SCIENCE DEPARTMENT
BGS

Year 7

Physics Friend

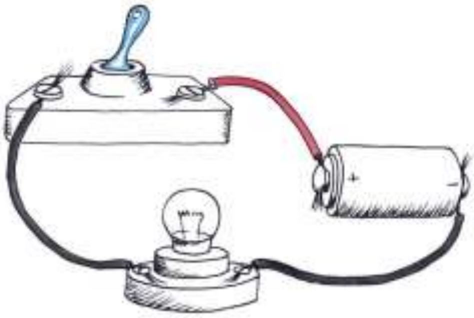
Electric Circuits

This booklet contains information to support your work in science lessons. You **<u>must</u>** bring it with you to all science lessons on the Electric Circuits topic.

Replacement booklets must be paid for at a cost of £1.

Name:

Form:



Science Teacher:

CONTENT

Key Words

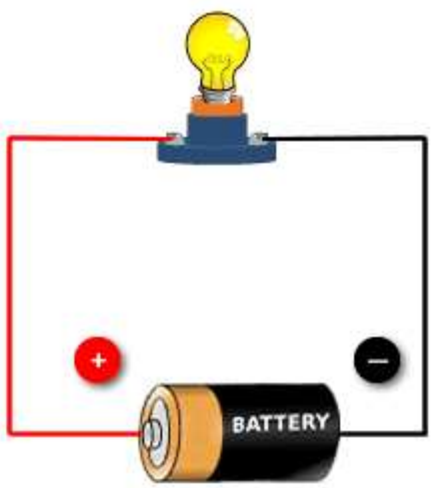
Ammeter	Amps	Battery	Bulb
Buzzer	Cell	Current	Electrons
Energy	Motor	Parallel	Potential difference
Resistance	Series	Short-circuit	Switch
Volt	Voltmeter	Wire	

Now, find these words in the wordsearch below:

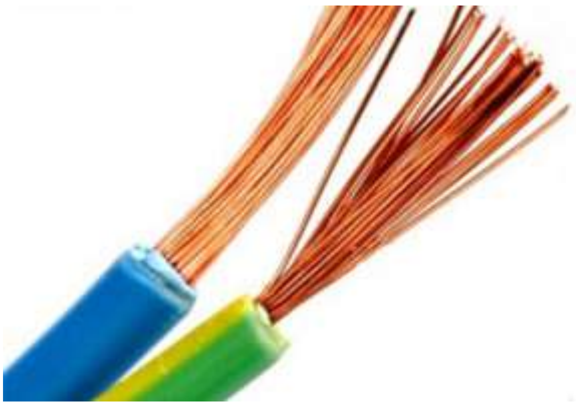
R	P	O	P	L	B	D	J	P	E	N	E	R	G	Y	X	N	I
E	K	M	C	L	B	U	I	P	A	R	A	L	L	E	L	N	M
S	M	O	E	Q	U	A	Z	F	O	C	V	W	V	W	G	G	E
I	J	T	L	D	L	M	T	Z	F	T	U	O	R	Q	L	J	L
S	P	O	L	E	B	L	J	T	E	E	E	R	L	I	V	X	E
T	O	R	S	W	I	T	C	H	E	R	R	N	R	T	U	R	C
A	Q	V	O	L	T	M	E	T	E	R	E	E	T	E	N	X	T
N	Y	K	W	B	R	H	Q	T	Y	V	Y	K	N	I	N	K	R
C	A	S	H	O	R	T	C	I	R	C	U	I	T	C	A	T	O
E	Z	H	Z	Q	R	F	K	A	M	P	S	R	O	N	E	L	N
Q	S	E	R	I	E	S	W	I	R	E	A	H	Z	M	D	C	S
H	P	O	T	U	Z	Y	O	L	H	A	M	M	E	T	E	R	G

Fundamentals of Electric Circuits

Any functional electrical circuit needs both a complete circuit made of a conductor, and an energy source. The following diagram shows a complete circuit.



Batteries are the usual source of energy for small or handheld electrical devices. Some electrical circuits can be plugged in to a wall socket. In this case, the energy comes from a generator in a power station. Other generators, such as a wind turbine, can also provide this energy. Solar panels (which are not generators; they have no moving parts), can also provide energy to an electrical circuit.



