Components in a circuit

All metals are good electrical conductors. Materials that do not allow electricity to pass through them are called insulators. Examples are wood, plastic, rubber, cloth and air.

A simple electric circuit consists of components such as cells, wires, bulbs, switches and buzzers.

Recognised symbols can be used to represent a simple circuit in a diagram.

Making current flow

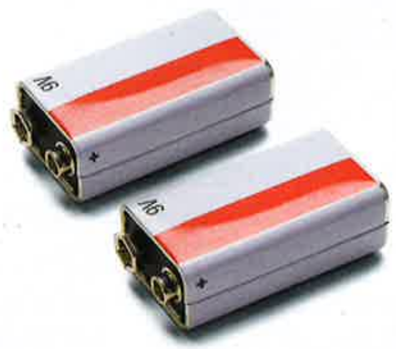
Components only work if the circuit is complete and contains a power supply. Then an electric current can flow.

When the switch is open (off), the circuit is not complete and none of the components will work.

Changing the voltage

The brightness of a lamp or the loudness of a buzzer is related to the number and voltage of cells used in the circuit.

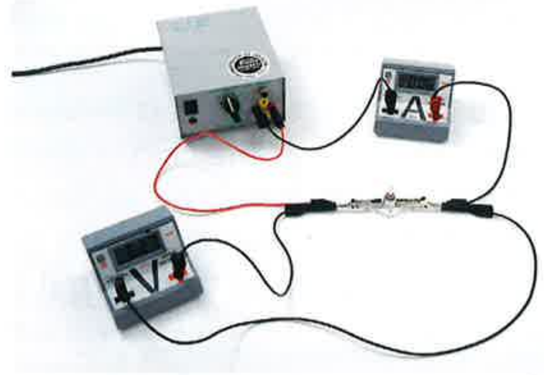
If more cells are added to a circuit, the brightness of bulbs or the loudness of buzzers in the circuit will increase.



In this chapter you will find out

Explaining electric circuits

- Components in an electric circuit provide opposition to the current, known as resistance, and transfer energy to the surroundings.
- Components in circuits can be arranged in series or in parallel. These arrangements have different effects on the voltage and current, and provide different applications.
- The current, voltage and resistance are related to each other.
- Models are a good way of explaining what happens in a circuit.



Current

- Current is a movement of electrons and is the same everywhere in a series circuit.
- Current depends on the 'push' given by the battery, known as the voltage.
- Current divides between loops in a parallel circuit and combines when loops meet.

Potential difference

- Voltage, or 'potential difference', is the amount of energy per unit of charge transferred through the electrical pathway.
- In a series circuit, voltage is shared between each component. In a parallel circuit, voltage is the same across each loop.

Electrostatic force

- Around a charged object, the electric field affects other charged objects, causing them to be attracted or repelled.
- The field strength decreases with distance.

Describing electric circuits

We are learning how to:

- Describe circuits and draw circuit diagrams.
- Explain what is meant by current.
- Explain how materials allow current to flow.

A light bulb in an electric circuit lights up instantaneously. Even if the circuit were the size of a football pitch, there would be no time delay for the light to come on. What is actually going on in the circuit for energy to be transferred so quickly?

Components in electric circuits

An electric circuit is a loop of wire with its ends connected to an energy source, such as a battery or cell. Strictly, a 'battery' is two or more cells together.

When a circuit is complete, energy is transferred from the battery to the wires by a flow of charge that we call an electric current. Devices such as light bulbs, motors and buzzers are **components** that can make use of this energy transferred.

If there are any gaps in the circuit, the current will not flow and energy cannot be transferred. A material that allows current to pass through it is called an **electrical conductor**. These contain small charged particles called **electrons** that are free to move within the conductor. An **electrical insulator** does not have any free electrons and cannot allow a current to pass.

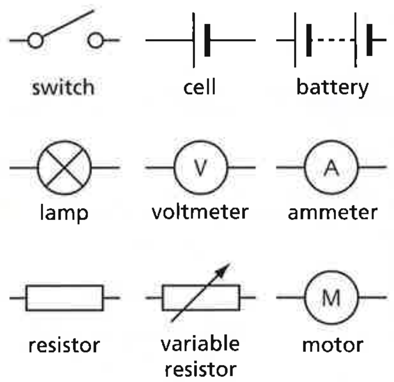


FIGURE 1.2.1a: Circuit symbols for common components.

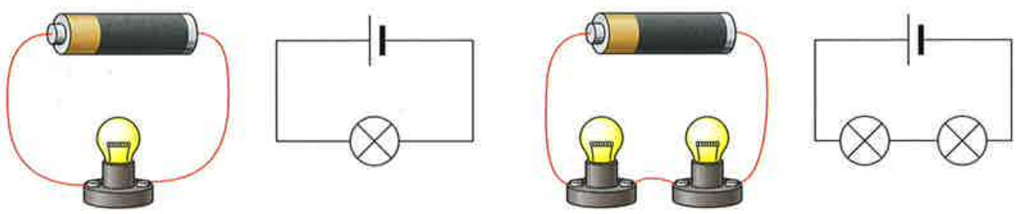


FIGURE 1.2.1b: How circuit symbols are used to represent components in a circuit diagram.

1. If pencil lead is placed in a circuit with a light bulb, the bulb lights up. What conclusion can you draw about this material?
2. Draw a circuit diagram for a circuit with one cell and three bulbs.
3. Why is it important to represent components with symbols?

Using models to explain current

Current is the rate of flow of charge (electrons) in the circuit, and is given the symbol *I*. It is measured by an **ammeter** in **amperes** (symbol A), after the French scientist André-Marie Ampère.

Models and analogies are often used to explain complex phenomena like current. One analogy is to compare electric current to water flowing in a stream. The charges are the water particles, and the current is the flowing stream.

