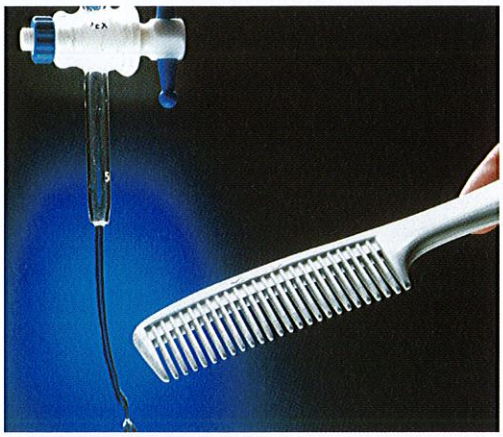
1.1 Charging up

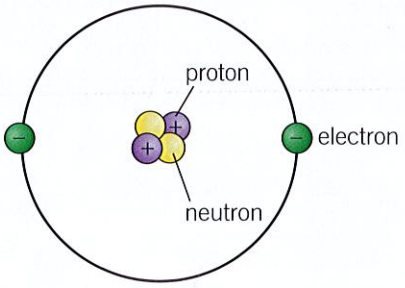
Learning objectives

After this topic you will be able to:

- explain how objects can become charged
- describe how charged objects interact
- describe what is meant by an electric field.



▲ You can bend a stream of water with static electricity.



▲ An atom contains three types of particle.

Link

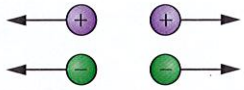
You can learn more about atoms in C1 2.2 Atoms

Because of static electricity you can stick a balloon to a wall or bend a stream of water. Static electricity produces lightning. What is static electricity, and where does it come from?

Attracting and repelling

There are two types of **electric charge**: **positive** charge (+) and **negative** charge (–). Charges **attract** or **repel** each other, like magnets do.

- **Positive** charges *repel* **positive** charges.
- **Negative** charges *repel* **negative** charges.
- **Positive** charges *attract* **negative** charges.



▲ Repelling.

▲ Attracting.

Memory jogger

Remember it like this: 'Like charges repel, unlike charges attract.'

A State the two types of electric charge.

Where does the charge come from?

Everything is made of particles called **atoms**.

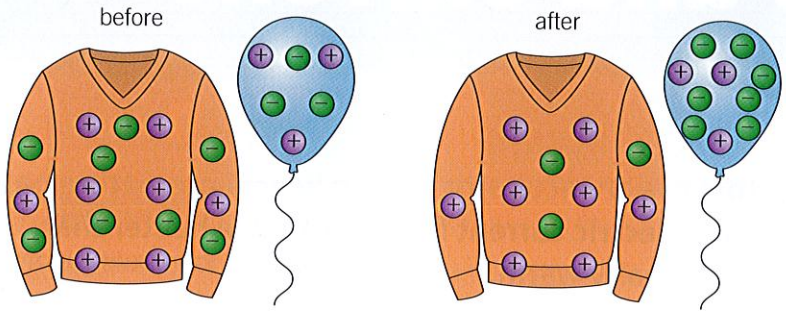
Atoms in turn are made of three types of smaller particle:

- **protons**, which have a positive charge
- **electrons**, which have a negative charge
- **neutrons**, which have no charge.

Charge is a property of a particle or object, just like mass.

Atoms contain equal numbers of protons and electrons. Overall an atom has no charge; it is **neutral**.

When you rub a balloon on your jumper some electrons are transferred from the jumper to the balloon. The balloon now has an overall negative charge. Your jumper has an overall positive charge. They will attract.



▲ Rubbing a balloon transfers electrons from your jumper to the balloon.

The balloon is made of rubber. The electrons stay on the balloon.

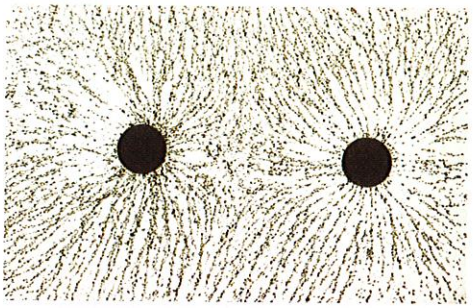
B State the charge on an electron, a proton, and a neutron.