Metals are good conductors of electricity, so they are typically used (for example, copper, aluminium, steel, gold). The metal in the wire is covered by a layer of plastic; this is the blue or yellow material that you can see on wires, also at the bottom left of the photo to the right. The insulation is a poor conductor of electricity, and is used to protect the wire and prevent electricity going to unwanted places. The colour or type of insulation has no effect on the performance of the circuit.

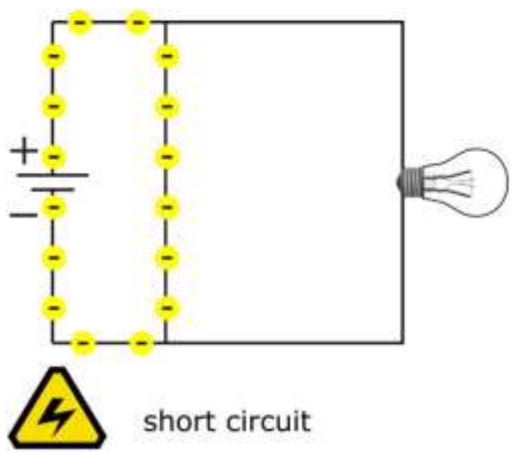
Electrical Safety

The voltages used in the practical experiments are low – less than 12 V. Typical household batteries (e.g. AA), and electrics in cars are also low voltage, and so are not dangerous. The voltage from mains electricity (in plug sockets), however, is higher; 230 V.

High voltages give the flowing charge more energy. This can be enough energy to travel through your body, causing burns, or stopping your heart from beating. Very high voltages (like in power stations or power lines) can spark through the air!

Electrical devices and appliances are designed and manufactured to be safe to use. They have insulation around wires, and usually have a case around the electrical components. Being safe with electricity involves not touching the direct electrical conductors, not introducing extra conductors (like water or metal), and avoiding it getting too hot.

A short-circuit is when there is a path of low resistance between the positive and negative terminals of an energy source (e.g. a wire connected to either side of a battery – see diagram to the right). This causes a large current to flow, which heats up the conductor. Many house and factory fires are caused by electrical faults, (such as the fire at Notre Dame cathedral in Paris in 2019).



Circuit breakers or fuses (see below) work by making an incomplete circuit when a large current flows. This can help to protect against faults.

Circuit breaker

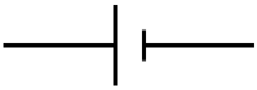
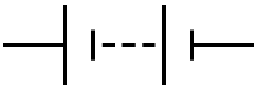
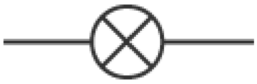
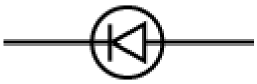
Different types of fuses

Questions:

1. What two things are needed for an electric circuit to work?
2. What happens in an electrical circuit when charge flows?
3. Explain why high voltage can be dangerous.
4. Describe two safety precautions you should take when using electric circuits.
5. What is a short-circuit, and why is it dangerous?

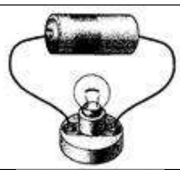
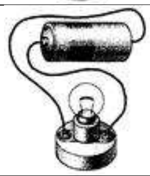
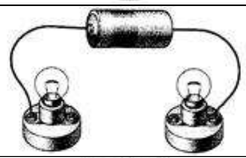
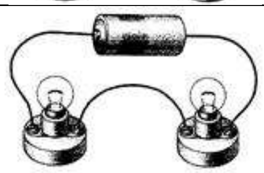
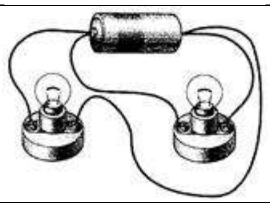
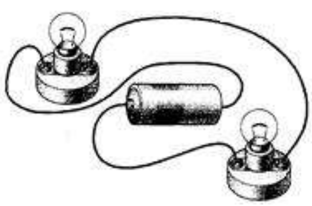
Making Electric Circuits

Circuit diagrams are drawn to represent a real electric circuit. These diagrams use symbols to represent the real electrical components. The components listed in the table below are important ones you need to know.

