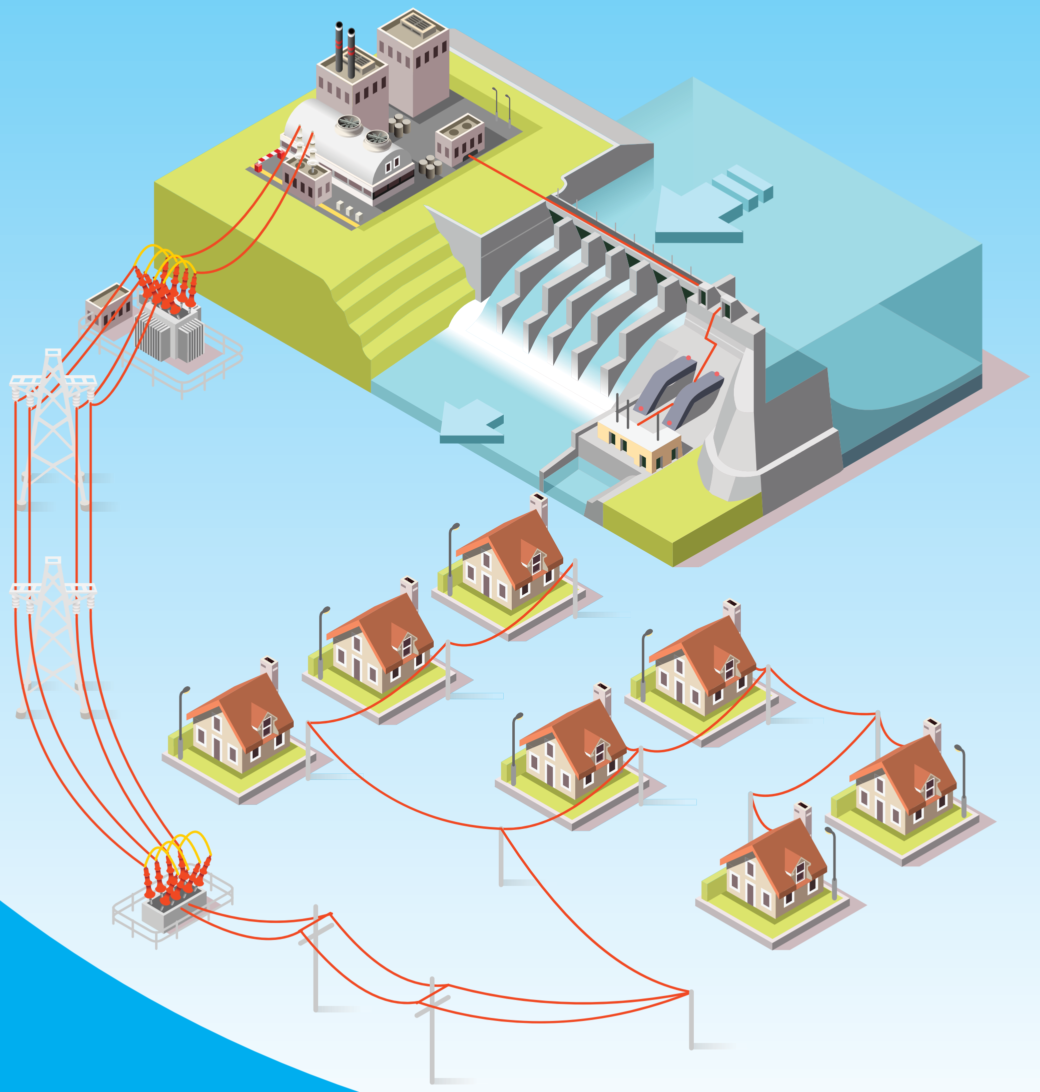
Name:

Junior Science
Electricity

Downloadable Resource



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Flying a Kite and Electricity

Benjamin Franklin was one of the seven key founding fathers of the United States of America. This group of men (along with many others) lead the American Revolution against the rule of the British and created the United States of America. He is described as a 'polymath' as he was knowledgeable and revolutionary in many areas including: writing, publishing, science, politics and inventing.

He invented many things but never patented them, which meant he didn't make any money from his inventions as he believed that all people should be able to benefit from new innovations. He is credited with creating the lightning rod, a glass instrument called a glass harmonica, the Franklin stove (which produced more heat and less smoke through its unique design), bifocal glasses and even some social innovations such as 'paying it forward' (doing a good deed for someone after a good deed has been done for you but not to the person who did the nice thing to you, it is really just passing on the kindness to others). He is also thought to be the first person to have used a pro and con list to decide something. In the area of the sciences, he studied human populations, ocean currents, light, weather, kites, refrigeration, the effect of temperature on conduction and of course electricity.