Lightning

In a thundercloud air moves around, producing regions that have a positive or a negative charge. Electrons jump from one charged area to another and this produces a big **current**, which quickly heats the air. You see **lightning** and hear thunder.

What is an electric field?

There is an **electric field** around a charge, just as there is a gravitational field around a mass. If you put a charged object in an electric field, a force will act on it.



◀ Pepper grains line up in an electric field. This shows the electric field between two charges that are repelling.

Atomic puzzle

Unscramble the words below and pair them up. Explain why you have chosen to pair them that way.

notpro oneturn iviespot gianteve laterun centrelo

Key Words

electric charge, positive, negative, attract, repel, atom, proton, electron, neutron, neutral, current, lightning, electric field

▲ Lightning can strike a plane.

Fantastic Fact

Since you took your last breath lightning has struck the Earth 100 times. On average, airliners will get struck by lightning once a year.

Summary Questions

1 Copy and complete the sentences below.

There are two types of electric charge: _____ charge and _____ charge. When you rub a polythene rod with a cloth you transfer _____ from the cloth to the rod. Two polythene rods would _____ if you brought them close together. A polythene rod would _____ a rod that had a positive charge.

(5 marks)

2 A student rubs a balloon on his jumper and sticks it to the wall. Explain in terms of electrons why the balloon sticks to the wall.

(3 marks)

3 Compare a gravitational field and an electric field.

(6 marks QWC)

1.2 Circuits and current

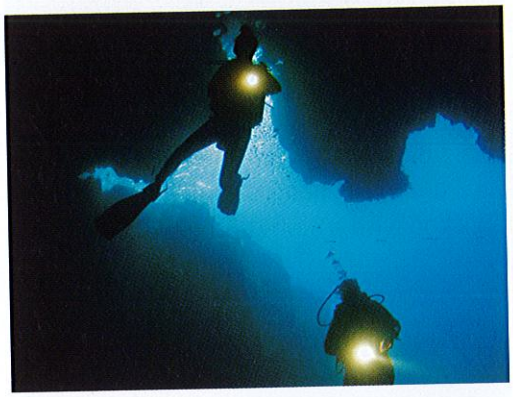
Learning objectives

After this topic you will be able to:

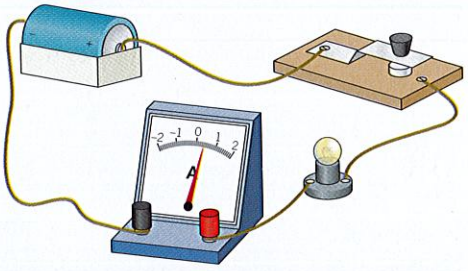
- describe what is meant by current
- describe how to measure current.

Doctors use an incubator to help keep a premature baby alive. An electric current flows through a heater that keeps the baby warm.

▲ A baby is kept warm using electric circuits.



▲ Divers need a torch to explore underwater caves.



▲ You connect an ammeter in a circuit to measure current.

What is current?

- When you complete a circuit, charged particles or charges move in the metal wires.
- The **current** is the amount of charge flowing per second.

When you press the **switch** on a torch the light comes on. The switch opens and closes a gap in the circuit. You need to close the gap and make a complete circuit for a current to flow.

When people talk about 'electricity' they usually mean 'electric current'.

A Describe what a current is.

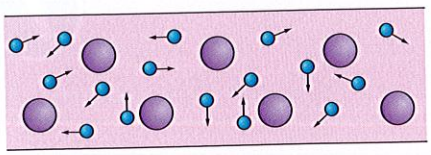
You can measure the current with an **ammeter**.

- Current is measured in amperes or **amps**.
- The symbol for amps is A. For example, the current in the circuit opposite is 0.4 A.

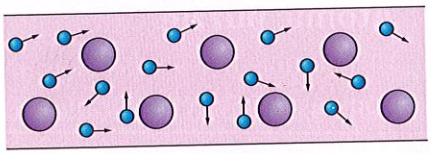
B Name the meter that you use to measure current.

Where do the charges come from?

The **cell** or **battery** pushes charges around the circuit. The battery does not produce the charges that move. They were already there in the wires. In a metal the charged particles that move are electrons.