Component	Symbol	Function
Wire		Made from a conducting material so it can carry current around the circuit
Switch		Can be opened or closed to turn the current in a circuit on or off
Cell		Provides a source of energy for an electric circuit
Battery		Multiple cells to provide a circuit with greater voltage
Bulb		Takes energy from the electrons in a circuit and transfers it in the form of light
Voltmeter		Used to measure the potential difference (voltage) across a component in a circuit
Ammeter		Used to measure the electric current flowing in a circuit
Resistor		Resists the flow of electric current; Can be used to limit the current passing through a circuit
Diode		Allows electric current to flow through it in one direction only

Constructing circuits and drawing circuit diagrams

For each of the circuits below, draw the simple circuit diagram and indicate whether you think the bulb(s) will light. Then construct the circuit to see if you are correct. If they do not light, think about what is wrong with the circuit.

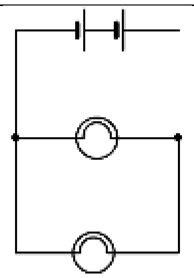
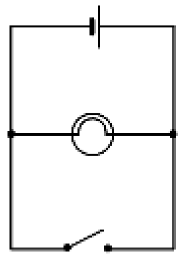
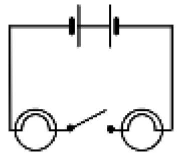
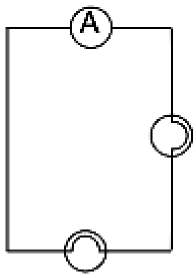
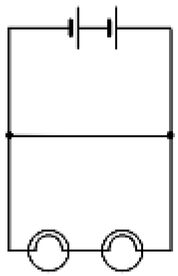
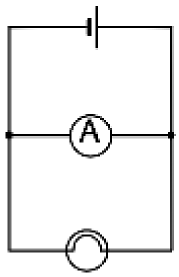
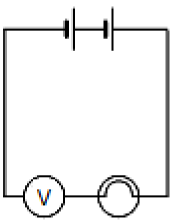
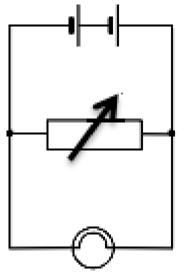
	Picture	Circuit diagram	Do the bulbs light?
A			
B			
C			
D			
E			
F			
G			
H			

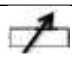
Faulty Circuits

There are several reasons a circuit might not work as it is supposed to. Some common faults include:

- The circuit is incomplete
- A component in the circuit is an insulator
- A short circuit (a path of very low resistance)
- Several cells in series are connected opposite way round
- An ammeter has been connected in parallel
- A voltmeter has been connected in series

For each of the circuits below, decide why the circuit does not work properly and how you would correct the fault. In your exercise book, write down what the fault is and draw a corrected circuit diagram.

 A	 B	 C
 D	 E	 F
 G	 H	

Hint: For H, the variable resistor, symbol , is meant to act like a dimmer switch. See if you can rearrange the circuit so that it works correctly.

Extension:

In the final box, draw your own faulty circuit with three faults in it. Get another student to determine what is wrong and how it should be corrected.

