ELECTRICITY

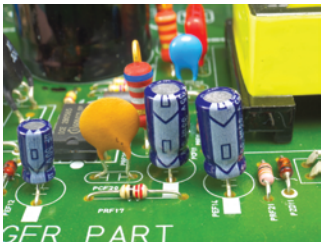
IDEAS YOU HAVE MET BEFORE:

STATIC ELECTRICITY

- Electrical insulators can be charged by rubbing (friction).
- There are two kinds of electric charge – positive and negative.
- Like charges repel, unlike charges attract.

ELECTRIC CURRENT

- An electric current is due to a flow of charge.
- Resistors are used to control the current in circuits.
- Ohm's law is used to calculate resistance.



ELECTRICAL ENERGY

- Cells are sources of electricity.
- A battery is a number of cells joined together.
- Energy sources can be used to drive electrical generators to produce electricity.

ELECTRICITY IN THE HOME

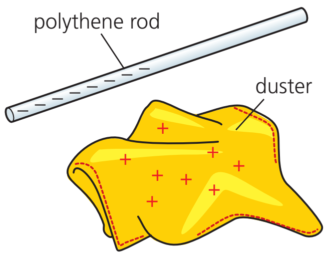
- Electricity supplied to the home is alternating current (a.c.).
- Care must be taken when using mains electricity as it has a high potential difference (230 V).
- Fuses and circuit-breakers switch off the current if a fault occurs.

2

IN THIS CHAPTER YOU WILL FIND OUT ABOUT:

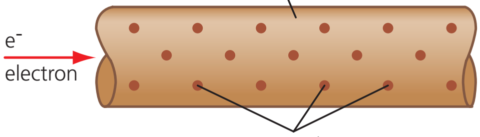
WHAT IS STATIC ELECTRICITY?

- Insulators become charged when they gain or lose electrons.
- When two materials are electrically charged, there is an electric field between them.
- Static electricity can give a person an electric shock and it may create a spark which could cause petrol vapour or natural gas to explode.



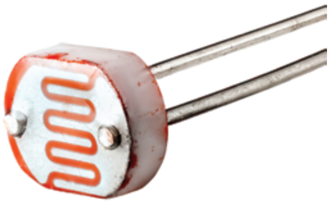
WHAT ARE THE KEY CONCEPTS IN ELECTRICITY?

- Electric current is the rate of flow of electrons through a conductor.
- Some electrical components resist the flow of electrons more than others so have greater resistance.
- Potential difference is a measure of the force pushing electrons through an electrical component.



WHAT ARE THE CHARACTERISTICS OF SOME ELECTRICAL COMPONENTS?

- When electrical components are connected in parallel there is more current passing through each component than when they are connected in series.
- A fixed resistor at constant temperature obeys Ohm's law, so the current through it is directly proportional to the potential difference across it.
- Diodes, thermistors and light-dependent resistors do not obey Ohm's law.



HOW CAN ELECTRICITY BE USED SAFELY IN THE HOME?

- Circuit-breakers and fuses are used to cut off the current when there is a short circuit.
- The earth is connected to the Earth so it provides a path for the current if there is a short circuit.
- The higher the power (in W) of an electrical device, the more expensive it is to use it.

Static electricity

Learning objectives:

- describe how insulating materials can become charged
- know that there are two kinds of electric charge
- explain these observations in terms of electron transfer.

KEY WORDS

conductor
insulator
attract
repel
electron

Explosions can be caused by a spark from the discharge of static electricity.

Producing static electricity

Clouds become charged. The greater the amount of charge on the cloud, the greater the potential difference between the cloud and the ground. If the potential difference is large enough, a spark in the form of lightning jumps across the gap and an electric current passes between the cloud and Earth (Figure 2.1) or between clouds.

Figure 2.1: Cloud-to-ground lightning

Metals are good **conductors.** Electric charges can move through them. But **insulators** such as glass, polythene or wood do not allow electric charges to move through them. Charge builds up. Many insulators can be charged by friction.

When a polythene rod is rubbed with a duster it becomes charged and can attract tiny pieces of paper (Figure 2.2).

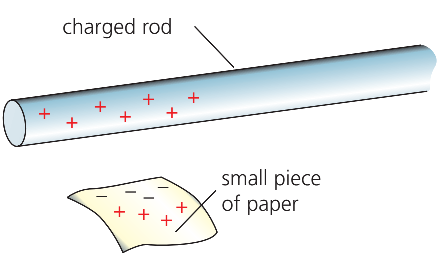


Figure 2.2: The charged rod attracts a small piece of paper by inducing a charge on the paper.

Other materials can be charged by friction:

- When a balloon is rubbed on a sweater it becomes charged and sticks to a wall.
- Some dusting brushes are designed to become charged and attract dust.
- When hair is combed with a plastic comb both the comb and hair become charged.

1. **Name a an insulator and b a conductor of electricity.**
2. **Explain why static charges do not build up on a conductor.**

Two kinds of electric charge

There are two kinds of electric charge, positive and negative (Figure 2.3).

When rubbed with a duster:

- acetate and Perspex become positively charged
- polythene becomes negatively charged.

Like charges **repel**, unlike charges **attract** (Figure 2.3).

Forces of attraction and repulsion between charged objects are examples of non-contact forces.

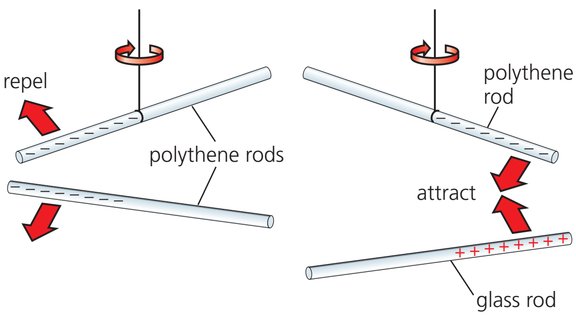


Figure 2.3: Like charges repel, unlike charges attract

3 **Polythene, acetate and Perspex rods are charged with a duster. State whether these pairs of rods will attract or repel each other:**

- **a** **a polythene rod and an acetate rod**
- **b** **two Perspex rods**
- **c** **a Perspex rod and a polythene rod**
- **d** **an acetate rod and a Perspex rod.**

4 **A Van de Graaff generator produces a large electrostatic charge. Beth puts her hands on a Van de Graaff generator when it is switched off (Figure 2.4). When it is switched on she becomes charged. Why does her hair stand on end?**

Figure 2.4: A Van de Graaff generator

Electron transfer

An atom consists of a small positively charged nucleus surrounded by negatively charged **electrons.** In a neutral atom there are equal numbers of positive and negative charges. All electrostatic effects are caused by the movement of electrons.

- If a polythene rod is rubbed with a duster electrons **move from the duster to the polythene** making the polythene negatively charged.
- If an acetate rod is rubbed with a duster electrons move **from the acetate to the duster** making the acetate rod positively charged.

5 **When a polythene rod is charged by rubbing it with a duster what charge, if any, does the duster gain?**

DID YOU KNOW?

The tyres on aircraft are made from a special rubber that conducts electricity to stop them becoming charged.

KEY INFORMATION

It is only electrons that move in an atom.

Electric fields

Learning objectives

- explain what an electric field is
- draw an electric field pattern for a charged sphere
- use the idea of an electric field to explain static electricity.

KEY WORDS

electric field
spark

The electric field created by a charged object stretches out into space for ever. That means it can attract or repel another charge right across the universe. The force would be very weak though.

What is an electric field?

Charged objects can attract and repel each other because they create electric fields around them. Figure 2.5 shows the electric field that is created by a positive charge. If you place a second charge within this field, then it will feel a force of attraction or repulsion from the charge that has created the field.

A field is a region of space where a force can act at a distance. This means that objects do not need to be in contact with each other to exert a force – they just need to be within the other object's field. An **electric field** is a region where a force acts on a charged particle.

1 **Explain why all of the arrows are pointing away from the charge in Figure 2.5.**

2 **Describe how the electric field in Figure 2.5 changes when the positive charge is replaced with a negative charge.**

The strength of an electric field

The electric field in Figure 2.5 gets weaker as the distance from the charge increases. A charge that is close to the sphere will feel a stronger force of attraction or repulsion than one that is further away.

3 **An electron moves in a circle around the charge in Figure 2.5. The charge is at the centre of the circle. State what happens to the size of the electric force on the electron.**

Sometimes the electric fields created by two or more charges interact with each other to form a new electric field. Figures 2.6 and 2.7 show the electric field created by a positive and a negative charge and the field created by two positive charges.

KEY INFORMATION

There are other types of fields as well as electric fields. These include gravitational and magnetic fields.