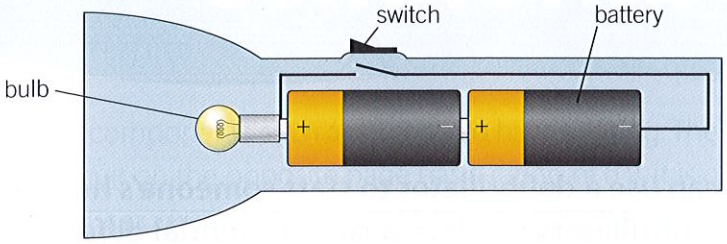
▲ The electrons are already in the wire.



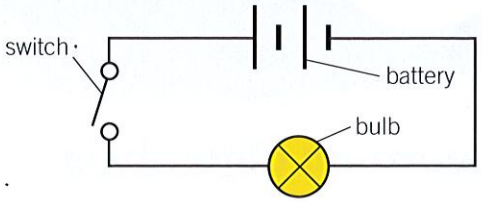
▲ The electrons move when you connect the battery.

Using circuit symbols

You can build circuits using components such as batteries, bulbs, and **motors**. It would take a long time to draw a picture of each circuit so you can use circuit symbols instead.



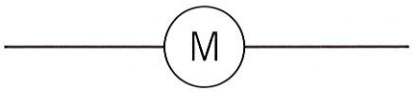
▲ This is a picture of a torch...



▲ ...and this is the circuit diagram.

In the torch diagram there are two cells. Cells used together like this are called a battery. People often use the word 'battery' for a single cell, but in physics we call it a cell.

You must make sure that you connect cells the right way round or they will not work.

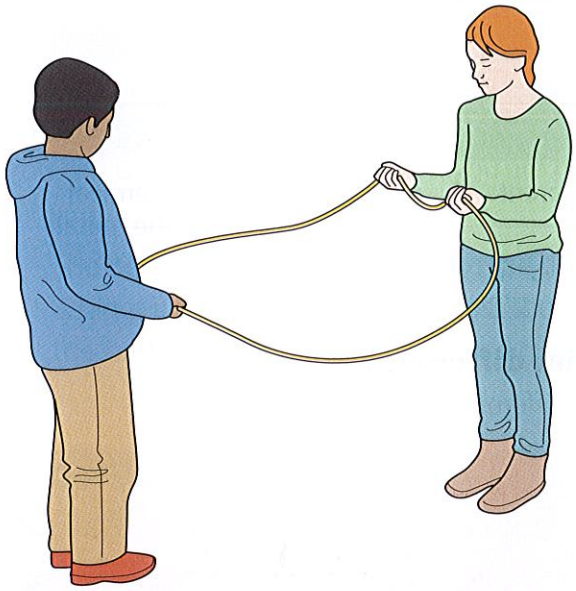


▲ Circuit symbols make it simpler to draw circuits.

Modelling electric circuits – part 1

You cannot see what happens in the wires when a current flows. Scientists use models such as the rope model to show what is happening. One person pulls the rope, and another person grips the rope lightly. The rope moves around. In this model:

- The rope represents the charges in the circuit.
- The amount of rope moving past a point per second is the current.



◀ A rope model can help you to understand circuits.

Confusing words?

For each of these words write one sentence using the word with its correct scientific meaning. Write a second sentence where it has a different, everyday meaning.

- charge
- current
- cell

Key Words

current, switch, ammeter, amps, cell, battery, motor

Summary Questions

1 Copy and complete the sentences below.

Current is the amount of _____ flowing per _____. In a metal wire charged particles called _____ move when you connect a battery. You can use a meter called an _____ to measure current. Current is measured in _____, which has the symbol _____.

(6 marks)

2

a Draw a circuit diagram to show how you could use a switch to turn a battery-powered motor on and off. *(2 marks)*

b Describe what happens in the wires when you close the switch. *(1 mark)*

3 Explain how you would use equipment and models to teach a primary-school student that the charges do not originate in the battery.