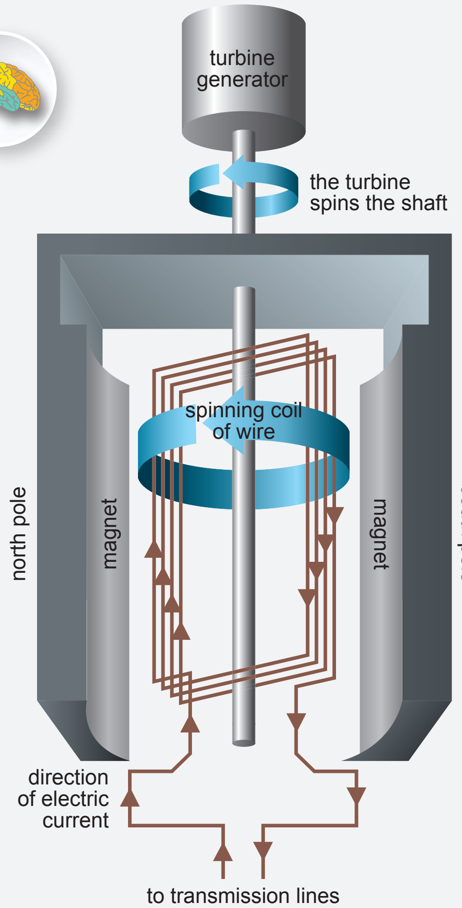
It is widely (but wrongly) believed that Benjamin Franklin discovered electricity by flying a kite in a lightning storm. It has long been thought that he set up a kite with a small, thin pointed piece of wire attached (that acted as a lightning rod) and a key hung from the end of the string. When the kite was flown in a storm cloud, lightning was expected to strike the metal wire on the kite and travel down the wet string to charge the key with electricity. It was thought that when Franklin touched the key he received a small shock, which proved electricity existed. However, this experiment seems unlikely as the current produced by a bolt of lightning could kill a person. In fact, several scientists were electrocuted attempting this experiment after reading about it! It is now believed that Benjamin Franklin actually wrote about the experiment as a possible but theoretical method for proving the existence of electricity inside lightning. If he did the experiment, it is likely that he created the contraption described above but flew it in the lower region of a storm cloud where negative charges collect. These charges would have charged up the rod and key and given him a small static electrical shock, no more than when you get a shock from a car door. What he did learn from this idea was that a conductive material such as metal in a long thin shape with a pointed end, will collect and discharge electricity from lightning in a 'safe', silent manner. This then lead to the idea of the lightning rods.

A lightning rod is a tall pointed metal rod that is attached to the top of a tall building and wired to the ground. When lightning strikes it, it carries the electrical energy (often several million volts worth) into the Earth where it dissipates without causing damage or harm.

He also established that all electricity was the same type of energy and that it had a positive to negative flow. (We now know that this is the opposite of actual electron flow.) This led to convention for the direction of current flow, which we use today in his honour. Another idea Benjamin Franklin established was that electrical charge can't be created or destroyed but can only be transferred (much like energy in general).

Benjamin Franklin truly was a man of many talents. He not only had a hand in shaping modern day USA but he also left his mark with the scientific discoveries and social changes he introduced. After his death in 1790 from a lung infection, 20 000 people attended his funeral which shows how important and respected he truly was. Due to his various successes he has been honoured in many ways including having his face on American bank notes, statues throughout Philadelphia, postage stamps of his face, as well as his name on numerous buildings and roadways. He also gave £1000 (around $4,400 USD) to a trust on the condition that it was not used but allowed to gain interest for 200 years. Over time, it has become worth $5 million (USD) and has been used for mortgage loans, scholarships and the formation of a trade school called the Franklin Institute of Boston. Benjamin Franklin was an amazing man who left behind an amazing legacy.

How Most Electricity is Made



What do wind, coal, steam, natural gas, sunlight and uranium have in common? While it may not seem obvious at first, they can all be used to produce electricity. The sources of energy for electricity production are of two types; those from renewable sources and those from non-renewable sources.

Renewable sources are those that will be naturally replenished on a human timescale, which means that humans will see them restored and renewed within their lifetimes. These sources include water (tides, rain, lakes, and rivers – often referred to as hydro), wind, light, geothermal heat and biomass/biogas. Non-renewable sources will not be renewed in a rate that humans will witness; they take far too long to be restored. These include coal, oil, natural gas and nuclear.