KEY INFORMATION

An electric field has a direction. In Figure 2.5 this is shown by the arrows on the field lines. The direction of an electric field is always the direction that a force would act on a positive charge inside the field.

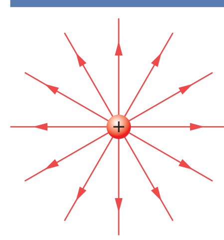


Figure 2.5: The electric field round a point charge

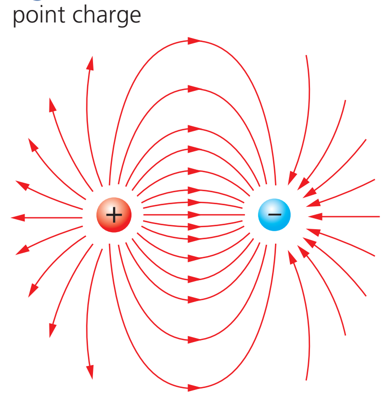


Figure 2.6: The electric field around a positive and negative charge

4 Copy Figures 2.6 and 2.7. Label them to show a place where the strength of the field is:

a strong

b weak

c zero.

5 A hydrogen atom consists of a positively charged proton and a negatively charged electron. It is placed in the centre of the field in Figure 2.8.

a State the direction of the force the field exerts on the proton.

b Suggest why the hydrogen atom breaks apart if the field is very strong.

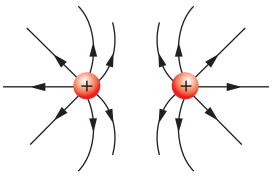


Figure 2.7: The electric field around two positive charges

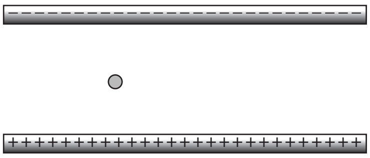


Figure 2.8

Sparking

The atoms and molecules in the contain positive and negative charges. If the two charges shown in Figure 2.6 are charged spheres with air between them, the negative charges are pulled to the left and the positive charges are pulled to the right due to the electric field.

We can increase the strength of the electric field between the two charged spheres by increasing the amount of charge on them. This makes the potential difference between the charged spheres increase.

If the potential difference between the spheres becomes large, then the electric field is strong enough to break the charges in the air apart to form negative and positive ions. The ions then rush towards the spheres colliding with each other and you get a **spark**.

Lightning is a very big spark. As a thundercloud charges up there is a large potential difference between the cloud and the Earth. When the potential difference is large enough, the lightning strikes.

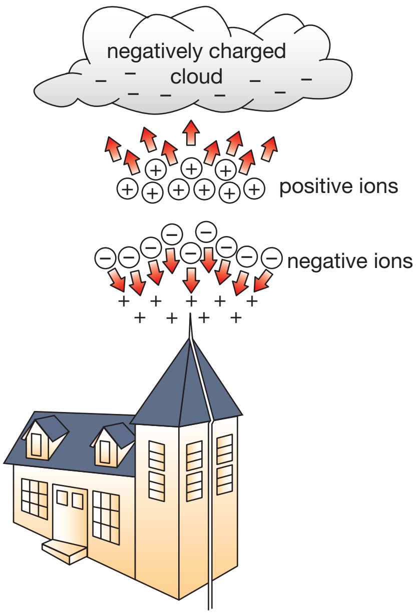


Figure 2.9: A lightning conductor causes the ions to form at a lower potential difference. The ions move in a controlled way and discharge the thunder cloud before any lightning is formed.

6 Can a spark occur between two charges which are in a vacuum? Explain your answer.

7 Suggest why sparks are more likely to occur between two charged objects that are close together rather than far apart.

DID YOU KNOW?

To create an electric field that is strong enough to produce lightning, the potential difference between thunderclouds and the Earth can reach up to 35 million volts.

Electric current

Learning objectives:

- know circuit symbols
- recall that current is a rate of flow of electric charge
- recall that current (*I*) depends on resistance (*R*) and potential difference (*V*)
- explain how an electric current passes round a circuit.

KEY WORDS

potential difference (pd)
parallel
resistance
voltmeter
coulomb

Japanese scientists have managed to achieve an electric current of 100 000 amperes – by far the highest to be generated in the world.

Electric current and charge

Current is a rate of flow of electric charge. Electric charge is measured in **coulombs (C)**. We now know that an electric current is actually a flow of electrons from negative to positive. Electric current is measured in amperes (A). This is often abbreviated to amps.

electric charge, Q = current, I × time, t.
(in C) (in A) (in s)

$$Q = It$$

Example: A current of 1.2 A flows for 30 s. How much charge flows?

$Q = It = 1.2 \times 30 = 36$ C

1. **Calculate the current when 80 C of charge flows in 16 s.**
2. **A current of 6 A builds up a charge of 96 C. Calculate how long the current flows.**

Current, resistance and potential difference

Potential difference (p d) is the difference in energy carried by electrons before and after they have flowed through a component. It is measured in volts (V) using a **voltmeter**. A voltmeter is always connected across the component. We say the voltmeter is connected in **parallel** (Figure 2.11). Circuit symbols are shown in Figure 2.10.

For an electric current to flow, there needs to be a complete loop and a source of potential difference.

Potential difference is sometimes referred to as voltage. Current, *I*, **resistance**, *R* and potential difference, *V* are linked by the equation:

potential difference, V = current I × resistance, R
(in volts, V) (in amperes, A) (in ohms, Ω)

$$V = IR$$

Example: Calculate the potential difference across a 5 Ω resistor when the current through it is 2A.

$V = IR = 2 \times 5 = 10$ V.

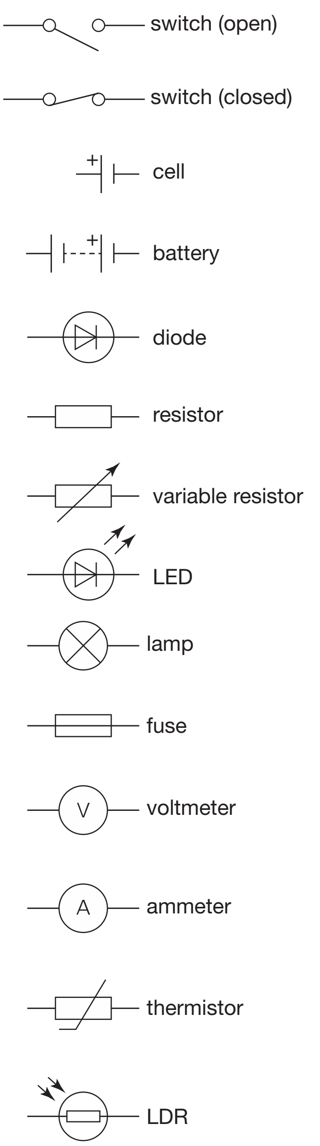


Figure 2.10: Circuit symbols

1 volt is the energy transferred when 1 coulomb of charge moves through a component. 1 V = 1 J/C. If a 12 V battery is used to light a lamp, each coulomb of charge going from the battery receives 12 J of energy.

3 **State two things that are needed for there to be an electric current.**

4 **Calculate the resistance of a car headlamp when the supply potential difference is 12 V and the current is 3 A.**

5 **A 6 V battery passes a current of 1 A through a lamp for 1 minute. Calculate how much energy is transferred from the battery to the lamp.**

6 **Calculate the potential difference across a 6 Ω resistor when the current through it is 1.5 A.**

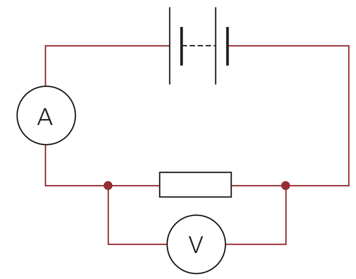


Figure 2.11: Measuring the pd across a resistor using a voltmeter

Current in a circuit

Electrons are 'pushed' around a circuit by a battery. They bump into the atoms in the resistor. This makes the atoms vibrate more so the resistor gets hotter. The increased atomic vibrations make it harder for the electrons to travel through the resistor so its resistance increases (Figure 2.12).

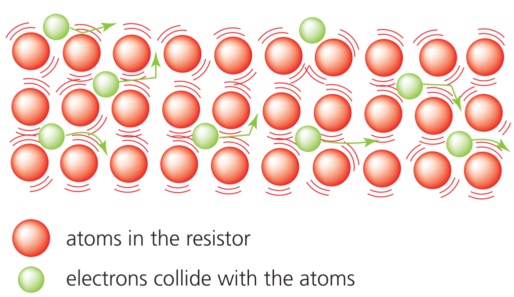


Figure 2.12: The movement of electrons in a wire carrying a current

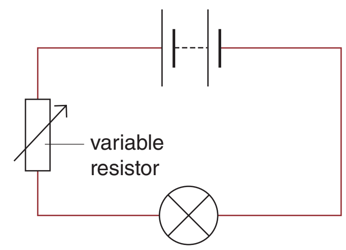


Figure 2.13: Circuit with variable resistor and lamp

The filament in a lamp connected in a circuit becomes so hot it emits light.