Another analogy used to represent current is that of a convoy of coal trucks. The trucks represent the charged particles, the movement of the trucks represents the current, and the coal they carry represents the energy they transfer.

FIGURE 1.2.1c: In the analogies pictured in the photos, what represents the charge and what represents the current?

4. Using first the water analogy and then the coal-truck analogy, draw diagrams to show the difference between a low current and a high current.
5. Which analogy is better at explaining that current transfers energy to different components? Explain your answer.

Scientific explanation of current

When the battery is connected, the electrons in all parts of the wires within the circuit move at the same time, in the same direction and at the same rate. This movement constitutes the current. In this way, no matter where the components are in the circuit, they will all conduct at the same time – there is no delay because all the electrons in the circuit move simultaneously.

Current is not used up in the circuit. It has the same value before and after each component in the circuit.

6. Explain the strengths and limitations of the two analogies above, in light of the scientific explanation for current.
7. Explain why current is not used up in a circuit.

Did you know...?

A current of 1 amp means there are 6 250 000 000 000 000 000 electrons flowing past a point every second!

Know this vocabulary

component
electrical conductor
electrons
electrical insulator
current
ammeter
ampere

Understanding energy in circuits

We are learning how to:

- Describe what voltage does in a circuit.
- Recall how voltage can be measured.
- Explain the effect of increasing the voltage supplied.

We know that an electric circuit gets its energy from a cell or battery. The amount of potential energy within a battery is related to the number of volts it has.

FIGURE 1.2.2a: A voltmeter is a tool to measure voltage, but what do we mean by voltage?

What is voltage?

We can think of **voltage** as a measure of the size of 'push' that causes a current to flow around a circuit. Because the current is a flow of charge, something is needed to make the charges move.

If there is no voltage, then there can be no current flowing because there is nothing to cause the charges to move. The larger the voltage, the bigger the 'push' and the more current that can potentially flow.

The symbol for voltage is *V* and the unit is **volts** (V).

The energy source for the voltage is usually a battery or cell, but it can also come from a mains socket. A large energy source, like a big car battery of 12 V, will provide more 'push' or voltage and hence more current than a small cell of 1.5 V. Voltage is measured using a **voltmeter** (Figure 1.2.2a).

If two cells or more are connected together side-by-side, the voltage across them is the sum of the voltage of each cell. This is because both cells are 'pushing' the same way.

1. Why does no current flow if there is no voltage?
2. Figure 1.2.2b shows two circuits, one with one cell and the other with three cells. If, instead, there were two cells, what reading would the voltmeter give?

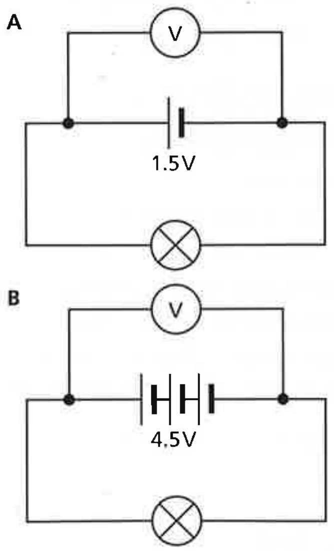


FIGURE 1.2.2b: Measuring the voltage across cells. The circled V represents a voltmeter.

Voltage and components

If there is a higher voltage, there will be more current flowing and therefore more energy being transferred to the components. A light bulb will be much brighter if it is connected to a 6 V battery rather than to a 3 V battery in a similar circuit.

Figure 1.2.2c shows how the voltmeter must be connected *across* a component (here a bulb) to measure the difference in potential across the component. Voltage is also known as **potential difference.**

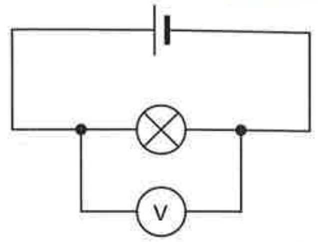


FIGURE 1.2.2c: Measuring the voltage across a bulb.

3. In which of the circuits in Figure 1.2.2b will the light bulb be the brighter? Explain your answer.
4. What might happen to a motor if it were connected to the 230 V mains electric supply rather than to a 12 V battery?

Using analogies to explain voltage

Imagine blowing gently through a straw. The air flowing through the straw is like a current and the amount of push given to the air is like the voltage. If you blow harder (more voltage) there is more air flow (more current).

A high waterfall is also like a large voltage. It will transfer a lot of energy to the water (charge), making the river flow very fast (a large current). The difference in height makes the river flow. In a circuit, the difference in charge across the battery provides the push for the current.

FIGURE 1.2.2d: The difference in height makes the water move.

5. Compare a circuit with a 12 V battery and one light bulb with a circuit that has a 1.5 V cell and one light bulb. Use the two analogies above to explain how they will be different.
6. Explain one limitation for each of the analogies outlined.

Did you know...?

Electric eels can produce electrical discharges of around 500 V in self-defence.

Know this vocabulary

voltage
volt
voltmeter
potential difference

Electromagnets

Explaining resistance

We are learning how to:

- Explain what resistance is and how it affects the circuit.
- Investigate and identify the relationship between voltage and current.
- Calculate the value of a resistor used in a circuit.

All materials offer some opposition to the flow of current – we call this 'resistance'. The amount of resistance can vary widely, even in different metals. Why are some metals, like gold, better at conducting electricity than other metals, like tin?

What is resistance?

The word 'resistance' means to oppose. In electric circuits, electrical **resistance** opposes the 'push' provided by the voltage. The overall current flowing through the circuit, therefore, depends on both the voltage and the resistance.

If there is a high voltage and a low resistance, then a large current will flow. This is because there is not very much opposition to the 'push' given by the voltage. Imagine a motor in a circuit. The current through it causes it to spin. If the motor is swapped with one of higher resistance, then there will be more opposition to the flow of charge and, for the same voltage, the current will be smaller. The motor with a higher resistance will spin more slowly.