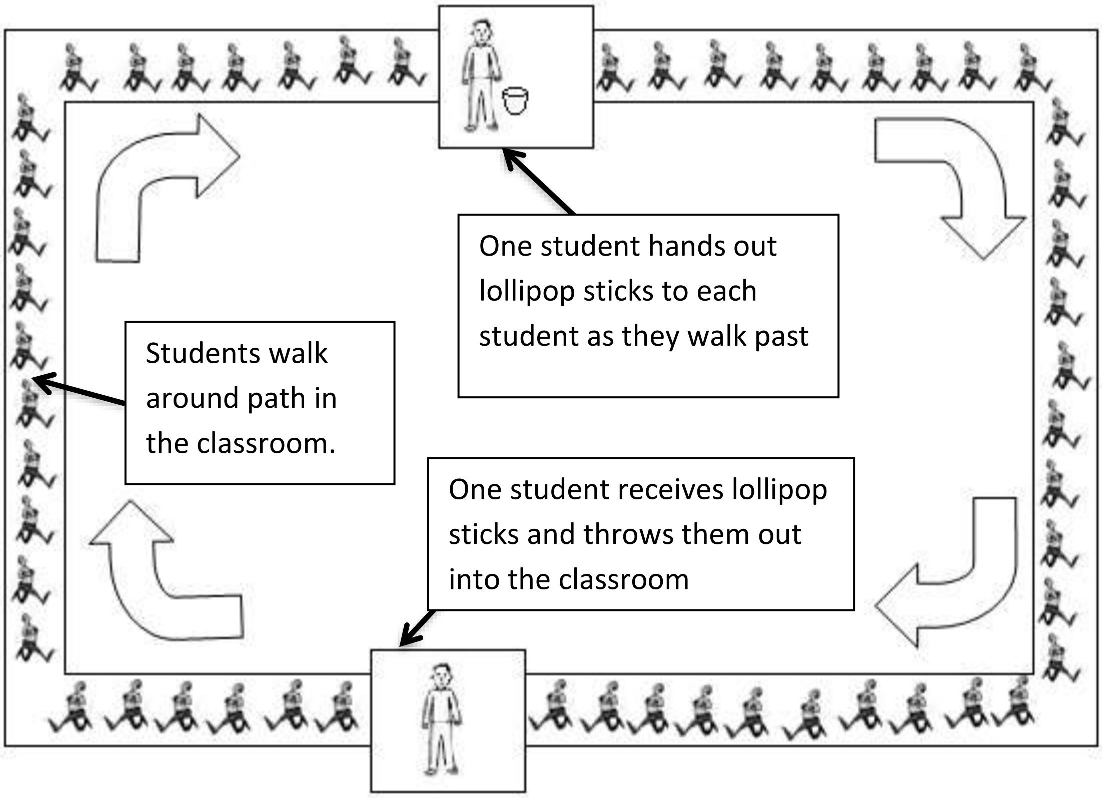
Questions:

1. Draw the circuit symbols for a battery and a bulb.
2. What is the difference between a series and a parallel circuit?
3. Describe how to connect a voltmeter and an ammeter in a circuit and what each measures.
4. Aside from wires not being plugged in correctly, explain one reason why a circuit might not work. How could this be fixed?

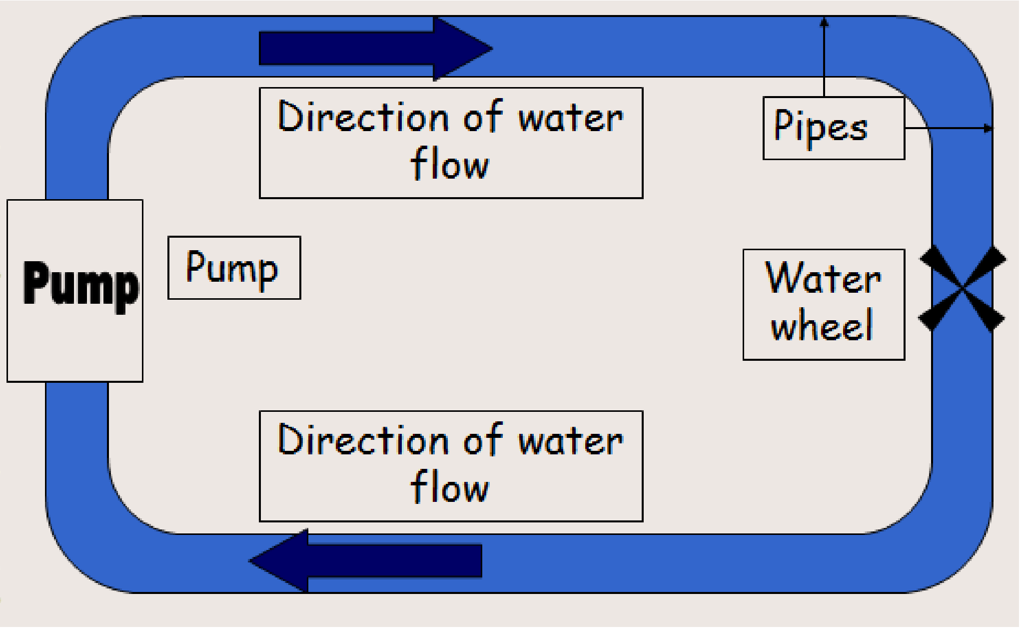
Models of Electric Circuits

A scientific model is a representation of how a physical system works. It is normally used when the concepts involved cannot be directly seen. Every model has strengths and limitations. In lessons, your teacher will discuss the following models of electricity.