Note that the net direction in which the electrons move is opposite to the direction of the conventional current. The conventional current direction, from positive to negative, was well established before scientists understood that the electrons actually moved from negative to positive. So they did not change it.

DID YOU KNOW?

Superconductors are materials that have an electrical resistance of zero at very low temperatures. No battery is needed to maintain a current.

7 **Explain why the wire in Figure 2.13 gets hot.**

8 **The circuit shown in Figure 2.14 includes a variable resistor. Explain how it can be used as a dimmer switch.**

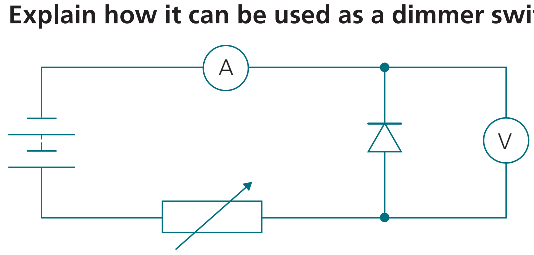


Figure 2.14

ADVICE

When a current passes through a wire the wire can get hot and its resistance increases. When carrying out experiments involving current, only leave the circuit switched on for as long as you need to record measurements.

Series and parallel circuits

Learning objectives:

- Recognise series and parallel circuits
- Describe the changes in the current and potential difference in series and parallel circuits

KEY WORDS

series circuit
parallel circuit

All the electrical appliances in a home are connected in a parallel circuit. If they were connected in series you would need to switch on every single appliance in order to watch TV.

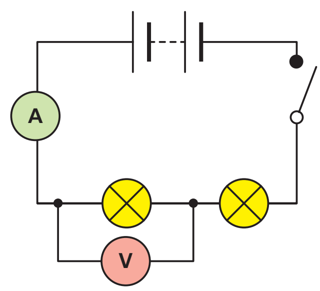
Lamps in series and parallel

In the **series circuit** in Figure 2.15 the lamps are connected next to each other and form a single loop with the battery and the switch. In the **parallel circuit** both sides of the lamps are connected to each other – a little like the rungs of a ladder.

When they are shining, the lamps connected in parallel are brighter than lamps connected in series.

If an extra lamp is added to the series circuit, then all of the lamps in the circuit are even dimmer. If an extra lamp is added to the parallel circuit the lamps are the same brightness as before.

Series circuit



Parallel circuit

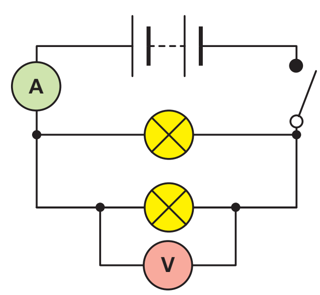


Figure 2.15: A series circuit and a parallel circuit.

1. **All of the lamps in Figure 2.15 are not currently shining. State what you would have to do to the circuits to make the lamps shine.**
2. **A third lamp is added to the series circuit. Describe what happens to the brightness of the two lamps that were already in the circuit.**
3. **Suggest what would happen if one bulb was unscrewed in each circuit.**

Resistors in series

In the series circuit in Figure 2.16 the current has to pass through **both** resistors, R_1 **and** R_2. There is nowhere else for it to go. This means that the readings on all of the ammeters are the same.

When components are connected in series, the same current flows through each component. The size of the current depends on the total resistance of the components.

For components in series the total resistance is the sum of all of the resistances. The total resistance of the circuit in Figure 2.16 is $R_1 + R_2$.

The potential difference of the power supply is shared between the components. This means that the reading of voltmeter V_1 plus the reading of voltmeter V_2 would equal the potential difference of the battery.

4 A motor, a lamp and a 12 V battery are connected in series. The resistance of the motor is 10 Ω and the resistance of the lamp is 20 Ω. The current through the lamp is 0.4 A.

a Determine the current through the motor.

b Calculate the total resistance of the circuit.

c If the potential difference across the motor is 4 V then what is the potential difference across the lamp?

d Suggest how the current would change if the lamp was replaced with a 50 Ω resistor.

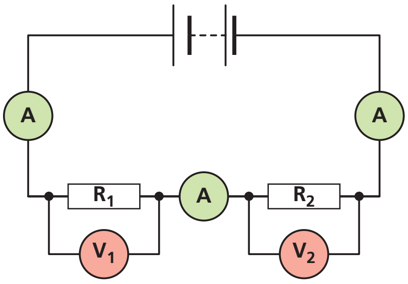


Figure 2.16: A series circuit

Resistors in parallel

In the parallel circuit in Figure 2.17, the current can pass through either R_1 or R_2 in the circuit. This means that the reading on ammeter A_1 is equal to the sum of the readings on ammeters A_2 and A_3.

The potential difference of the power supply is the same as the potential difference across each component. So the reading of both voltmeters V_1 and V_2 would be the same and would equal the potential difference of the power supply.

Adding a resistor in series increases the total resistance because the electric charge has to pass through another component. Adding a resistor in parallel decreases the total resistance because you are providing an alternative path for the electric charge to go. The total resistance of a parallel circuit is always smaller than the smallest resistance of any component.

DID YOU KNOW?

A current of 1 A means that more than 6 000 000 000 000 000 000 electrons pass each point every second. This is only a small fraction of the electrons in the wire!

5 The 10 Ω motor, 20 Ω lamp and 12 V battery from Q4 are now connected in parallel. A current of 1.8 A passes through the battery and a current of 1.2 A passes through the motor.

a Determine the current through the lamp.

b Calculate is the potential difference across the motor.

c Explain whether the total resistance of this circuit is greater or smaller than 10 Ω.

d A further resistor is added in parallel to the motor and the lamp. Explain what happens to the size of the current passing through the battery.

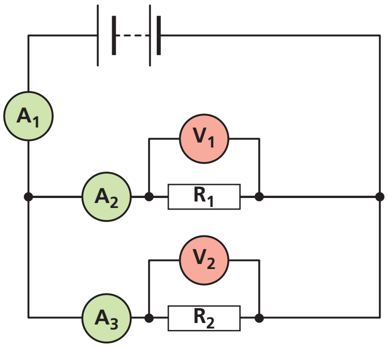


Figure 2.17: A parallel circuit.

Investigating circuits

Learning objectives:

- use series circuits to test components and make measurements
- carry out calculations on series circuits.

KEY WORDS

ammeter
equivalent resistance

When a sports match is televised it can take 24 km of electrical cabling to connect up the TV cameras and the studio. If the equipment goes wrong, engineers need to check quickly that the cables are working. How can they do this?

Circuits for testing and measuring

You can use the circuit in Figure 2.18 to check if a component or an electrical cable conducts electricity easily. The buzzer should sound when the cable or the component is attached to the terminals.

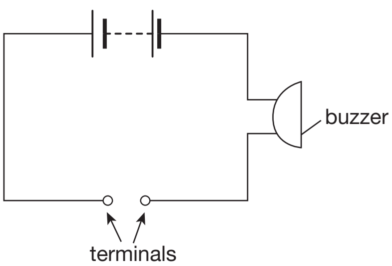


Figure 2.18: A circuit for testing components and cables

1 Explain how the circuit in Figure 2.18 works.

The circuit in Figure 2.19 is used to investigate the resistance of a component. You connect the component between the terminals. This circuit can be used to investigate lamps and diodes as well as components that measure temperature and light intensity.

The **ammeter** measures the current passing through the component and the voltmeter measures the potential difference across the component. Ammeters are always connected in series with the component and voltmeters are always connected in parallel. Voltmeters have a very high resistance which means that only a very small current flows through a voltmeter. Ammeters have a very low resistance which means that they do not have very much effect on the resistance of the circuit.

You can change the current by altering the resistance of the variable resistor. The resistance is usually altered by moving a slider or by turning a dial.

KEY INFORMATION

Remember: the resistance of a component equals the potential difference divided by the current.

2 An electric heater is placed between the terminals of the circuit in Figure 2.19. The ammeter reading is 2 A and the voltmeter reading is 12 V.

a Calculate the resistance of the heater.

b Describe how you could alter the circuit so that a current of 1 A passes through the heater.

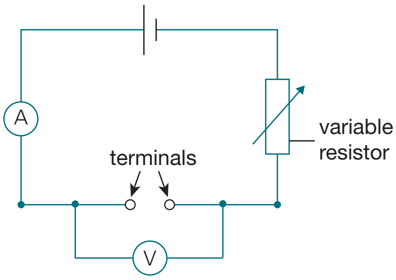


Figure 2.19: A circuit to measure the resistance of a component

Circuit calculations

These rules help you to calculate currents, potential differences and resistances in circuits.