All components in a circuit provide some resistance.

1. A buzzer is an electrical device that creates a sound when there is a current through it.
   a) A circuit, A, has a 6 V battery and a buzzer. Another circuit, B, has a 6 V battery and a buzzer with higher resistance. In which circuit will the buzzer be louder?
   b) Explain your answer to a) using ideas about resistance and current.

Conductors and insulators

Resistance depends on the type of material an object is made from. Materials that are very good conductors of electric current have a very low resistance. Electrical insulators have a very high resistance, and do not allow current to flow easily.

All metals conduct electricity well because they have many **free electrons** that can move when a voltage is applied.

Did you know…?

There are many different models used to help explain electricity. One of them compares a circuit to water being pumped around pipes. If the pipe is narrower the resistance to flow is greater.

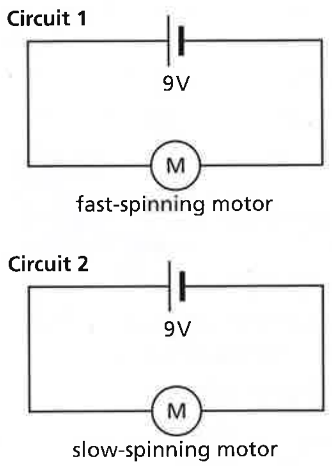


FIGURE 1.2.3a: The resistance in circuit 1 is low, so there is a big current; what can you say about circuit 2?

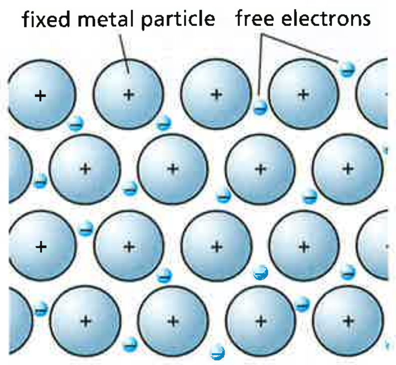


FIGURE 1.2.3b: Conduction in metals depends on free electrons.

As the electrons move, they will collide with other particles in the metal structure. This is the cause of resistance in most ordinary metals. It is why even the best electrical conductors, like platinum, will have some resistance.

In an insulator, the electrons are more tightly bound to atoms than in a conductor; far fewer electrons are free to move and so there is insignificant current.

2. As an analogy of a circuit with resistance, think of an obstacle race. Which parts of a circuit do the obstacles represent? Which parts of the circuit do the people represent?
3. What would happen to a light bulb if the copper wires in a circuit were replaced with platinum? Explain your answer.

Working out resistance

Resistance is measured with the unit **ohms** (Ω) and is represented by *R*. All the components in a circuit will have their own resistance. It is possible to investigate the relationship between voltage (*V*) across and current (*I*) through a component, as shown in Figure 1.2.3c.

The definition of resistance is:

$$\text{resistance} = \frac{\text{voltage}}{\text{current}} \qquad R = \frac{V}{I}$$

As resistance can be calculated from potential difference and current, we can use this to find out what the resistance of a component is. A team of students is investigating this to see if the resistance of a component stays the same.

Figure 1.2.3d shows the circuit they set up. The rectangle is the resistance – that's what they're trying to find the value of. They altered the settings on the power pack so that there was a range of voltages. Their results are shown in Table 1.2.3.

TABLE 1.2.3: Investigation results.

Potential difference/V	Current/A
0.9	0.03
1.9	0.07
3.1	0.10
3.9	0.12
5.0	0.15
6.1	0.19

4. What calculation needs to be done on each pair of readings to find the resistance?
5. a) Calculate the resistance for each pair of readings.
   b) What do you notice about the values?

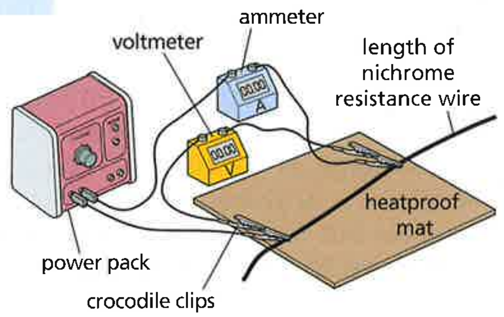


FIGURE 1.2.3c: As the voltage supplied is changed using the power pack, the current is measured using the ammeter. The resistance of the length of nichrome wire between the crocodile clips can then be determined.

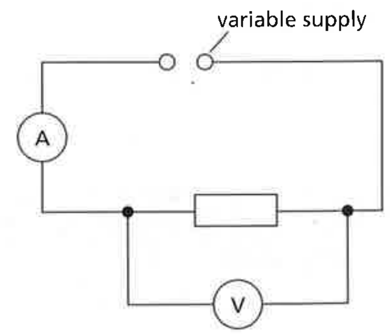


FIGURE 1.2.3d: Circuit to determine resistance.

Know this vocabulary

resistance
free electron
ohm

Describing series and parallel circuits

We are learning how to:

- Describe how voltage, current and resistance are related in different circuits.
- Understand the differences between series and parallel circuits.

You have learned about what voltage, current and resistance are. Now you will see how they interact in a circuit.

Relating voltage, current and resistance

The size of the voltage and the size of the resistance both determine how much current flows. Look at the three different circuits in Figure 1.2.4a. In circuit 1, there is a voltage of 3 V and one light bulb of resistance 3 Ω.

In circuit 2, there are two identical light bulbs in series, providing twice as much resistance, but supplied with the same voltage as in circuit 1. The current flowing through the circuit is now less, because there is the same 'push' (voltage) but twice the opposition to the flow of electrons (resistance). The light bulbs are not as bright as in circuit 1.

In circuit 3, there are now two cells and the same two light bulbs, each with a resistance of 3 Ω. The light bulbs will both be just as bright as in circuit 1. This is because the resistance and the voltage are both doubled compared to circuit 1, so the current will be the same.