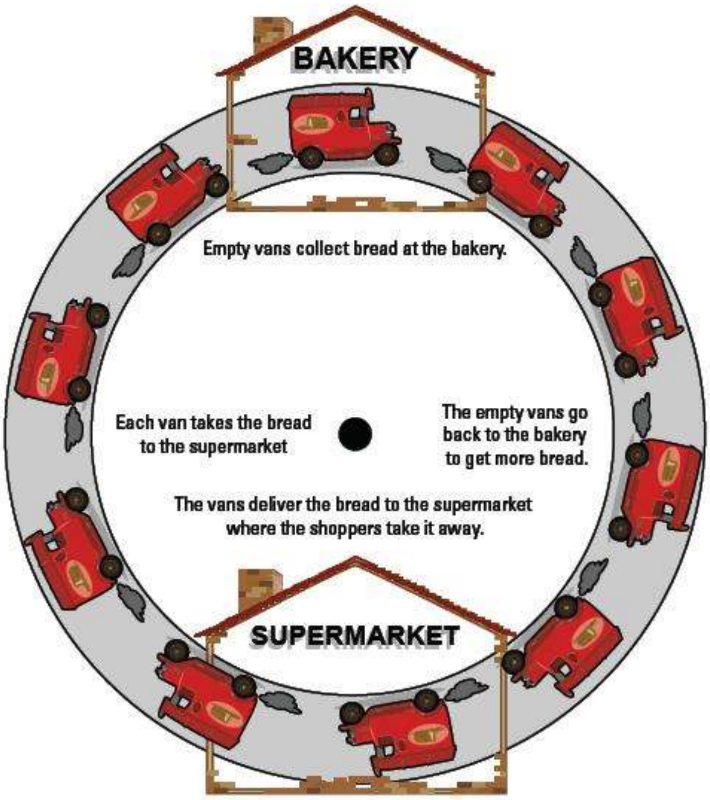
Model 1: The lollipop model



Model 2: The water model



Model 3: The supermarket model



What represents…	Lollipop model	Water model	Supermarket model
…the wire?			
…the charge?			
…the battery?			
…the energy?			
…the bulb?			

Questions:

1. What is a scientific model?
2. Why are scientific models useful?
3. Give an example of a limitation of an electric circuit model.
4. Describe a model for an electric circuit, using a different analogy to the ones given in the notes.

Charge & Current

In a circuit, electric **charges** flow through the components (like water flowing in a river).

Electric **current** is the amount of charge flowing past a certain point in a certain amount of time (high current might be like a fast flowing river viewed from the riverbank).

> Charges not flowing, i.e. static electricity, is responsible for making your hair stand up!

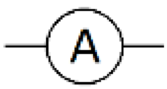
> Saying that "electricity" flows is too vague; you should always say that charge flows.

By convention, charge flows from the positive side of a power source (longer line of a cell symbol), through components, to the negative side.

The first physicists studying electricity did not know whether positive or negative charges flow. They decided to be positive about the situation, and just picked the positive ones! We now know that negatively-charged **electrons** are the particles which flow in circuits.

An **ammeter** is the component used to measure current in an electrical circuit. This shows the current measured in **Amperes (A)**, e.g. 0.25 A.

Current <u>through</u> a component is measured, so an ammeter should always be connected in series with components. Remember that the symbol for an ammeter is:



The equation for calculating current is:

$$I = \frac{Q}{t}$$

"I" represents current, measured in Amperes or Amps, shortened to A (e.g. 5 A).

"Q" represents charge, measured in Coulombs, shortened to C (e.g. 2 C).

"t" represents time, measured in seconds, shortened to s (e.g. 10 s). If time is given in minutes, it should be converted into seconds.

1 Amp is 1 Coulomb of charge flowing through a component in 1 second.

Electrons carry a very small amount of charge – 1.6×10^{-19} C. To make 1 Coulomb, you would need 6.24 billion billion (6.24×10^{18}) electrons!

Electrons can also be made to move when two objects are rubbed together – this is how we get **static electricity**. An object can gain a negative charge if it picks up extra electrons, or a positive charge if it loses electrons. You will probably have experienced the phenomenon of static electricity at some point.