For resistors in series, the total potential difference is the sum of the potential differences across the resistors and the current is the same through all of the resistors. The total resistance is the sum of the resistances of the resistors.

For resistors in parallel, the potential difference across each resistor is identical, but the total current is the sum of the currents that pass through each of the resistors.

3 **A resistor, an ammeter and a voltmeter are connected in series with a 12 V power supply. The ammeter shows the current as 0 A. Suggest what is wrong with the circuit.**

4 **The potential difference across a resistor is 12 V and the current is 0.6 A. What is the value of its resistance?**

5 **A 5 Ω and a 7 Ω resistor are connected in series with a 6 V battery. Calculate the current in the circuit.**

6 **A 3 Ω and a 6 Ω resistor are connected in series with a 12 V battery. What is the potential difference across the 3 Ω resistor?**

7 **A 3 Ω resistor and a 6 Ω resistor are connected in series with a battery. A current of 1 A passes through the 3 Ω resistor. Determine the potential difference of the battery.**

8 **A 4 Ω resistor is placed in series with another resistor and a 12 V battery. The potential difference across the 4 Ω resistor is 8 V. Determine the resistance of the other resistor.**

DID YOU KNOW?

When you make a series circuit with a 1.5 V battery, a torch bulb and 2 m of connecting wire, it will take about 2 days for an electron to go around the circuit.

Equivalent circuits

Sometimes you can simplify circuit calculations by replacing all the components in a circuit with a single resistor (Figure 2.20). The single resistor needs to have the **equivalent resistance** of the components in the circuit. You can then work out the current passing through the power supply.

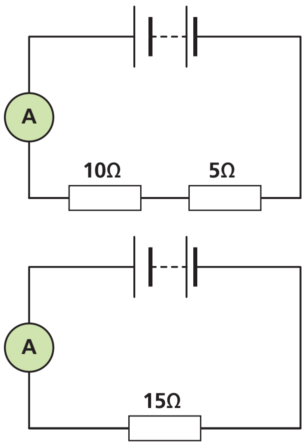


Figure 2.20: These circuits draw the same current from the battery.

9 **A 12 V car battery is supplying a current of 60 A to the electric components in a car. The driver then switches on the sound system and a larger current passes through the battery. What happens to the equivalent resistance of the circuit?**

10 **A 12 Ω motor is connected in parallel with a 6 Ω lamp. Together these are connected in series with a 5 Ω resistor and a 9 V battery. The equivalent resistance of the motor, lamp and resistor is 9 Ω. Calculate the current passing through the battery.**

Circuit components

Learning objectives:

- set up a circuit to investigate resistance
- investigate the changing resistance of a filament lamp
- compare the properties of a resistor and filament lamp.

KEY WORDS

filament bulb

New light bulbs have been introduced to replace the filament bulb. The so-called 'energy saver' light bulb lasts longer and is more economical to use, but it has the disadvantage that it contains mercury, which is toxic.

Measuring resistance

The circuit shown in Figure 2.21 can be used to measure the resistance of a fixed resistor. As the variable resistor is changed, the readings on the ammeter and voltmeter are recorded. A graph of current (I) against potential difference (V) is plotted. A straight line through the origin shows that current is proportional to potential difference (Figure 2.22). Such resistors are **ohmic** – they obey Ohm's law. Their resistance is constant. The resistance is equal to 1/gradient of an I–V graph. Copper wire and all other metals give this shape of graph as long as the temperature does not change.

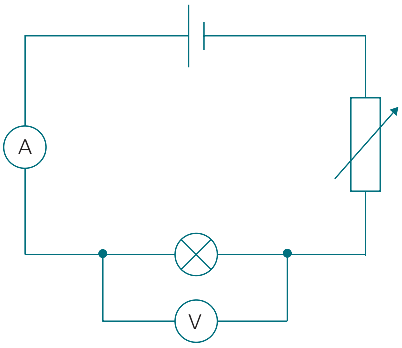


Figure 2.21: This circuit can be used to measure the resistance of a filament bulb.

1. **What does a straight line graph through the origin tell you about the quantities plotted?**
2. **Which meter is connected in parallel, the ammeter or the voltmeter?**

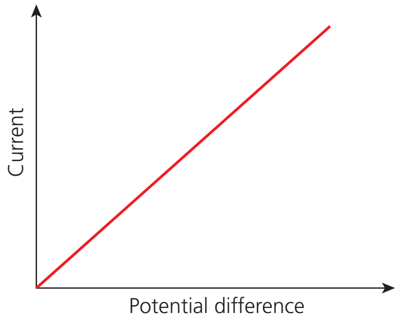


Figure 2.22: I–V graph for an ohmic conductor.

The changing resistance of a filament lamp

If you switch on a light bulb using a dimmer switch, you will see that you can change the brightness of the bulb. This is because the higher the current, the higher the temperature of the filament. The hotter the bulb, the whiter and brighter the light from it becomes.

If the fixed resistor in Figure 2.21 is replaced by a filament bulb, as in Figure 2.23, the corresponding graph of current against voltage is no longer a straight line. This is because the resistance of the filament bulb changes as its temperature changes. If you measure the gradient at different points on the graph (Figure 2.24) you will obtain different values for the resistance of the filament because the resistance is different for each voltage and current value.

The greater the gradient of the graph, the lower the resistance. The smaller the gradient of the graph, the higher the resistance.

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When the filament in a bulb gets hot, two things happen. The free electrons move faster, and the atoms in the filament vibrate more, taking up more space. As the atoms take up more space, the electrons collide with them more often, so the resistance and temperature of the bulb increase (Figure 2.23). This is why the resistance of a filament bulb increases with temperature.

The filament is made of tungsten as tungsten does not melt and evaporates very little at the typical filament bulb operating temperature of 2000 °C. An inert gas such as nitrogen or argon is usually included in the bulb to prevent the evaporation of the tungsten.

3 **Explain how do you know that the filament lamp is a non-ohmic conductor.**

4 **The filament in a bulb is made from tungsten. Tungsten, like other metals, obeys Ohm's law. Why is the I–V graph for a filament lamp not a straight line?**

Comparing I–V graphs

A fixed resistor at constant temperature produces a straight line *I–V* graph (Figure 2.22), showing the resistance is constant. The value of the resistance is equal to the inverse of the gradient of the *I–V* graph.

The filament of a lamp is a heating element that gets so hot that it emits light. This huge temperature change means that the filament is non-ohmic – its resistance increases as the temperature increases. The *I–V* graph is a curve (Figure 2.24) – it is non-linear. The resistance of the bulb at different voltages can only be found from instantaneous *I–V* values, not from the gradient.

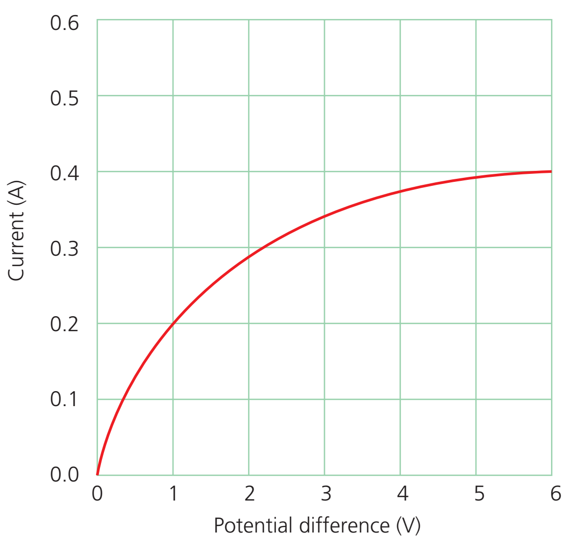

Figure 2.24: The changing slope of this graph shows that the resistance of the filament lamp increases as the current increases

5 **a** **Calculate the resistance at 1 V and 6V in Figure 2.23.**

b **Suggest why the resistance changes in this way.**

DID YOU KNOW?

The average light bulb has a lifetime of about 1000 hours. The tungsten used to make the filament evaporates at 2500 °C.

Figure 2.23: Coiled tungsten filament lamp

KEY INFORMATION

The resistance of a non-ohmic conductor is found from instantaneous values, not the gradient of the graph.

REQUIRED PRACTICAL

Use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits, including the length of a wire at constant temperature and combinations of resistors in series and parallel.

KEY WORD

potential difference
current
resistance
series
parallel

Learning objectives:

- use a circuit to determine resistance
- gather valid data to use in calculations
- apply the circuit to determine the resistance of combinations of components.

These pages are designed to help you think about aspects of the investigation rather than to guide you through it step by step.