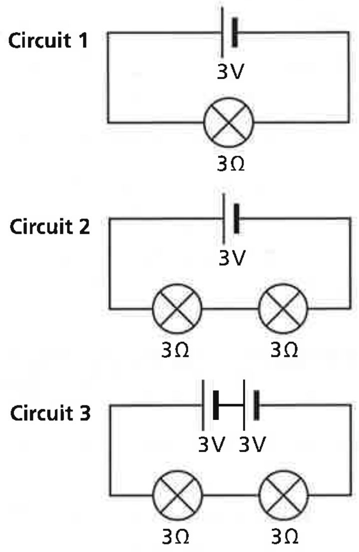


FIGURE 1.2.4a: How does voltage and resistance change in these circuits?

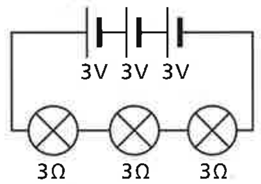


FIGURE 1.2.4b

1. What is the voltage and the resistance of the circuit in Figure 1.2.4b?
2. Explain whether the light bulbs in Figure 1.2.4b are dimmer or brighter than in:
   a) circuit 1; **b)** circuit 2; **c)** circuit 3 of Figure 1.2.4a.

Series and parallel circuits

In a **series circuit**:

- All the components are connected, one after the other, in a complete loop of conducting wire.
- There is only one path that the current can take.
- The voltage is shared between the components.

Figure 1.2.4c shows a series circuit with two light bulbs.

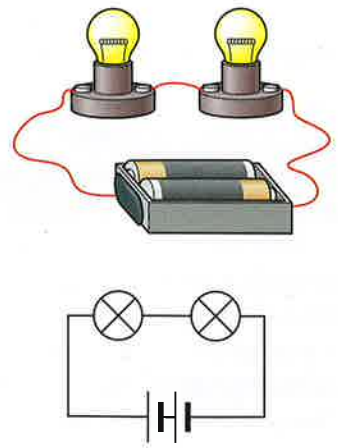


FIGURE 1.2.4c: How can you tell that the components in this circuit are connected in series?

In a **parallel circuit**:

- Each component is connected separately in its own loop between the two terminals of a cell or battery.
- The full voltage is supplied to each loop.
- The current from the battery is divided between the loops.

Figure 1.2.4d shows a parallel circuit with two light bulbs.

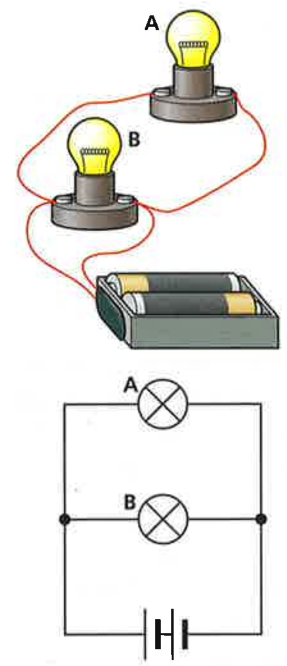


FIGURE 1.2.4d: What happens to bulb A in this parallel circuit if bulb B 'blows'?

A parallel circuit is rather like separate series circuits connected to the same energy source. The different components are connected by different wires. Therefore, if a bulb blows or is disconnected from one parallel wire, the components in the other loops keep working because they are still connected to the battery in a complete circuit.

If more bulbs are added in parallel, all the bulbs light up with the same brightness as before, because the potential difference across each is the same (equal to the battery voltage).

3. What would happen to the components in a series circuit if one of the bulbs stopped working?
4. Draw two circuits – one with just one bulb, and the other with three identical bulbs in series. Both circuits should have just one cell of the same voltage. Compare:
   a) the voltage in each circuit;
   b) the current in each circuit;
   c) the brightness of the bulbs in each circuit.
5. **a)** Draw a parallel circuit with four bulbs.
   b) Explain how this is different from a series circuit with four bulbs.

Explaining series and parallel circuits

When two light bulbs are connected in series, the resistance in the circuit is increased compared to that with one light bulb. The increased resistance opposes the flow of current, so fewer electrons pass per second, transferring less energy. The light bulbs are therefore not as bright as in a circuit with the same voltage but only one bulb.

However, when two light bulbs are connected in parallel, each loop behaves like a separate circuit. The resistance in each branch is the same as if there were just one light bulb in the whole circuit. There is the same current in each branch of the circuit, so the bulbs light up with the same brightness as in the single-bulb circuit. The energy stored in the battery will decrease twice as quickly and the battery will run out faster than in a series circuit.

6. Explain the advantages and disadvantages of arranging components in series or in parallel.

Did you know...?

Most circuits used are combinations of series and parallel parts.

FIGURE 1.2.4e

Know this vocabulary

series circuit
parallel circuit

Comparing series and parallel circuits

We are learning how to:

- Investigate and explain current and voltage in series and parallel circuits.
- Explain the circuits in our homes.

The arrangement of components in either series or parallel affects the amount of voltage they receive and the amount of current flowing through them. Why does the arrangement make this difference?

Current and voltage in series and parallel circuits

Figures 1.2.5a and 1.2.5b show a series circuit and a parallel circuit with light bulbs of the same resistance.

Series circuit

The ammeter shows the same readings in different parts of the circuit.

However, the voltage is divided between the components. See how the voltage across each of the components adds up to the total provided. We can write this as:

$V_{total} = V_1 + V_2 + V_3$

If the components have the same resistance, the voltage is divided equally.

Parallel circuit

The voltage in all parts of the circuit is the same regardless of how many loops there are.

However, the current splits up between each loop. Adding up the current in each part gives the total current flowing from the battery. We can write this as:

$I_{total} = I_1 + I_2 + I_3$

If the resistance in each part is the same, the same current will flow through each.