The modern world is favouring the use of renewable sources because non-renewable reserves are quickly diminishing and they produce a huge amount of pollution. While the source of energy may differ, the process by which electricity is made is much the same.

All power stations contain large turbines. A turbine has many blades attached to an axle which turn very quickly because of a flow of water, steam, air or other fluid through it. The turbine turns a generator which produces the electricity. The generator contains a coil of copper wire that is spun by the turbine within a set of large powerful magnets. This causes electrons to move in the wire generating an electric current. This current is sent to a transformer, which increases the voltage to over 220, 000 volts. This is done to save energy and transmission costs. It might seem strange increasing voltage to save energy but it works because with a higher voltage, a lower current can be used to deliver the same amount of energy. Less current means fewer electrons bumping along the power line wires. This wastes energy because the more collisions, then more electrical energy will be converted to heat in the wires.

If this high voltage was used in our houses, it would destroy all the appliances because household appliances run on around 240 volts (V). To prevent this, suburbs, towns and streets haver transformers that reduce the voltage and make it safe to use. Electrical energy is converted inside appliances into other forms of energy, such as heat and light in a light bulb or sound in a stereo. No matter how it is generated or what source it comes from, electricity is electricity, it is all the same.

Up to 80% of the electricity produced on Earth is made using a steam turbine. This is a turbine that is powered (turned) by super-hot/high-pressure steam. The steam is produced by heating water with burning coal, fission of nuclear elements such as uranium, using the Sun's heat, burning biomass materials (plant matter or animal waste) or burning biogas (which is mainly methane from rotting plant and animal material). The other way to get steam is from deep inside the Earth's crust which is very hot. Steam from this area of the Earth is called 'geothermal steam'. Other methods for turning turbines include burning natural gas (gas products turn the turbine), wind (gusts of wind turn a turbine) or water. Hydroelectric dams use the energy of water falling due to gravity to turn their turbines; some power stations rely on the rise and fall of tides to turn theirs. The Sun's light can also be used to produce electricity without turbines. Special materials in solar electric panels produce voltages and current when light shines on them.

In New Zealand, we rely mostly on hydroelectric dams to produce our power. 55% of electricity produced in 2012 was from these dams and in the South Island they use 98% hydro. Other sources used in New Zealand include: 19% natural gas, 8% geothermal steam, 2% oil, 7% coal, 6% wind and 3% other (biomass, like wood and biogas). Other countries use the various sources of energy in different amounts, depending on the resources that are available to them. For example, a country with little water but long sunshine hours could rely more heavily on solar production. Below are three tables for three different countries and their electricity production.

France (2012)		India (2013)		Norway (2010)	
nuclear	77%	coal	59%	coal and oil	42%
hydro	10%	hydro	17%	hydro	36%
natural gas	4%	natural gas	9%	nuclear	21%
coal	4%	nuclear	2%	biomass	0.5%
oil	0.5%	oil	1%	wind	0.5%
other renewable (wind and solar)	4.5%	other renewable (wind)	12%		

***Note**: Some countries, such as France, sell and export electricity to other countries nearby them. Data courtesy of Bluenomics.com.*

Cells in Series and Parallel

When you open a torch to replace the batteries, you will find that there are two or three separate cells placed end to end, with a spring providing pressure to connect them tightly. If you look at some other electrical devices such as toy trains or remote controlled cars you may find the cells are placed side by side instead. The difference between these two layouts is that one set of cells is in series and the other set is in parallel. The reason for these differences is that by altering the layout of the cells you can alter the output voltage.

When cells are arranged in **series**, each positive terminal is connected to the next cell's negative terminal and so on; they are in a single path which is the same as a series circuit. By connecting cells together this way, it allows a device that needs a large voltage to be powered by several cells of lower voltage. Some devices like a torch need higher voltages to make the lamp glow, so a combination of cells or a battery (remember two or more cells in series makes a battery) working in series provides the necessary voltage . A 9 V battery (like most smoke alarms use) has six individual 1.5 V cells in series inside it as shown in the image opposite.

When you have cells in series, you add the individual voltages to get the total voltage output. Looking at the diagram below, $V = V_1 + V_2 + V_3 + V_4$. So if each cell provides 1.5 V, then the total voltage output would be 1.5 x 4 = 6 V.

cells in series

When the cells are connected in **parallel**, all the positive terminals are joined together and all the negative terminals are joined together, as shown in the diagram below. This means that the voltage isn't altered and the voltage output is still equal to one cell. Looking at the diagram below, $V = V_1 = V_2 = V_3 = V_4$. So if each cell provides 1.5 V, then the total voltage output in this case would still be 1.5 V.

cells in parallel

If the total current required is known then each cell in parallel provides a fraction of it. For the diagram shown, each cell would provide a quarter of the total current. If further cells are added in series, then each cell supplies an even smaller fraction of the total current. This means that the more cells there are in parallel, the longer they will all last.