We can use a circuit to determine the resistance of a component as resistance can be calculated from potential difference and current. We can then see how the resistance is affected by factors such as the length of a wire or when several components are combined.

Using a circuit to get useful data

The resistance of a component, such as a piece of wire, can be calculated using the formula:

resistance = potential difference ÷ current

If we set up a circuit with an ammeter and a voltmeter in it, we can record the data to calculate the resistance. The circuit we can use is shown in Figure 2.24. The rectangle represents the component being tested, such as a length of wire.

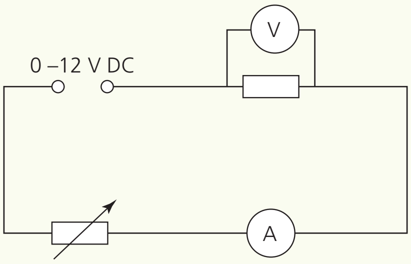

Figure 2.25: Circuit diagram for measuring potential difference across a component and the current passing through it

1. **Explain what you would expect to happen to the current passing through the component as the potential difference across it is increased.**
2. **Describe how the potential difference across the component is altered in the circuit shown.**
3. **If the current passing through the component increases, describe what will happen to its temperature.**

REQUIRED PRACTICAL

2.7

Length of a wire and its resistance

When the component being tested is a length of wire, we can find out how the resistance changes when the length is altered. For each length of wire, we can record the potential difference across the wire and current passing through it and use them to calculate the resistance. We can then plot a graph of resistance against length of the wire to show how changing the length of the wire affects the resistance.

One of the factors that can affect the accuracy of the results is temperature. As more current passes through the wire it gets hotter and this alters the resistance. It is important to avoid thermal energy building up in the wire.

4 **In this experiment, state what readings would be taken and what calculations would be done.**

5 a **Predict what effect the length of a wire will have on its resistance.**

b **Sketch a graph showing your prediction.**

6 **Suggest a good way of stopping the heating effect of the current affecting the results too much.**

Figure 2.26: Resistors in series

Investigating combinations of components

We can also join components together and see what the combined resistance is. We can connect them in series as shown in Figure 2.26. We can then measure the potential difference across it and the current passing through and calculate the combined resistance of the resistors in series.

We can also do this with components in parallel as shown in Figure 2.27. This will enable us to investigate what the combined resistance of the resistors in parallel is.

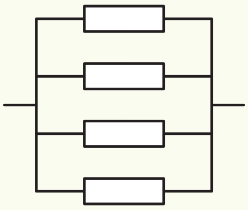

Figure 2.27: Resistors in parallel

7 a **Draw a circuit diagram to show how measurements could be taken to calculate the resistance of two components in series.**

b **Predict what you would expect the combined resistance to be, compared with the resistance of the individual components.**

8 a **Draw a circuit diagram to show how measurements could be taken to calculate the resistance of two components in parallel.**

b **Predict how you would expect connecting components in parallel to affect the overall resistance compared with the individual components. Explain your answer.**

REMEMBER!

The greater the resistance, the higher the potential difference is needed to make a certain current pass.

DID YOU KNOW?

The formula $V = IR$ is also known as Ohm's law. This is not strictly correct as it applies to any component, whereas Ohm's law only applies to certain components, and then only if the temperature is kept constant.

Control circuits

Learning objectives:

- use a thermistor and light-dependent resistor (LDR)
- investigate the properties of thermistors, LDRs and diodes

KEY WORDS

thermistor
light-dependent resistor (LDR)
sensors
diode
light-emitting diode (LED)

LDRs are placed on top of street lights to turn them on when it gets dark.

Control circuits

Control circuits use components to detect changes. These components are called **sensors**.

A **thermistor** (Figure 2.28) is a temperature-dependent resistor. Its resistance changes a lot as temperature changes. At low temperatures its resistance is high. As the temperature increases its resistance decreases.

A **light-dependent resistor (LDR)** is a component whose resistance changes a lot as light intensity changes. When it is light the resistance of the LDR is low. When it is dark the resistance of the LDR is very high.

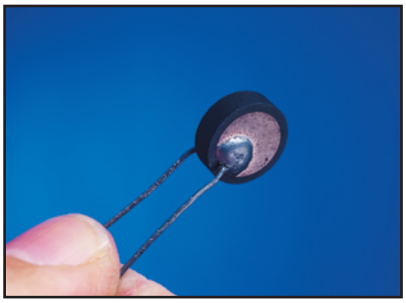

Figure 2.28: Thermistor

1. **What property of an LDR changes as the light level changes?**
2. **What happens when the temperature of a thermistor increases?**

The properties of thermistors

The resistance of a thermistor decreases as the temperature increases. Each thermistor has its own characteristics, but the resistance of a typical thermistor changes from 2000 Ω at –20 °C to 200 Ω at 20 °C.

A thermistor is made from a semi-conductor. A semi-conductor is neither a good conductor nor an insulator. When a semi-conductor is heated it can conduct more easily. This is because the rise in temperature releases more free electrons to carry the current. The higher the temperature the lower the resistance (Figure 2.29).

The resistance of a thermistor is highest when cold. It can be used to

- turn on a heater when it gets cold, either in the house or in a greenhouse
- act as a fire alarm
- keep a fish tank from becoming too cold.

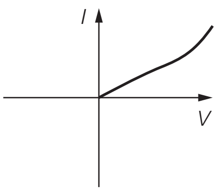

Figure 2.29: *I*–*V* graph for a thermistor

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3 **Explain how you know that a thermistor is not an ohmic conductor.**

4 **Increasing the current causes the thermistor to get hotter. How does this affect its resistance?**

The properties of light-dependent resistors

In bright sunlight an LDR has a resistance of about 100 Ω. When it is dark the resistance of the LDR becomes very large. It can be over 10 MΩ (10 000 000 Ω) in the dark.

An LDR can be used to make a simple light meter.

When it is bright the resistance of the LDR is low and the reading on the milliammeter is high (Figure 2.30). When it is dark the resistance of the LDR is high and the reading on the milliammeter is low.

This can be used by a cricket umpire to decide whether it is too dark to carry on playing safely.

5 **Describe what happens to the current if you cover and uncover an LDR when a bright light is shining on it.**

The properties of a diode

A **diode** is a component that only allows a current to flow in one direction – the direction in which the arrow points in the circuit symbol (Figure 2.31).

The current–potential difference characteristics for a diode (Figure 2.32) can be found using a circuit similar to the one used to draw the *I*–*V* graph for a filament lamp.

Most diodes start to conduct when the potential difference across them is about 0.6 V. The steep slope of the graph shows that current passes easily through the diode when it is conducting. With a negative potential difference, very little current flows.

6 **Explain what the *I*–*V* graph for a diode tells you about the resistance of the diode when the potential difference is negative.**

7 **Explain whether a diode obeys Ohm's law.**

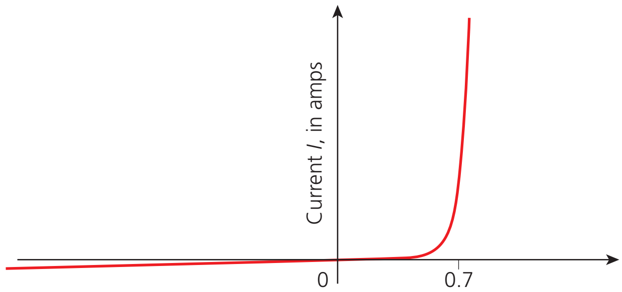

Figure 2.32: *I*–*V* graph for a diode

DID YOU KNOW?

Some incubators for new-born babies use thermistors that detect a 0.1 °C change in temperature.

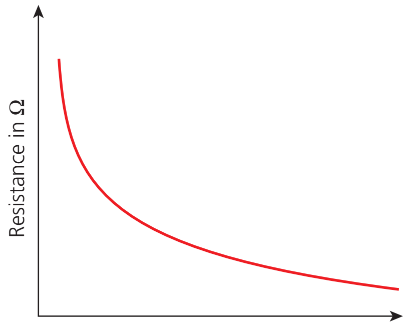

Figure 2.30: Change in resistance with light level in an LDR

REMEMBER!

The resistance of an LDR is Low in the Light.

Figure 2.31: The arrow on the diode symbol tells you which way the current passes through it.

Electricity in the home

Learning objectives:

- recall that the domestic supply in the UK is a.c. at 50 Hz and about 230 V
- describe the main features of live, neutral and earth wires.

KEY WORDS

earth
live
neutral
fuse

A circuit-breaker (Figure 2.33) is a resettable fuse. It has replaced the wire fuse in the main fuse box as it can be reset at the flick of a switch.

Figure 2.33: Circuit-breaker

Domestic electricity supply

A cell or battery has two terminals, positive and negative. The current is d.c. which means that it always passes in the same direction.