1. If another light bulb is added to the series circuit in Figure 1.2.5a, what will happen to the voltage across the other light bulbs? Explain your answer.
2. A 12 V battery is connected in a circuit with ten identical light bulbs in parallel. Compare this with the circuit in Figure 1.2.5b. What will the current be in each individual loop?

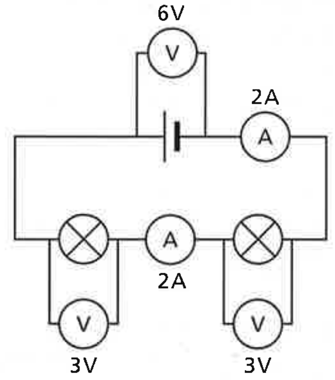


FIGURE 1.2.5a: A series circuit.

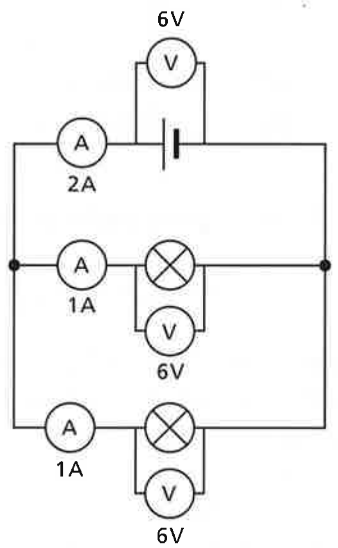


FIGURE 1.2.5b: A parallel circuit.

Did you know...?

During World War 2 there was a shortage of copper. In 1942, the ring main helped to reduce the amount of household wiring needed. This required longer wires, but they could be thinner.

Selecting series or parallel circuits, according to application

Each type of circuit has advantages and disadvantages. These are summarised in Table 1.2.5.

	Advantages	Disadvantages
Series circuits	Simple to set up. Shares the voltage between the components, which is useful if the components need a lower voltage than the supply voltage.	If one component fails, the whole circuit stops working. If more components are added, each gets less voltage and so might not work as well.
Parallel circuits	If a component in one of the loops fails, the other loops keep functioning. Each loop gets the same voltage, so adding more loops doesn't mean other loops suffer a voltage drop.	More complicated to set up. Adding more loops doesn't reduce the voltage, so if components need a lower voltage they won't work.

TABLE 1.2.5

We can therefore decide which type of circuit to use in each situation.

3. Which kind of circuit would you use to supply 20 bulbs, each rated at 12 V, with a power of 240 V?
4. Which kind of circuit would you use for emergency lighting in a restaurant, running from a 12 V supply and powering 12 V bulbs?

Household circuits

Figure 1.2.5c shows how the household electricity supply is connected in the UK. It is an arrangement known as the domestic **ring main**.

All the plug sockets in the ring main are connected in parallel, for the following reasons:

- If one of the electrical appliances should stop working, other appliances are not affected.
- The **mains supply** of 230 V is applied across all the sockets.
- Switches can be used to turn the current on and off within each branch.

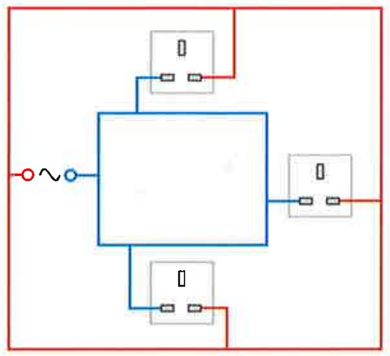


FIGURE 1.2.5c: Arrangement of sockets in a domestic ring main.

5. Suggest disadvantages with this arrangement.

Did you know...?

A wiring system that consists of wires arranged in complete loops around a building is called a ring main.

Mains supply is a supply of electricity to a building at the standard voltage for that area (230 V in the UK).

FIGURE 1.2.5d: Each socket has 230 V applied to it.

Know this vocabulary

ring main
mains supply

Investigating static charge

We are learning how to:

- Recognise the effects of static charge.
- Explain how static charge can be generated.
- Use evidence to develop ideas about static charge.

Static electricity is a common and sometimes spectacular phenomenon. You may have noticed that after walking across a carpet, you sometimes get a small electric shock when you touch a door handle. This happens when your body has become electrically charged. Lightning is a demonstration of static electricity at work on a grand scale.

FIGURE 1.2.6a: When a person's hair becomes charged the individual strands repel each other.

Static charge

Electric **charge** can either flow or be gathered in one place. Charge that is flowing is called a current and when it is not flowing it is called **static electricity**.

Electricity flows through conductors, such as a copper wire. However, when a charged material is not connected to a conductor, the electricity cannot flow away and so the charge stays in place.

When a charged object comes close to a conductor the electricity jumps across as a spark. If your body has become charged by walking on a carpet, you feel the charge flowing away through your fingers when you reach for the door handle.

1. Name some materials that are good conductors of electricity.
2. What does the word 'static' mean?
3. How could a material that conducts electricity become charged?

Attraction and repulsion

When an object becomes charged with static electricity, a **field** of electrostatic force exists around the object. This is a non-contact force. This force can **attract** other materials and may be strong enough to lift them. A charged balloon brought close to someone's head can attract strands of hair and lift them up without the balloon coming into contact with the hair. Scraps of paper can be made to jump off a table and stick to a charged plastic comb held a few centimetres above it.

FIGURE 1.2.6b: Static electricity can cause attraction.

When two objects of the same material become charged they **repel** each other.