(6 marks QWC)

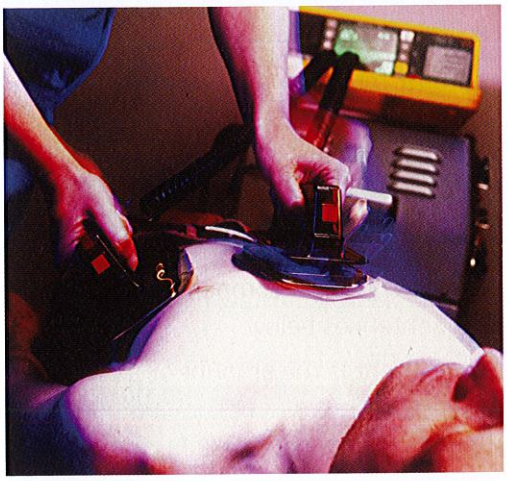
1.3 Potential difference

Learning objectives

After this topic you will be able to:

- describe what is meant by potential difference
- describe how to measure potential difference
- describe what is meant by the rating of a battery or bulb.

A doctor can use a defibrillator to start someone's heart if it stops. Defibrillators produce a large potential difference (sometimes called a voltage), much bigger than a battery can produce.



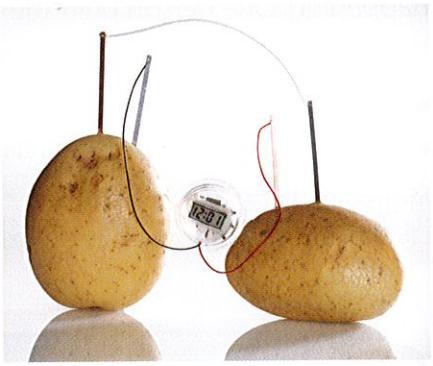
▲ You can save someone's life with a big potential difference.

What is potential difference?

The cell or battery provides the push to make charges move. The push is called a **potential difference**, or p.d. for short.

- The potential difference across a cell tells you about the size of the force on the charges.
- The potential difference also tells you how much energy can be transferred to the components in the circuit by the charges.

▲ Batteries come in different shapes and sizes.



▲ In a potato cell a chemical reaction between the metals and the potato produces a potential difference.

Measuring potential difference

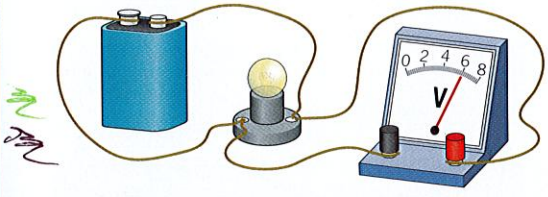
You measure potential difference using a **voltmeter**.

- Potential difference is measured in **volts**.
- The symbol for volts is V. For example, the potential difference across the cell opposite is 6 V.

You can measure the potential difference of a cell by connecting a voltmeter across it. This is also called the **rating**.

A Name the meter that you use to measure potential difference.

You can measure the potential difference across a component in a circuit using a voltmeter.



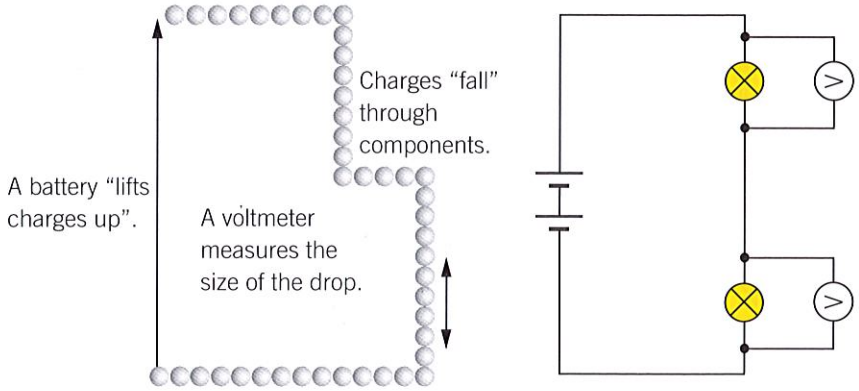
▲ You connect a voltmeter either side of the component.

B State the unit of potential difference.

Circuit components such as bulbs also have a rating. The bulb in the circuit on the opposite page has a rating of 6 V. It is designed to work at a potential difference of 6 V, and no higher.

'Potential difference' or 'voltage'?

Sometimes people talk about the '**voltage**' of a cell or battery. It is better to talk about potential difference. You can think of a circuit as being a bit like this:



▲ You can think of the battery 'lifting' up the charges. In the circuit above the voltmeters would read the same.