Mains electricity differs in two ways (Figure 2.34):

- The current alternates, that is it changes direction. It has a frequency of 50 Hz.
- It has a much higher potential difference (about 230 V).

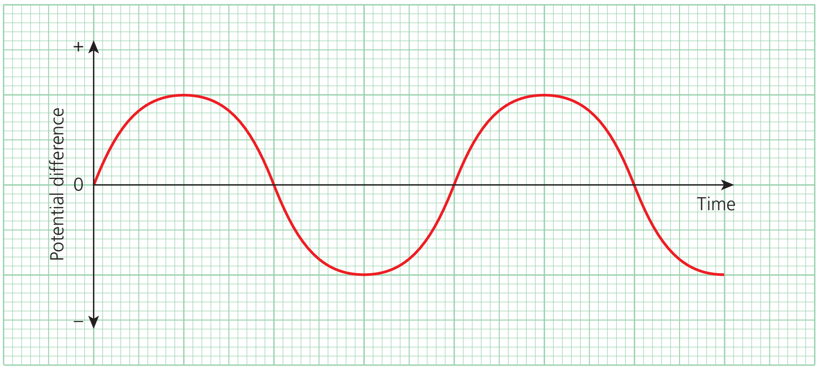

Figure 2.34: The potential difference variation from the mains

1. **How many times does the potential difference change direction each second?**
2. **Describe the difference between a direct and an alternating potential difference.**

Connecting a three-pin plug

Live, neutral and **earth** wires can be seen in a plug (Figure 2.35). If the appliance is working properly, there should be no current in the earth wire.

The three wires inside the mains cable are colour-coded:

- brown is connected to the live terminal (L)
- blue is connected to the neutral terminal (N)
- green/yellow stripe is connected to the earth terminal (E).

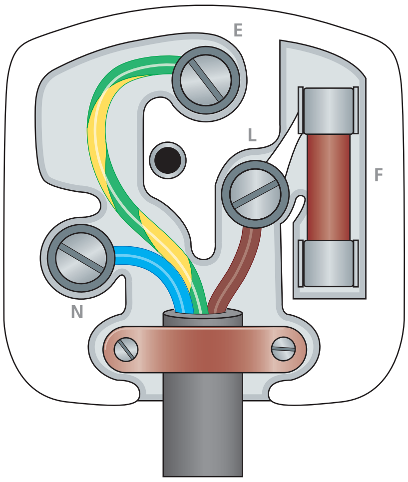

Figure 2.35: What colour is the earth wire?

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3 **Explain why most electric wires in the home are covered in plastic.**

4 **State the colour of the neutral wire.**

Live, neutral and earth wires

Our bodies are at Earth potential – there is no potential difference between our bodies and the Earth. If the casing of a faulty appliance becomes live, the potential difference between it and Earth is 230 V. If a person touches it, there is a complete circuit and current passes through the person's body to Earth. The person receives an electric shock. If the appliance is earthed it is connected to the Earth or ground (Figure 2.35). Any charge in it flows safely down to the ground through the low-resistance earth wire. This stops a person receiving an electric shock if they touch the live case of a faulty appliance.

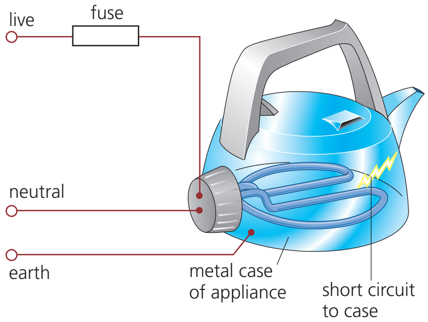

Figure 2.36: The arrangement of wires in a metal-cased appliance

The mains electricity supply usually comes from a power station. Two wires connect a house to a power station – live and neutral.

- The live wire carries a high potential difference into and around the house. The **fuse** in the plug (F) is always connected to the live wire.
- The neutral wire provides a return path to the local sub-station. The neutral wire is earthed. There is no current in the neutral wire until an electrical appliance is connected.
- The earth wire is a safety wire. It is connected to the metal case of an appliance to prevent it becoming charged if touched by a live wire. It provides a low-resistance path to the ground. There is normally no current in it.

5 **Describe the function of the earth wire.**

6 **Explain why a battery-powered torch has two connections to its power supply but a mains lamp has three.**

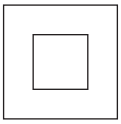

Figure 2.37: Double insulation symbol

DID YOU KNOW?

A double-insulated appliance does not need an earth connection (Figure 2.37). It has a plastic case with no electrical connections to it, so the case cannot become live.

REMEMBER!

A fuse is always connected in the live wire.

Transmitting electricity

Learning objectives:

- describe how electricity is transmitted using the National Grid.
- explain why electrical power is transmitted at high potential differences.
- understand the role of transformers.

KEY WORDS

National Grid
transformer

In the USA the potential difference used is 110 V instead of 230 V as in the UK. This means the wires have to carry twice the current to make appliances work.

The National Grid

When electricity was first delivered to homes, each town had its own local power station. If the power station broke down then the town did not receive any electric power. Each power station produced electricity at a different potential difference. This meant that electric appliances, such as light bulbs, would only work in one town. If you moved house you would have to buy new ones.

The **National Grid** is a collection of power stations, power cables and transformers that connect power stations to factories and houses across Great Britain. Everything is connected up in a grid so that electrical power can be transferred along many different routes. This means that the electrical power in your house can come from lots of different power stations.

Figure 2.38: Power cables connected in the National Grid

1. **State an advantage of connecting your house to the National Grid rather than just connecting it up to a local power station.**
2. **Explain what the words National and Grid mean when referring to the transmission of electrical power.**

Changing the potential difference

The potential difference of the domestic UK mains supply is 230 V. This means that there is a potential difference of 230 V between the live wires and the earth wires in a house.

Electrical power is transmitted across the country at 400 000 V. The potential difference between a live power line and the Earth is very large.

3. **Explain why it would not be a good idea for the potential difference to be 400 000V in a domestic electricity supply.**

An electric current passing through the National Grid's power cables heats up the cables. Energy is being transferred to the thermal energy stores of the surroundings rather than useful energy stores in houses and factories.

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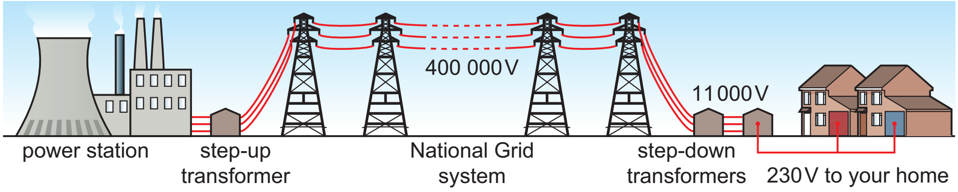

Figure 2.39: The National Grid.

The higher the current, the more energy is wasted and the National Grid becomes less efficient. For the same electrical power, increasing the potential difference reduces the current. So using a high potential difference makes the National Grid more efficient.

4 **Suggest why it is important that energy wasted by National Grid is minimised.**

5 **How does increasing the potential difference make the National Grid more efficient?**

Figure 2.40: Step-up transformers are installed close to the power stations.

Transformers

Transformers are devices that can change the potential difference. They are made from two coils of wire with some iron passing between them. Varying the number of turns on each coil changes the potential difference.

Step-up transformers increase the potential difference. They are connected between the power stations and the National Grid (Figure 2.40). Step-down transformers decrease the potential difference.

6 **State where step-down transformers are connected in the National Grid.**

7 **Transformers have no moving parts. Suggest why this means that they are very efficient.**

Figure 2.41: Birds on power lines

Power and energy transfers

KEY WORD

power

Learning objectives:

- describe the energy transfers in different domestic appliances
- describe power as a rate of energy transfer
- calculate the energy transferred.

Much more energy is transferred when you heat a room than when you light a room.

Energy transfers

Electrical devices that we use every day are designed to transfer energy. All electrical appliances transfer energy electrically. But different appliances transfer energy in different ways. They transfer energy from the a.c. mains supply or stores such as batteries to stores such as the kinetic energy store of a motor or the thermal energy store of hot water in a kettle.


Figure 2.42: A hairdryer

1 State the energy transfers and stores when a kettle is used to heat water.

Power and energy transferred

Consider a hairdryer (Figure 2.42). The hairdryer receives 1500 J of energy each second from the mains supply. It transfers 1500 J of energy per second electrically from the mains supply to two main energy stores: thermal energy stored in the air and kinetic energy in the moving air.

The **power** is the amount of energy transferred each second. The units are joules per second, of watts (W). As the hairdryer transfers 1500 J each second, its power is 1500 W or 1.5 kW.