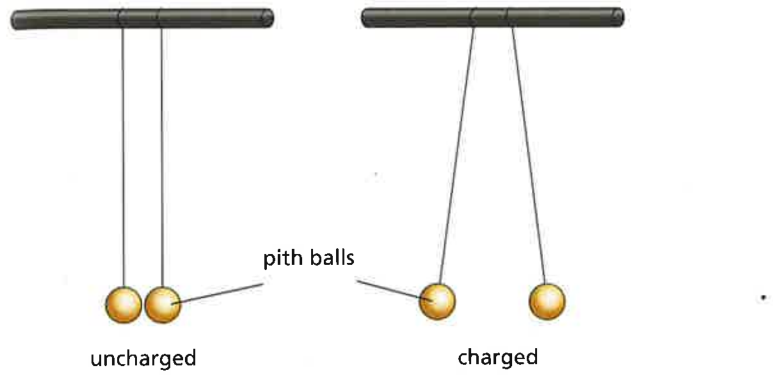


FIGURE 1.2.6c: Repulsion between two identical charged objects.

4. What could small pieces of dust and paper experience when a charged object is brought close?
5. How could you find out if two charged combs repel each other?

Factors affecting field strength

If you push a supermarket trolley you are applying a **contact force** because you are in contact with the object. Electrostatic force, however, like gravity, is a **non-contact force**. If we have an object with a static charge it produces an electric field. Fields are an important idea in science.

A charged balloon will produce an electric field – an area around the balloon in which anything affected by the charge will be subject to a force. If we were to use the charged balloon to attract bits of tissue paper, it would work only if the bits were within the field.

The strength of the field will depend on two things:

- the strength of the charge on the balloon;
- the distance between the balloon and the bits of paper.

6. What evidence supports the idea that static electricity exerts a non-contact force?
7. How could you show that the field around the balloon got weaker as the distance from the balloon increased?
8. There's another non-contact force we've met already, as well as electrostatic. What is it?
9. Some people don't like getting shocks from static charge. Suggest how they could reduce the likelihood of getting them.

Did you know...?

Some items of clothing become charged so easily that when you take them off, the cloth crackles and sparks as the charge escapes. This occurs in dry weather, and a dark room is needed to see the effect.

Know this vocabulary

charge
static electricity
field
attract
repel
contact force
non-contact force

Explaining static charge

We are learning how to:

- Explain static charge in terms of electron transfer.
- Apply this explanation to various examples.

In ancient Greece, people started to put forward ideas about atoms. They thought that atoms were the most basic particles and that they could not be split further. It was not until the 1800s that ideas really developed beyond this. Scientists have developed a much better understanding of what atoms are like inside. These more modern ideas form the basis of our understanding in many areas of chemistry and physics, including static electricity.

Atoms and electrons

The simplest modern model of an atom is a nucleus being orbited by **electrons**. The nucleus has a positive electric charge because it contains positively charged **protons** – along with neutrons, which have no charge. Electrons have a negative electric charge. Overall, an atom is electrically neutral because the positively charged protons are balanced by an equal number of negatively charged electrons.

If some electrons get transferred from one object to another the charges no longer balance. This is what happens when an object becomes **charged up**.

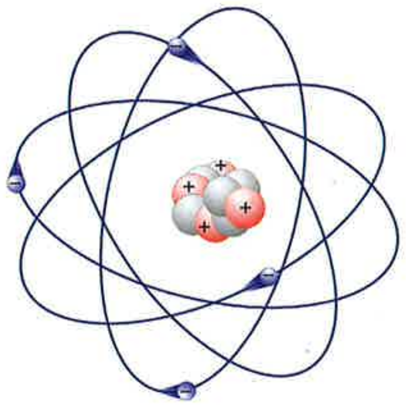


FIGURE 1.2.7a: Atoms contain a balance of positively charged protons and negatively charged electrons.

1. What are atoms made up of?
2. Why do atoms have no charge overall?
3. How can an object become negatively charged?
4. How can an object become positively charged?

Positive and negative charge

When a nylon rod is rubbed with a cloth, electrons are transferred from the rod to the cloth. Because electrons have negative charge this makes the cloth **negatively charged**. The rod has lost electrons so the positive charge of the protons is no longer balanced – the rod is left **positively charged**.

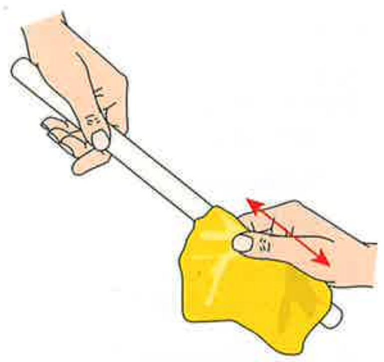


FIGURE 1.2.7b: Rubbing transfers electrons, either from the rod to the cloth or from the cloth to the rod.

Other materials behave differently. A polythene rod, for example, gains electrons when rubbed with a cloth. It becomes negatively charged and the cloth, which has lost electrons, becomes positively charged.

5. Describe what happens to a cloth when it is rubbed on a nylon rod.
6. Explain how different materials behave differently when rubbed with a cloth.

Did you know...?

A Van de Graaff generator produces electricity by friction. The ones used in schools can produce 100 000 volts. Bigger Van de Graaff generators can exceed two million volts.

Charging by electron transfer

There are two types of static charge – negative and positive. Both types are produced in the same way – by transferring electrons. When something is charged up by friction, one material is rubbed against another. This results in some negatively charged electrons being transferred from one to the other.