When using multiple cells, the way that they are connected together (series or parallel) is very important because if the voltage supplied is greater than what a component can take, it is likely that the component will be damaged or completely destroyed.

Ω Electrical Resistance and Ohm's Law

George Simon Ohm

Georg Simon Ohm was a German scientist and mathematician who lived from 1789 to 1854. His father was an intelligent self-educated locksmith who took it upon himself to educate Georg and his brother. His father believed that maths and science were very important so made these the focus of his lessons to his sons. When he was eleven, Georg was sent to a school but no maths and science was taught which hugely disappointed his father. Because of this, he sent him to be educated in Switzerland and later Georg became a teacher. He taught many subjects in many different schools and universities but was never really satisfied with these jobs. He then accepted a teaching position at a school that prided itself on its science education. It was here that he started teaching physics. Within his school laboratory was a large range of equipment that he spent his spare time tinkering with and conducting his own experiments and investigations. It was during these investigations that he discovered his law and published it within a complex and detailed paper titled *'The Galvanic Circuit Investigated Mathematically'*, which stated his theories behind electricity. He had discovered that the product of the circuit (the voltage) is created by the strength of the current and the resistance within the circuit. Despite its merits, the paper and his ideas were widely criticised and the lack of support from his school resulted in his resignation. Georg went on to develop other ideas and laws and worked at the University of Munich as the professor of experimental physics. Like so many famous scientists it wasn't until after his death that he and his work were recognised for their true value.

A Model for Electric Current and Voltage in Circuits

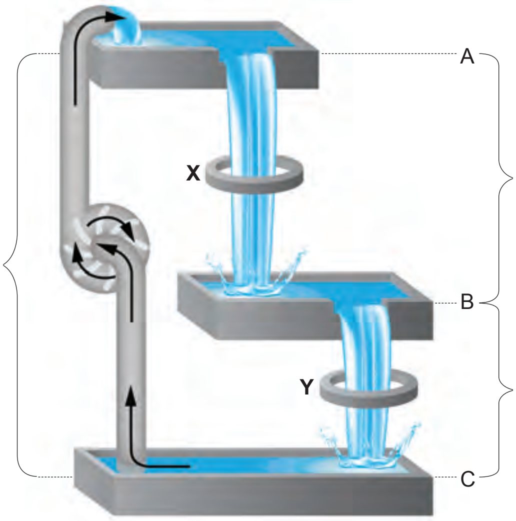
1. Use the word bank to help you complete the following information.

Word Bank

power releases particle potential energy model pumped gravitational flow energy current

A water ______ is very useful when trying to understanding how electric ______ (I) and voltage (V) behave in circuits. The first diagram below shows water being ______ from level C to Level A and then being allowed to fall back to level C via Level B.

The energy from a motor is used to drive a pump which lifts the water. Each litre of water gains the same amount of ______ potential energy in rising from level C to level A.



Each litre of water that falls from level A to level B *releases the same amount of ______.

Each litre of water that falls from level B to level C* ______ the same amount of energy.

*Gravitational ______ *energy is released as kinetic energy, sound energy and some heat energy.*

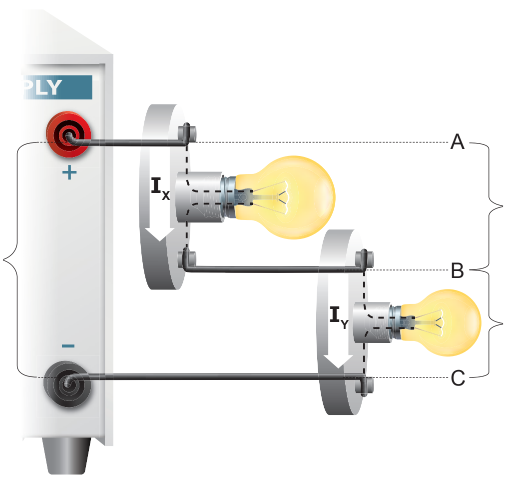
Observations:

1: The total energy given to each litre of water by the pump. = The energy released by each litre of water between level A and B. + The energy released by each litre of water between level B and C.

2: The total amount of water pouring through circle X. = The total amount of water pouring through circle Y. (The water only has one path to take.)