Figure 2.43: An electric drill

2 An electric drill (Figure 2.43) connected to the a.c. mains transfers 400 J every second.

a Describe how the drill transfers energy and the stores it transfers energy to.

b State the power of the drill.

The amount of energy transferred by an appliance depends on its power and the length of time it is used. We can use this equation to calculate the amount of energy transferred.

Electrical energy = power × time

(in joules, J) (in watts, W) (in seconds, s)

$E = Pt$

Example:

The hairdryer in Figure 2.42 is used for 5 minutes. Calculate the total energy transferred by the hairdryer.

$E = Pt$

$= 1500\text{ W} \times (5 \times 60)\text{ s}$

$= 450\,000\text{ J}$ (or 450 kJ)

3 **An electric oven with a power rating of 2.5 kW is switched on for 45 minutes.**

Calculate the total energy transferred by the oven.

4 **A hairdryer transfers 10 000 J of energy from the a.c. mains supply in 5 s. Calculate its power.**

Charge and energy transferred

When charge flows in a circuit, electrical work is done. We can calculate the amount of energy transferred by electrical work using the equation:

energy transferred, E = charge flow, Q × potential difference, V

(in joules, J) (in coulombs, C) (in volts, V)

$$E = QV$$

Example:

A charge of 50 C flows through a device with a potential difference across the device of 12 V.

Calculate the total energy transferred.

$E = QV$

$= 50\text{ C} \times 12\text{ V}$

$= 600\text{ J}$

5 **A charge of 30 C flows through a TV which is connected to the mains supply of 230 V.**

Calculate the total energy transferred.

6 **A device transfers a total of 1800 J with a charge of 75 C.**

Calculate the potential difference across the device.

DID YOU KNOW?

Homes and offices use electricity at 230 V but hospitals and schools receive it at 11 000 V. Large factories receive it at 33 000 V.

Calculating power

Learning objectives:

- calculate power
- use power equations to solve problems
- consider power ratings and changes in stored energy.

KEY WORD

power

We use the word power a lot – 'a powerful idea' or 'a powerful piece of music'. However, in science, we use it in a very specific way – as a measure of how quickly energy is transferred. Unlike ideas or music, this power can be calculated.

Calculating power

The power transfer in any component is related to the potential difference across it and the current passing through it. We can calculate power using the equation:

power, P = potential difference, $V \times$ current, I

(in watts, W) (in volts, V) (in amps, A)

$P = VI$

When a current passes through a resistor, such as a kettle element, it has a heating effect. Work is done by the electrons which is transferred to thermal energy in the element.

As $V = IR$, so $P = (IR) \times I = I^2R$

So the power transfer is also given by the equation:

power = $(\text{current})^2 \times$ resistance

(in watts, W) (in amps, A)^2 (in ohms, Ω)

Example: Jo boils a kettle of water to make a cup of tea (Figure 2.44). The kettle has a power rating of 2.4 kW.

The mains supply is 230 V. Calculate:

a the current in the kettle element

b the resistance of the kettle element.

Answer:

a $P = VI$

Rearrange the equation to make I the subject:

$I = P \div V = 2400\text{ W} \div 230\text{ V} = 10.4\text{ A}$

b Resistance of element, $R = P \div I^2 = 2400 \div (10.4)^2 = 22.2\ \Omega$

Figure 2.44: An electric kettle

1 **An electric heater takes a current of 4 A when connected to a 230 V supply.**

a Calculate its power.

b Calculate its resistance

2 **A lamp has a power of 36 W when connected to a 12 V supply.**

a Calculate the current through the lamp.

b Calculate the resistance of the lamp.

Heating up

We can use equations for power and energy transfer to solve problems.

Example:

An electric kettle connected to the 230 V mains supply draws a current of 10 A. It contains 2 kg of water. Calculate the rise in temperature of the water when the kettle is switched on for
1 minute.

The specific heat capacity of water is 4200 J/kg °C

Power of kettle, $P = VI = 230\ \text{V} \times 10\ \text{A} = 2300\ \text{W}$

Energy transferred in 1 minute (= 60 s) = Pt

= 2300 W × 60 s = 138 000 J

If we assume all this energy is given to the 2 kg of water in the kettle we can calculate the rise in temperature, $\Delta\theta$.

Energy transferred to water = mc $\Delta\theta$

138 000 J = 2 kg × 4200 j/kg °C × θ

θ = 138 000 ÷ (2 × 4200) = 4.5 °C

3 **In the example above it was assumed that all the energy carried by electricity is transferred into thermal energy of the water. Suggest what other stores the energy might be transferred to.**

4 **Al has an outdoor swimming pool. It is 15 m long, 10 m wide and 2 m deep. The density of water is 1000 kg/m³.**

a Calculate the mass of water in the pool.

b Al wants to warm the water from 17 °C to 22 °C.

Calculate how much energy is transferred.

c The power of the heater is 2 kW. Calculate how long it takes to raise the temperature of the water.

Changes in stored energy

A more powerful appliance can transfer energy more quickly.

A **battery-operated toy car** with a power rating of 5 W transfers 5 J every second. It increases the store of kinetic energy in the toy car. It also increases the store of energy in its surroundings by transferring energy by sound and friction.

An **electric cooker** with a power rating of 2 kW transfers 2 kJ every second. It increases the stores of thermal energy in the saucepan food is being cooked in and in the food itself. It increases the thermal energy stored in the food, the saucepan and the surroundings.

5 **Explain how the stored energy changes for these appliances when they are in use.**

a A microwave oven with a power rating of 800 W.

b A vacuum cleaner with a power rating of 1.6 kW.

KEY CONCEPT

What's the difference between potential difference and current?

Learning objectives:

- understand and be able to apply the concepts of current and potential difference.
- use these concepts to explain various situations

KEY WORDS

Potential difference
current
charge
resistance
power
energy

When we're exploring and using electrical circuits it's useful to be able to measure things. This enables us to explain why electricity is sometimes really safe and sometimes lethally dangerous. It isn't simply a case of saying that 'there's more electricity in one than the other'. You may well have seen a Van de Graaff generator being used. This produces sparks that will jump several centimetres of air, yet science teachers will sometimes demonstrate how they can make people's hair stand on end.

Potential difference and current

To understand what is going on, we need to think about two quantities, **potential difference** and **current**. These are not the same; understanding the difference will help make sense of a lot of things to do with circuits.

Current is a flow of **charge**. If you rub a balloon on a woollen jumper it becomes charged. The charge stays in the balloon (which is why it's called static – it doesn't move). As soon as it moves – we have a current. If you set up a simple circuit with battery, wires and a bulb, the bulb lights because there is a current in the circuit. Current is a flow of electrons moving through the wires. Current is measured in amperes (A).

Potential difference is the work done in moving that charge. It is an indication of how much energy the charge has. It is measured in volts (V). Potential difference is often referred to as voltage and both terms can be used, but the appropriate scientific term is potential difference. A 1.5 V battery isn't pushing charge very hard Figure 2.45, if you touch the two terminals you won't feel anything. A 12 V battery (such as that used in a car) pushes the charge harder and the mains (230 V) is pushing it much harder. At these levels it will overcome the **resistance** of the body and push the charge through you. The current can easily become enough to be fatal.

Figure 2.45: A 1.5 V battery

1. **If you pull a nylon jumper over your head in a darkened room you can sometimes feel something crackling and see sparks. What is happening?**
2. **Trucks have electrical systems that run on 24 V. How could you produce this using two car batteries?**

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The difference between potential difference and current

Potential difference is the energy transferred from one coulomb of charge between two points. Current is the flow of electrical charge.The size of the electric current is the rate of flow of electrical charge.

The bulb in the torch shown in Figure 2.46 is designed to use 4.8 V and carry 750 mA of current. This means the torch needs three 1.5 V batteries in series; these would push the charge through the bulb hard enough to make the bulbs glow, but not so hard that the bulbs would blow.

Figure 2.46: A torch

The electrical heater shown in Figure 2.47 is designed to use mains voltage (230 V) and carry 8 A. The charge is carrying more energy and there is more electrical charge flowing.

When lightning strikes, both the potential difference and current are huge. A thunderstorm can generate a potential difference of up to 500 000 V and the current from lightning can reach thousands of amps.

So why can someone be charged up using a Van de Graaff generator and not be in danger? The potential differences are high (even a small table top machine can produce up to 100 000 V) but the current is tiny, usually only a few milliamps. The high voltage produces the spectacular effects but the low current means it's safe.

Figure 2.47: An electric heater

3 **Is it true to say that the highest voltages are always the most dangerous?**

4 **Why do electricians sometimes say the 'It's the volts that jolts but the current that kills.'**

Why are potential difference and current important ideas?