A charged object produces an **electric field** around itself, i.e. an area of space in which another charged object will experience a non-contact force. The force between objects with the same charge (both positive or both negative) is repulsive, while the force between objects with opposite charges (one positive and the other negative) is attractive.

Questions:

1. What is electric current?
2. What is the formula used to calculate electric current?
3. Describe the direction of conventional current flow in an electric circuit.
4. How should an ammeter be connected in a circuit to measure current?
5. If a charge of 10 Coulombs flows past a point in 2 seconds, calculate the current.

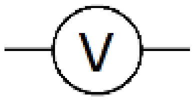
Potential Difference & Energy

A circuit's energy source provides energy to electrical charges. The flowing charge then uses up this energy in the circuit components.

Potential difference (p.d.) is the amount of energy gained (in a battery) or lost (in a component) per Coulomb of charge. Potential difference is also called **voltage**.

Remember that current is measured <u>through</u> a component. Be careful not to mix these up – it won't make sense otherwise!

A voltmeter is the component used to measure the potential difference <u>across</u> a component, i.e. before and after it. It is connected in parallel (see page 6) with a component to do this. The circuit diagram symbol for a voltmeter is:



The equation to calculate potential difference is:

$$V = \frac{E}{Q}$$

"V" represents potential difference, measured in Volts, shortened to V (e.g. 12 V).

"E" represents energy, measured in Joules, shortened to J (e.g. 10 J).

"Q" represents charge, measured in Coulombs, shortened to C (e.g. 3 C).

1 Volt is 1 Joule of energy carried by 1 Coulomb of charge.

Re-arrange this equation below to calculate energy or charge:

$E =$

$Q =$

Questions:

1. What is potential difference?

2. How is a voltmeter connected in a circuit?

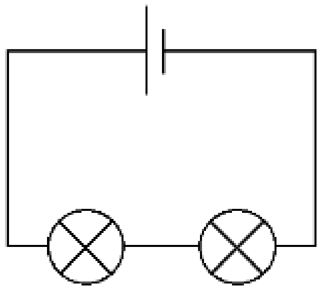
3. In a series circuit, how is the potential difference of the battery related to the potential difference across the components?

4. In a series circuit with a 9V battery and three bulbs, the voltage across two of the bulbs is 3V and 2V. Calculate the voltage across the third bulb.

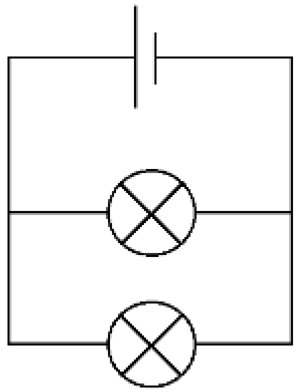
5. If a component transfers 20 Joules of energy when 4 Coulombs of charge flow through it, calculate the potential difference across the component.

Parallel Circuits

Given two bulbs and a cell, there are two ways that they could be connected. The bulbs could either be in **series** or in **parallel.**



These bulbs are in series. This means that the current passing from the bulb must go through both bulbs, one after the other. This is like a TV series where each episode follows on one from the other.



In a parallel circuit, the bulbs lie on different branches of the circuit. Any electron either travels through one bulb or the other, but not both.

Investigation

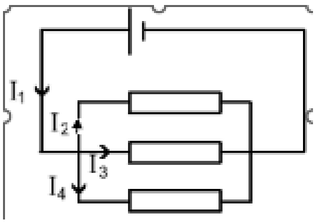
1. Start by setting up a circuit with just a battery and one bulb. Make a note of the brightness of the bulb. Now add another bulb in series. What happens to the brightness of the bulbs?
2. Start again as before, but now add a bulb in parallel with the original bulb. What do you notice about the brightness of the bulbs this time?
3. Set up the series circuit from above. Disconnect a wire and then carefully remove one of the bulbs from its holder (this is like breaking a bulb in the circuit). **Be careful as the glass is fragile so don't squeeze them too hard**. Now reconnect the circuit. What happens to the brightness of the bulbs?
4. Set up the parallel circuit from above. Again, disconnect a wire then remove one of the bulbs from its holder and reconnect the circuit. What happens to the brightness of the bulbs now?

Summarise your findings in the table on page 19.