Modelling electric circuits – part 2

You can use the rope model when you are thinking about potential difference. In the rope model:

- The person pulling the rope is like the battery.
- A bigger potential difference across the cell would come from the 'battery' person pulling harder.

Are bigger batteries better?

A student wants to collect some data about the size of batteries and the potential difference across each one. Write a plan that they could use to collect the data.

Key Words

potential difference, voltmeter, volts, rating, voltage

Foul Fact

Mary Shelley wrote *Frankenstein* after finding out that Louis Galvani made dead frogs' legs move using a battery in 1818.

Summary Questions

1 Copy and complete the sentences below.

The potential difference of a cell or battery tells you the size of the _____, and how much _____ can be transferred by the charges. You measure potential difference or p.d. with a _____. The _____ of a battery tells you the p.d across it, and the _____ on a bulb tells you the p.d. at which it is designed to work.

(5 marks)

2 A student connects a circuit with a cell, an ammeter, and a buzzer and listens to the buzzer. She adds another cell.

a Describe and explain what happens to the current. *(2 marks)*

b Describe and explain what happens if she turns one of the cells around. *(2 marks)*

3 A lot of people get current and potential difference (or voltage) mixed up. Use a model to explain the difference in detail.

(6 marks QWC)

1.4 Series and parallel

Learning objectives

After this topic you will be able to:

- describe the difference between series and parallel circuits
- describe how current and potential difference vary in series and parallel circuits.

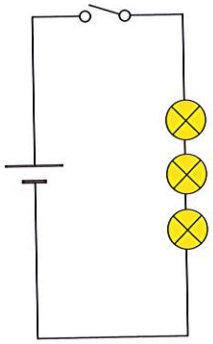
▲ Modern Christmas lights stay on if one bulb blows.

Christmas lights make a great display. In old sets of lights, if one of the bulbs broke they would all go out.

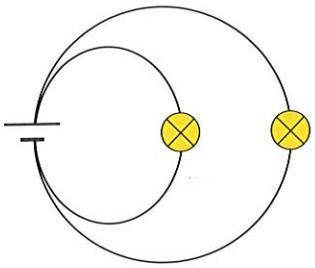
Two types of circuit

The old type of Christmas lights were connected in **series**. All the bulbs formed one loop, including the battery and the switch.

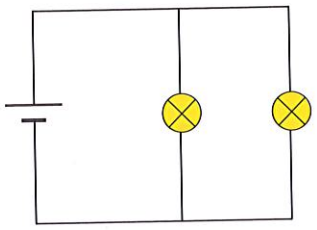
There is another type of circuit called a **parallel** circuit. In a parallel circuit there is more than one loop or branch. Parallel circuits are sometimes called 'branching circuits'.



▲ In a series circuit there is only one loop.



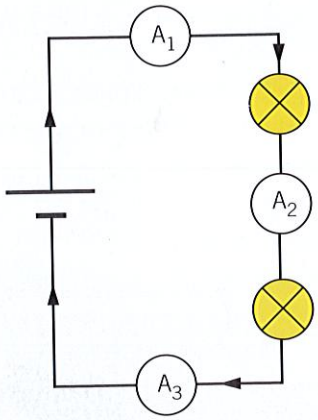
▲ This is a parallel circuit because there is more than one loop...



▲ ...which you can also draw like this.

Parallel circuits are very useful because if one bulb breaks, the other lights stay on. You can control each lamp separately in a parallel circuit by adding a switch to each branch. Each bulb is independent of the others.

A State two differences between series and parallel circuits.



▲ In a series circuit, the reading on all the ammeters is the same.

What happens to the current?

Series circuits

In the circuit opposite, the ammeters A_1, A_2, and A_3 all show the same reading. In a series circuit the current is the same everywhere.

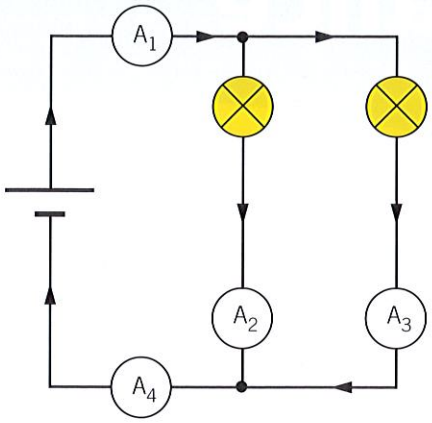
If you add components to a series circuit the current will get smaller.