Electrical power shows how quickly energy is being transferred; it is calculated from voltage times current. Increasing either of those means more power.

Resistance shows how hard the current is being opposed. A greater resistance means that there is less current (if the voltage is the same). Sometimes we want a lot of current to flow, such as in an electric oven (Figure 2.48), so it produces a lot of heat. On other occasions we want the current to be very small, such as the power indicator light on a TV. They both operate from the mains, but the indicator light has a much higher resistance. Resistance is calculated from voltage divided by current.

An electric oven

5 **What is the power rating of a bulb working on the mains voltage of 230 V and drawing a current of 0.05 A?**

6 **What would the resistance of this bulb be?**

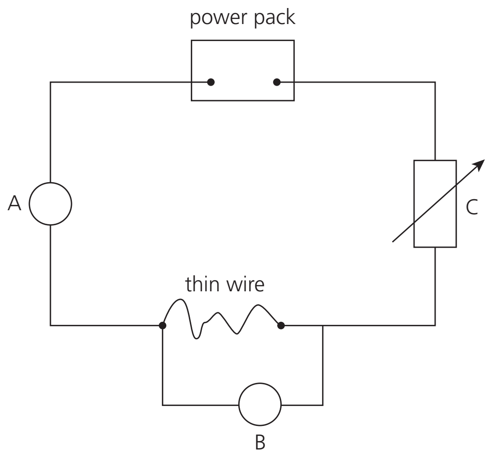
Check your progress

You should be able to:

Describe how insulating materials can become charged →	Recall that there are two types of charge and that like charges repel and unlike charges attract →	Explain how a person can get an electric shock and explain static electricity in terms of electric fields
Recall that an electric current is a flow of electrical charge and is measured in amperes (A) →	Remember that charge is measured in coulombs (C) and recall and use the equation $Q = It$ →	Explain the concept that current is the rate of flow of charge. Rearrange and apply the equation $Q = It$
Recognise and use electric circuit symbols in circuit diagrams →	Draw and recognise series and parallel circuits. Compare the brightness of lamps connected in series and parallel →	Recall that the current in a series circuit is always the same and that the total current in a parallel circuit is the sum of the currents through each branch
Recall that the current through a component depends on the resistance of the component and the potential difference across it →	Recall and apply the equation $V = I\,R$ and for series circuit $R_{total} = R_1 + R_2$ →	Explain the effect of adding more resistors to series and parallel circuits
Set up a circuit to investigate the relationship between *V*, *I* and *R* for a fixed resistor →	Draw *I*–*V* graphs for a fixed resistor →	Analyse and interpret *I*–*V* graphs for a fixed resistor
State the main properties of a diode, thermistor and light-dependent resistor (LDR)	Describe the behaviour of a thermistor and LDR in terms of changes to their resistance	Describe applications of diodes, thermistors and LDRs and explain their uses
Draw *I*–*V* graphs for a filament lamps	Explain the properties of components using *I*–*V* graphs	Use *I*–*V* graphs to determine if the characteristics of components are ohmic or non-ohmic
Recall that cells and batteries produce low-voltage direct current	Recall that domestic supply in the UK is 230 V a.c. and 50 Hz	Explain the difference between direct and alternating potential difference
Identify live, neutral and earth wires by their colour-coded insulation	Explain why a live wire may be dangerous even when a switch in the main circuit is open	Explain the dangers of providing any connection between the live wire and earth or our bodies
Recall that the National Grid is a system of cables and transformers linking power stations to consumers	Describe how step-up and step-down transformers change the potential difference in the National Grid	Explain why electrical power is transmitted at high voltages in the National Grid
Understand that everyday electrical appliance bring about energy transfer	Recall and use the equation energy transferred $E = Pt$	Recall and apply the equation energy transferred $E = QV$
Recall that power is measured in watts (W) and 1 kW = 1000 W	Recall and use the equation $P = V \times I$	Recall and apply the equation $P = I^2R$

Worked example

The diagram below shows a circuit used to investigate the resistance of a piece of thin wire.



1 **Name the three components in the circuit labeled A, B and C.**

A is an ammeter, B is a voltmeter and C is a thermistor.

2 **Give the purpose of component C.**

To regulate the temperature.

3 **The student recorded the potential difference across the thin wire and the current passing through it. She plotted her results on a graph. Explain which variable she should plot on each axis.**

She should plot potential difference on the x-axis and current on the y-axis.

4 **The student increased the potential different to 12 V. Explain what you think would have happened.**

The wire gets very hot.

5 **Explain how you would expect the graph to look if the wire had been replaced by a filament lamp.**

The same

A and B are correct, but C is a variable resistor.

Component C is used to change the potential difference or voltage across the test material.

This is correct, but the explanation has not been given. Potential difference is plotted on the *x*-axis because it is the independent variable, and current is plotted on the *y*-axis because it is the dependent variable.

The wire gets hot because of the large current passing through it. Large currents transfer lots of energy.

The line would initially be straight but then curve upwards as the temperature of the filament increases.

End of chapter questions

Getting started [Foundaton Tier]

1. What colour is the insulation on the earth wire in a three-pin plug? **1 Mark**
2. Draw the circuit symbol for a voltmeter. **1 Mark**
3. Calculate the current when 100 C of charge flows in 20 s. **2 Marks**
4. When measuring an electric current, should the ammeter be connected in series or parallel? **1 Mark**
5. Describe how you could charge a balloon so that it will stick to the wall. **1 Mark**

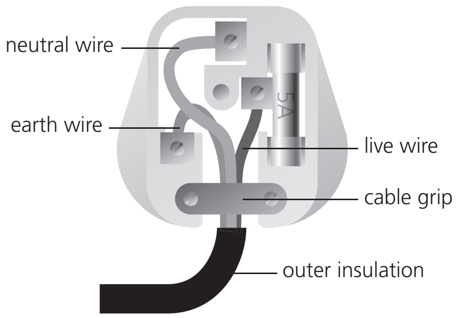


Figure 2.49

6. Describe what is wrong with the wiring in the plug in Figure 2.49. **2 Marks**

Going further [Foundation and Higher Tier]

7. Draw the circuit symbol for a thermistor. **1 Mark**
8. What are the frequency and voltage of the domestic mains supply in the UK? **2 Marks**
9. Two balloons are hung down next to each other by cotton threads. What will happen if both balloons are positively charged? **1 Mark**
10. What happens to the brightness of the lamps and the current in a series circuit if an additional lamp is added? **2 Marks**
11. A 2 kW kettle is attached to a 230 V mains supply. Calculate the current through the kettle. **2 Marks**

More challenging [Higher Tier]

12. What happens to the resistance of an LDR when the light level is decreased? **1 Mark**
13. Explain how a person gets an electric shock if they are charged and then earthed. **1 Mark**
14. Explain how a fuse acts as a safety device. **2 Marks**
15. Draw a circuit diagram of a circuit you could use to find the resistance of a short piece of nichrome wire. **2 Marks**

16 **Calculate the current through a lamp of resistance 8 Ω when connected to a 12 V battery.** 2 Marks

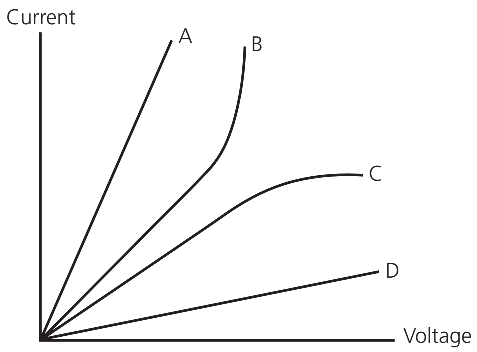


Figure 2.49

17 **The current–voltage characteristics for four components, A–D, were investigated and the results drawn on the graph in Figure 2.49. Which component was a filament lamp and which was a high-valued resistor?** 2 Marks

Most demanding [Higher Tier]

18 **Express power as an equation in terms of current and resistance.** 1 Mark

19 **What happens to the resistance of a thermistor as the temperature increases?** 1 Mark

20 **Explain the effect of adding resistors in series and in parallel on the total resistance of a circuit.** 2 Marks

21 **Calculate the energy transferred in 1 minute by a 60 W light bulb connected to a 230 V mains supply.** 2 Marks

22 **Four appliances were switched on for various times. Incomplete information about each and how long they were on for is shown in the table below. Which appliance transferred the most energy in the time given and how much energy was transferred?** 2 Marks

Appliance	Power rating (W)	Current (A)	Voltage (V)	Time left on (s)
Kettle	3000	12		20
Microwave	920		230	60
Torch		5	12	200
Food mixer		6	230	50

23 **Some railways use a supply at 25 kV whereas others use 750 V. Explain which supply leads to higher losses and why.** 3 Marks

Total: 37 Marks