	Series	Parallel
Adding more bulbs causes the brightness of the bulbs to…		
Breaking one of the bulbs causes the other bulbs to…		

Current Law

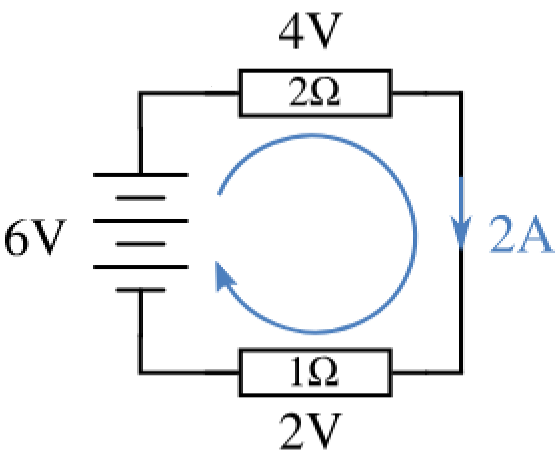
At any point in a circuit, the total amount of current flowing into the point is equal to the total amount of current flowing out of the point.



This means in series circuits that the current is the same everywhere in the circuit, while in parallel circuits, the current through each branch adds up to be equal to the current through the battery. In the diagram to the left, $I_1 = I_2 + I_3 + I_4$.

Voltage Law

Around any closed loop (from one side of a battery to the other) in a circuit, the sum of voltage gains (from cells/batteries) is equal to the sum of voltage drops (across bulbs, resistors, etc.).



This means in series circuits that the voltage across each component adds up to the voltage across the battery. See the diagram to the left for an example. In parallel circuits, the voltage across each branch is equal to the voltage across the battery.

Questions:

1. How can you relate the behaviour of series and parallel circuits to the models of electricity?
2. Decide if each of the following statements is true or false and circle the correct answer. If they are false, write a corrected statement at the bottom of the page.

1. Series means that the components follow on one after another.	True/false
2. In a parallel circuit, the electrons go through all the components.	True/false
3. Adding more bulbs to a series circuit makes the bulbs brighter.	True/false
4. Adding more bulbs to a parallel circuit makes the bulbs dimmer.	True/false
5. In a series circuit, a bulb breaking will cause all the bulbs to go out.	True/false
6. In a parallel circuit, a bulb breaking will cause the remaining bulbs to get dimmer.	True/false
7. In a circuit with two bulbs and a battery, the battery will last longer if the bulbs are in series.	True/false
8. The current decreases as you go around a series circuit.	True/false

Corrections

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Resistance

The word "resistance" is associated with pushing back, slowing down or stopping something, perhaps also with protests.

Electrical resistance is the opposition to the flow of charge, i.e. trying to slow down or reduce current. The resistance of a component (or part of a circuit) can be measured. Resistance has the symbol R, and the units ohms (Ω).

Where there is more than one path for current, more current will flow through the path with the lower resistance, rather than the higher one.

Insulating materials (like plastic, wood, or air) have a high resistance to the flow of charge, while **conductors** have a low resistance.

The equation to calculate resistance is:

$$R = \frac{V}{I}$$

"R" represents resistance, measured in Ohms, represented by Ω (e.g. 150 Ω).

"V" represents potential difference, measured in Volts.

"I" represents current, measured in Amps.

"Ω" is the Greek capital letter "omega".

A 1 Ω resistor will allow 1 A of current to flow when 1 V p.d. is applied across it.

Questions:

1. What is electrical resistance, and what is its unit of measurement?

2. Write down the formula for calculating resistance in a circuit. What do each of the symbols represent?

3. How does resistance affect the flow of current in a circuit? What happens if there's a higher resistance in one path compared to another?

4. In the water circuit model, how could you represent electrical resistance?

5. A bulb has a potential difference of 6V across it, and a current of 0.5A flows through it. Calculate the resistance of the bulb.

PD, Current & Resistance

The potential difference (voltage) from a battery provides energy to the charges in a circuit. If no potential difference is present, no current will flow because the charge has no energy to move.

A voltmeter connected across a battery shows how much energy is given to each coulomb of charge. For example, a 3V reading means each coulomb receives 3 joules of energy.

Adding more bulbs in series increases the total resistance in the circuit because the current has to pass through each bulb one after another. This makes it harder for current to flow, reducing the overall current.