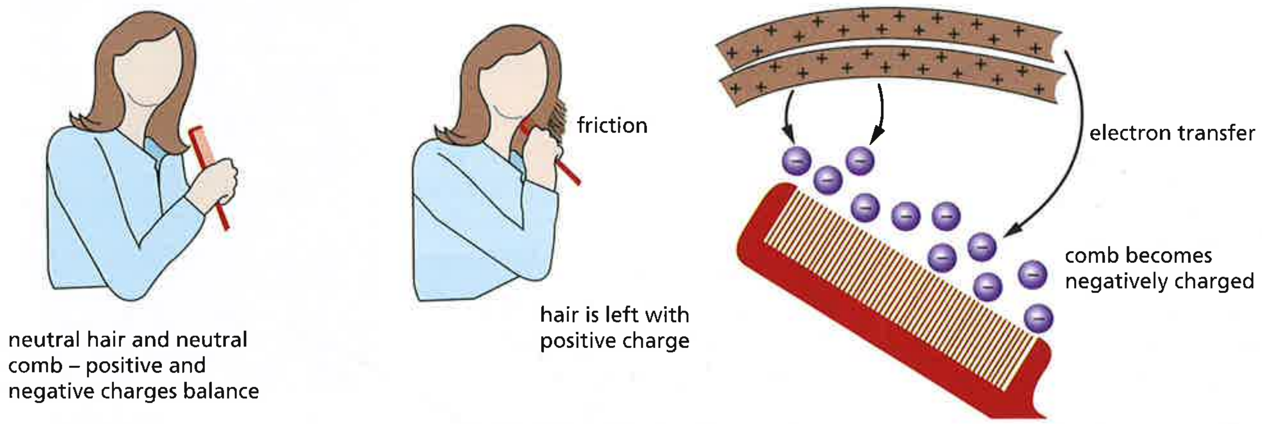


FIGURE 1.2.7c: Electrons are transferred when you comb your hair with a plastic comb.

This means that one material has lost electrons and doesn't have enough to balance out its positively charged protons. This material now has a positive charge. The other material has gained excess electrons so it has a negative charge.

For example, if you brush your hair vigorously with some types of plastic comb or brush, your hair becomes charged and so does the comb. In this case, electrons are being transferred from your hair to the comb. This means your hair is lacking electrons and has a positive charge. The comb has gained electrons and has a negative charge.

7. How can you tell that your hair has become charged?
8. How could you show that the comb has also become charged?
9. Neither your hair nor the comb will stay charged permanently. Using the idea of electron transfer, suggest what you think happens.

Know this vocabulary

electron
proton
charged up
negatively charged
positively charged

Understanding electric fields

We are learning how to:

- Explain static electricity in terms of fields.
- Explain how charged objects affect each other.

Charged objects can affect their surroundings even when they are not in contact. Sometimes people believe that they can 'feel' electricity in the air. The idea of an electric field helps to explain this.

Rules of attraction and repulsion

An **electric field** exists around a charged object, which can exert a non-contact force.

Two similarly charged objects – both negative or both positive – **repel** each other. This is called repulsion.

Two oppositely charged objects – negative and positive – **attract** each other.

A charged object can also attract an uncharged object. For example, water has no overall electrical charge – it has a balance of negatively and positively charged particles. Despite this, water is affected by an electric field (Figure 1.2.8a).

FIGURE 1.2.8a: The water is attracted towards a charged rod.

1. What is the area around a charged object called?
2. Looking at Figure 1.2.8a, what evidence suggests that a non-contact force is working?
3. All substances contain charged particles. But most objects have no charge – explain why.

Charged particles moving

Within many substances, charged particles are free to move. When there is no electric field present, the charged particles are spread evenly.

In Figure 1.2.8b the negatively charged balloon has electrons spread over its surface. When it is brought towards the wall, the negatively charged particles in the wall atoms are repelled. This leaves the surface of the wall with a positive charge. The opposite charges of the balloon and the wall's surface attract one another.

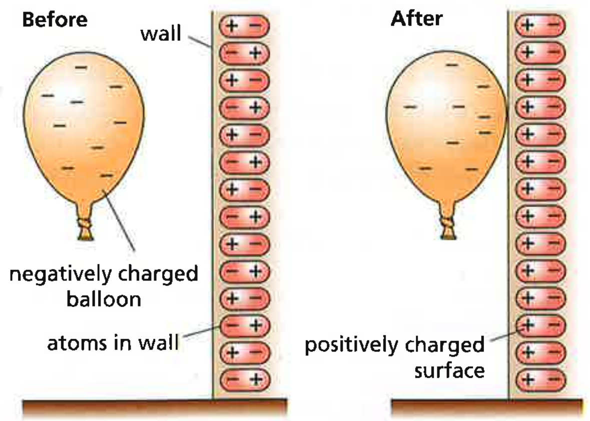


FIGURE 1.2.8b: The charged balloon affects the charges in the atoms of the wall.

4. Describe how charged particles move when an object is put in an electric field.
5. Draw a labelled diagram, similar to Figure 1.2.8b, to show how a positively charged rod can attract a trickle of water.
6. Suggest why a metal rod is unlikely to be able to attract a trickle of water.

Loss of charge

Static charge depends on electrons being unable to flow into or out of an object. If a charged polythene rod is connected to a conductor, such as a wire, electrons will flow away from the rod. The rod loses its charge and becomes neutral.

Air is not a good conductor, but it can transfer some electrons, so charged objects gradually lose their charge. In wet weather, the water vapour in the air can transfer more electrons so charge is lost more quickly.

When a Van de Graaff generator is turned on, the globe becomes positively charged. If the charge builds up enough, the air can start to conduct. Sparks will jump across the gap to anything in good contact with the ground.

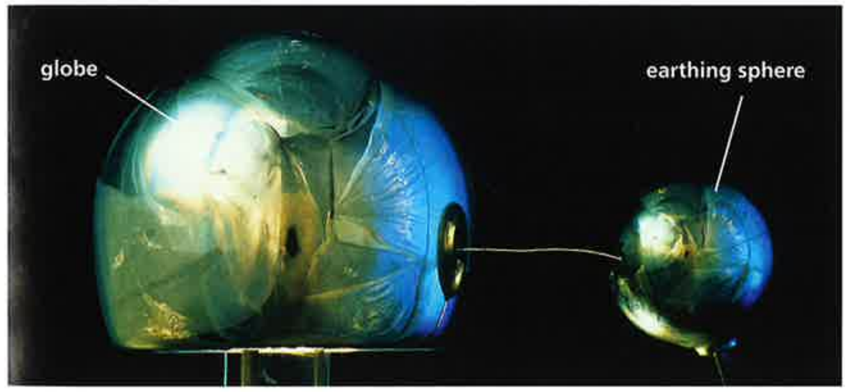


FIGURE 1.2.8c: A Van de Graaff generator and earthing sphere.