Parallel circuits

A parallel circuit has more than one loop. In the circuit at the top of the next page, the current in each branch is the same. The ammeters A_2 and A_3 show the same reading.

The ammeters A_1 and A_4 measure the total current. The currents in all the branches of a parallel circuit add together to make the total current. Here the total current is double the current in each branch.

If you add another branch to a parallel circuit the current in the other branches stays the same but the total current increases.



▲ In a parallel circuit, the current in all the branches adds to the total current.

B State what happens to the total current as you add more branches in a parallel circuit.

Modelling circuits – part 3

You can use the rope model when you are thinking about different types of circuit. In the rope model:

Series circuits

- The rope moves at the same speed everywhere.
- As more people hold the rope, the rope moves more slowly.

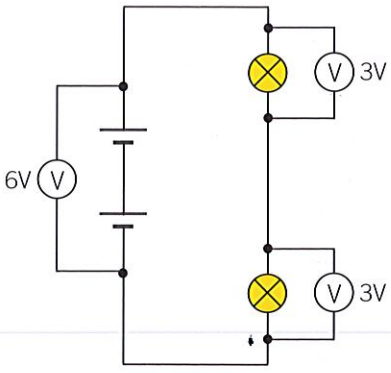
Parallel circuits

- There are more loops of rope.
- All the loops are driven by the same 'battery' person.

What happens to the potential difference?

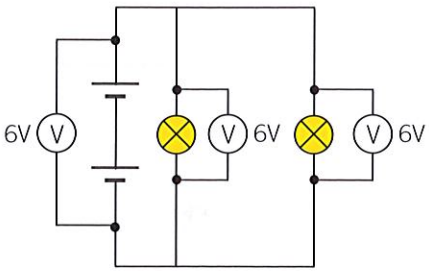
Series circuits

The potential difference across each component *adds up to* the potential difference across the battery.



Parallel circuits

The potential difference across each component *is the same as* the potential difference across the battery.



Current issues

In a circuit with a single cell and a single bulb, the current is 0.2 A. Calculate the current if you add another bulb in series with the first bulb. Explain your answer.

Key Words

series, parallel

Fantastic Fact

A family in Australia holds the world record for Christmas tree lights. Their display contained over 330 000 separate lights.

Summary Questions

1 Copy the sentences below, choosing the correct **bold** words.

A series circuit has **more than one/one** loop. A parallel circuit has **more than one/one** loop. If a bulb in a **parallel/series** circuit breaks the rest of the bulbs stay on. If a bulb in a **parallel/series** circuit breaks the rest of the bulbs go out.

(4 marks)

2 State what happens to the total current as you add more bulbs in a parallel circuit.

(1 mark)

3 Compare the readings on ammeters and voltmeters when you connect them in series and parallel circuits.

(6 marks QWC)

1.5 Resistance

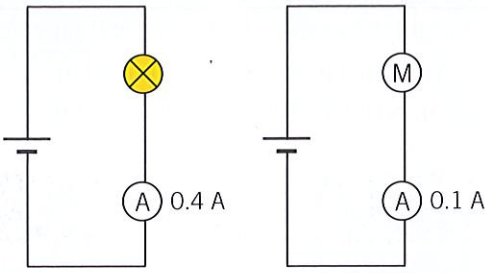
Learning objectives

After this topic you will be able to:

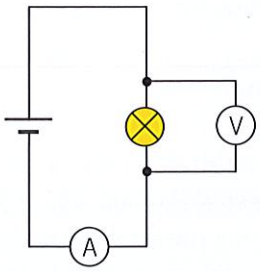
- describe what is meant by resistance
- calculate the resistance of a component and of a circuit
- describe the difference between conductors and insulators in terms of resistance.

The current in the wires connected to a television is much smaller than the current in the wires to a microwave. The reason for this is to do with resistance.

◀ Electrical devices have different currents through them.



▲ The currents in these circuits are different, even though the cells are the same.



▲ You can use an ammeter and a voltmeter to find the resistance of a lamp.

What's the resistance?

A bulb in a circuit has a current of 0.6 A through it and a potential difference of 12 V across it. Calculate the resistance of the bulb.