As resistance in a circuit increases (like adding more bulbs in series), the current decreases.

To calculate the resistance of a component, you need some measurements for voltage and current. You can get these using the following method:

1. Draw the below results table.

Voltage (V)			Current (A)			Resistance (Ω)
Repeat 1	Repeat 2	Average	Repeat 1	Repeat 2	Average	

2. Construct a circuit with the component (e.g. a bulb) and 1 cell/battery. If the bulb is very dim, another battery should be added in series.
3. Add an ammeter in series with the component.
4. Add a voltmeter in parallel to the component.
5. Record the voltage and current.
6. Take a repeat reading (to avoid getting anomalies).
7. Calculate an average of the voltage and current, and calculate resistance from these averages.

Questions:

1. What is the relationship between potential difference (voltage) and current in a circuit?

2. How does adding more bulbs in series to a circuit affect the resistance and current?

3. What happens to the total current in a circuit when you add more bulbs in parallel? Why?

4. Explain what potential difference is and how it is measured in a circuit.

5. If a circuit has a potential difference of 9V and a resistance of 3Ω, what is the current in the circuit?

Revision

1. Which two things are essential for any functional electric circuit?

a) A battery and a switch

b) A complete circuit made of a conductor and an energy source

c) A bulb and a motor

d) Wires and an ammeter

2. What happens when electrical charge flows through a functioning circuit?

a) The circuit cools down.

b) Energy is transferred from one place to another.

c) The battery gains energy.

d) The wires become insulators.

3. Which of the following is a safety precaution when using electric circuits?

a) Touching the circuit when it is working.

b) Leaving circuits connected when not in use.

c) Disconnecting circuits when not in use.

d) Short-circuiting the battery regularly.

4. How are components connected in a series circuit?

a) In multiple paths, splitting the current.

b) Side-by-side, sharing the voltage.

c) One after another, in a single path for the current.

d) Randomly, with no specific order.

5. What does an ammeter measure, and how is it connected in a circuit?

a) Voltage, in parallel.

b) Current, in series.

c) Resistance, in parallel.

d) Energy, in series.

6. Why are scientific models useful when studying electric circuits?

a) They make the circuits work better.

b) They help to visualise and understand things we cannot see.

c) They always show every detail perfectly.

d) They replace the need for real experiments.

7. If 15 Coulombs of charge flow past a point in a circuit in 3 seconds, what is the current?

a) 5 Amperes

b) 45 Amperes

c) 0.2 Amperes

d) 18 Amperes

8. What is potential difference (voltage)?

a) The total resistance of the circuit.

b) The amount of charge flowing per second.

c) The energy transferred to a component per coulomb of charge.

d) The speed at which electrons move.

9. According to the Current Law, what is true about current at any point in a circuit?

a) Current is always used up at components.

b) The total current flowing into the point is equal to the total current flowing out.

c) Current is always greater after a component than before.

d) Current decreases as it moves around the circuit.

10. If the resistance in a circuit increases, what happens to the current (assuming voltage stays the same)?

a) The current increases.

b) The current decreases.

c) The current stays the same.

d) The current becomes zero

Year 7 physics equation sheet

$$Distance = Speed \times Time$$

$$Speed = \frac{Distance}{Time} \qquad Time = \frac{Distance}{Speed}$$

$$Mass = Density \times Volume$$

$$Density = \frac{Mass}{Volume} \qquad Volume = \frac{Mass}{Density}$$

$$Gravitational\ field\ strength = \frac{Weight}{Mass}$$

$$Weight = Mass \times Gravitational\ field\ strength$$

$$Mass = \frac{Weight}{Gravitational\ field\ strength}$$

$$Charge = Current \times Time$$

$$Current = \frac{Charge}{Time} \qquad Time = \frac{Charge}{Current}$$

$$Charge = \frac{Energy\ Transferred}{Potential\ Difference}$$

$$Energy\ Transferred = Charge \times Potential\ Difference$$

$$Potential\ Difference = \frac{Energy\ Transferred}{Charge}$$

$$Resistance = \frac{Potential\ Difference}{Current}$$

$$Potential\ Difference = Current \times Resistance$$

$$Current = \frac{Potential\ Difference}{Resistance}$$