7. Explain why experiments with static electricity give better effects in dry weather.
8. a) Explain why, if someone is charged up by a Van de Graaff generator, their hairs rise up and spread out.
   b) Explain the process of discharging the globe of a Van de Graaff generator.
9. Suggest ways of avoiding getting electrostatic shocks in everyday life.

Did you know...?

An electrostatic field exists around a charged object in three dimensions – above and below it as well as on all sides.

Know this vocabulary

electric field
repel
attract

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

Recognise arrangements of electric circuit components in series and in parallel.	Use circuit diagrams to construct real series and parallel circuits and vice versa.	Suggest the advantages of series and parallel circuits for particular applications.
Describe what is meant by current, voltage and resistance.	Apply a range of models and analogies to describe current, voltage and resistance.	Evaluate different models and analogies for explaining current, voltage and resistance.
Know that a complete circuit is needed for current to flow.	Know that current is a movement of electrons and is therefore a flow of charge.	Know that current is divided between the loops in a parallel circuit.
Know that resistance reduces the current flowing.	Explain the idea of resistance, using models such as water flow in pipes.	Understand that resistance is the ratio of voltage to current.
Understand that voltage is also called potential difference and this makes current flow around a circuit.	Understand that in a series circuit the potential difference is shared by the components.	Understand that potential difference is the amount of energy transferred from the battery to the charge or from the charge to the components.

Describe the relationship between current, voltage and resistance in a qualitative way.	Use data to identify a pattern between current, voltage and resistance.	Use data and the mathematical relationship between current, voltage and resistance to carry out calculations.
Describe the effect that a charged object has on other charged objects.	Explain what is meant by an electrostatic field.	Suggest how objects may become electrostatically charged.
Know the two types of static charge.	Explain how electron transfer can result in either type of charge.	Explain the operation of a circuit using the idea of electrons moving from the negative to the positive terminals of a power supply.
Describe how friction between objects may cause electrostatic charge through the transfer of electrons.	Explain various examples of electrostatic charge; use ideas of electron transfer to explain different effects.	Explain why some electrostatic charge mechanisms are more effective than others.

Questions

KNOW. Questions 1–3

See how well you have understood the ideas in this chapter.

1. What is the unit of current? [1]

a) volt **b)** ohm **c)** amp **d)** joule

2. Explain how a series circuit is different from a parallel circuit. [2]

3. Thinking about electrostatic charge, which of these statements is true? [1]

a) positive (+) charge repels negative (–) charge
b) positive (+) charge attracts positive (+) charge
c) negative (–) charge attracts positive (+) charge
d) negative (–) charge attracts negative (–) charge.

APPLY. Questions 4–6

See how well you can apply the ideas in this chapter to new situations.

4. Figure 1.2.10a shows four circuits A–D. Which of the following shows the correct order, from the circuit that has the brightest bulbs to the one that has the dimmest? [1]

a) A, B, C, D **b)** D, C, B, A **c)** C, D, A, B **d)** C, B, D, A

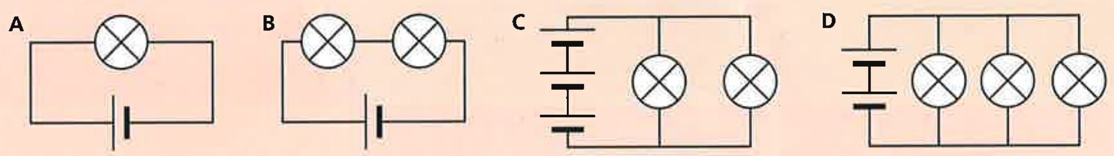


FIGURE 1.2.10a: All cells and all lamps are identical.

5. Figure 1.2.10b shows a model of a circuit. How would you change this model to show an increased voltage and increased resistance? [2]

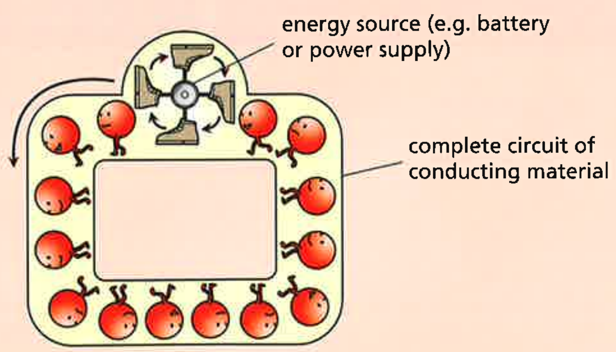


FIGURE 1.2.10b

6. Suggest how you could find out if one electrostatically charged rod has more charge than another of the same material. [2]

EXTEND. Questions 7–8

See how well you can understand and explain new ideas and evidence.

7. Table 1.2.10 gives some data from an investigation comparing the different lengths of the same wire. The values of resistance have been calculated using $V/I = R$.

Plot a graph of the resistance against the length of the wire.

TABLE 1.2.10

Length of wire (cm)	Average voltage (V)	Average current (A)	Average resistance (Ω)
10	0.47	0.23	2.0
20	0.59	0.17	3.5
30	0.64	0.13	4.9
40	0.69	0.11	6.3
50	0.72	0.09	8.0
60	0.76	0.07	10.9
70	0.82	0.06	13.7

8. Jo is asked to construct a circuit with a battery and two parallel loops, each containing two bulbs in series. [4]

a) Draw the circuit diagram.
b) If the total resistance in the circuit is 20 ohms and the voltage supplied by the battery is 5 V, how much current will flow out of the battery?
c) Show on your diagram where an ammeter could be put in the circuit to check this.
d) Explain what will happen to the other bulbs if one of the bulbs should blow.