Different components, different current

Components do different jobs in an electric circuit.

Each circuit component has a different **resistance**. This tells you how easy or difficult it is for the charges to pass through the component. Resistance is measured in **ohms**, which has the symbol Ω. Ω is a letter from the Greek alphabet.

The current depends on the push of the battery and also the resistance of the component. You can calculate the current using this equation:

$$\text{current (A)} = \frac{\text{potential difference (V)}}{\text{resistance } (\Omega)}$$

You can use the idea of resistance to explain why the current decreases as you add more bulbs in a series circuit. Adding more bulbs increases the resistance, so the current is less.

A State what is meant by resistance.

Measuring resistance

You can use an equation to calculate the resistance of a component.

Here is the equation to calculate resistance:

$$\text{resistance } (\Omega) = \frac{\text{potential difference (V)}}{\text{current (A)}}$$

B State the unit of resistance.

For example, if you found that the current through a bulb was 0.2 A when the voltage across it was 6 V, you could work out the resistance:

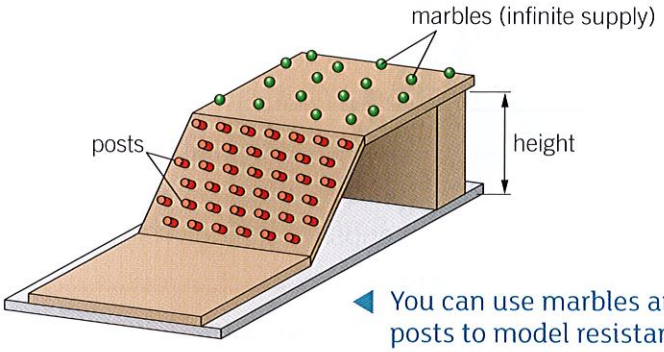
$$\text{resistance} = \frac{\text{potential difference}}{\text{current}}$$

$$= \frac{6\text{ V}}{0.2\text{ A}}$$

$$= 30\ \Omega$$

What happens inside a wire?

You can use a model with marbles to show what happens inside a wire when a current flows. The charges that move in a wire are electrons.



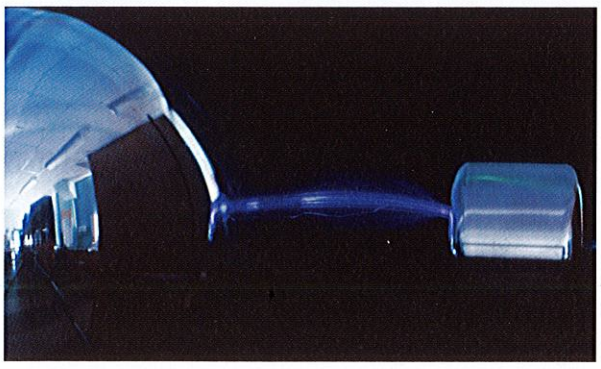
◀ You can use marbles and posts to model resistance.

The marbles behave like electrons. As they fall down the slope they collide with the posts. Inside a wire the moving electrons collide with the atoms of the wire. They transfer energy, and the wire gets hot.

Conductors and insulators

Metals are good **conductors.** They have a very low resistance because they contain lots of electrons that can move. The resistance of a 10-m piece of copper wire is about 0.2 Ω.

Other materials such as plastics do not have many electrons that are free to move. The resistance of plastic objects is very high, over a thousand million million ohms. The air is usually an **insulator** but it can conduct if the potential difference is big enough. Insulators have a high resistance.



◀ A spark happens when the air conducts electricity.

Fantastic Fact

Many people think that Thomas Edison invented the lightbulb. What he invented was the first lightbulb with a filament that didn't burn out when a current flowed in it.

Key Words

resistance, ohms, conductor, insulator

Summary Questions

1 Copy and complete the sentences below.

The current in a circuit depends on the _____ and the _____. The current will be bigger if the _____ is smaller. Inside a metal wire _____ collide with atoms and transfer _____ to them. _____ are materials that contain lots of charges that are free to move. _____ contain fewer charges that can move.

(7 marks)

2 In the circuit diagrams on the opposite page the cell has a potential difference of 3 V. Calculate the resistance of the motor and the lamp.

(4 marks)

3 Compare the resistance of conductors and insulators.

(6 marks QWC)