The water model above can be likened to the ______ supply and two **different** lamps in the diagram below:

The mains wall socket gives energy to the power supply which it uses to separate + and − charge onto the terminals. Each *charged ______ gets the same amount of energy. This results in a voltage gain V_{PS} across the power supply terminals. (PS = power supply)



The *charged particles each release the same amount of ______ as they flow through the **large** lamp. This results in a voltage drop V_{AB} across the lamp.

The *charged particles each release the same amount of energy as they ______ through the **small** lamp. This results in a voltage drop V_{BC} across the lamp.

Since the circuit consists of metal conductors, the moving charged particles will be* ***electrons**.*

Observations:

1: $V_{PS} = V_{AB} + V_{BC}$

2: $I_X = I_Y$ (The current only has one path to take.)

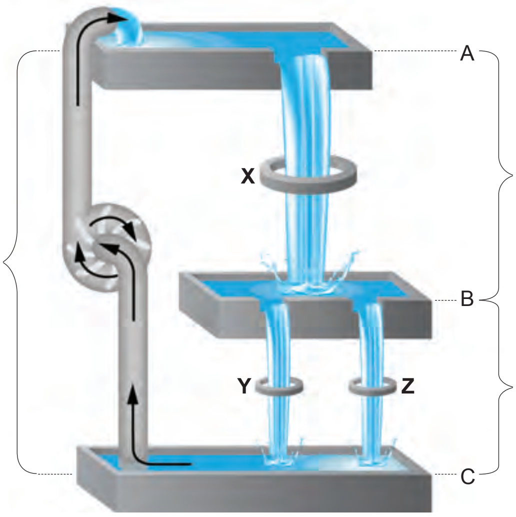
2. Use the word bank to help you complete the following information.

Word Bank

falls both splits same kinetic terminals same

The next diagram shows water again being pumped from level C to the top at Level A and then being allowed to fall back to level C via Level B. There is a difference this time as the flow ______ at level B before falling down to the bottom at level C.

The energy from a motor is used to drive a pump which lifts the water. Each litre of water gains the ______ amount of gravitational potential energy in rising from level C to level A.



Each litre of water that falls from level A to level B *releases the same amount of energy.

Each litre of water that ______ from level B to level C *releases the same amount of energy.

Gravitational potential energy is released as ______ energy, sound energy and some heat energy.

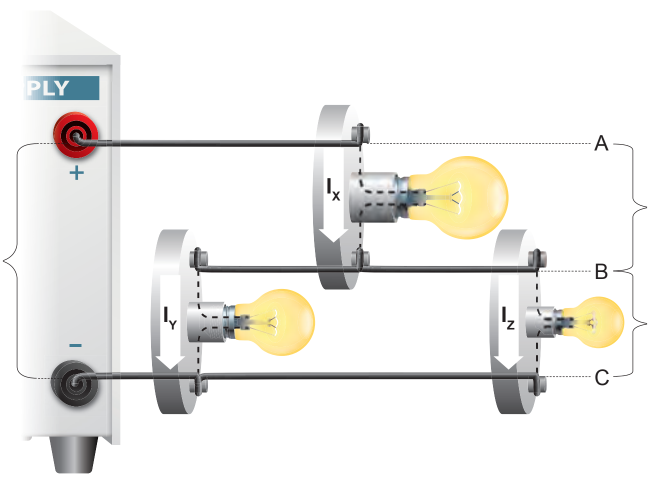
Observations:

1: The total energy given to each litre of water by the pump. **=** The energy released by each litre of water between level A and B. **+** The energy released by each litre of water between level B and C.

2: The total amount of water pouring through circle X. **=** The total amount of water pouring through circle Y. **+** The total amount of water pouring through circle Z.

The water model above can be likened to the power supply and three **different** lamps in the diagram below:

The mains wall socket gives energy to the power supply which it uses to separate + and − charge onto the ______. Each *charged particle gets the same amount of energy. This results in a voltage gain V_{PS} across the power supply terminals. (PS = power supply)



The *charged particles each release the ______ amount of energy as they flow through the large lamp. This results in a voltage V_{AB} across the lamp.

The *charged particles each release the same amount of energy as they flow through the **parallel** lamps. This results in a voltage V_{BC} across ______ lamps.

*Since the circuit consists of metal conductors, the moving charged particles will be **electrons**.*

Observations:

1: $V_{PS} = V_{AB} + V_{BC}$

2: $I_X = I_Y + I_Z$

Word Games

1. Terminology Tornado

Using the following science term, see how many words of 3 or more letters you can make in 10 minutes.

Points
3-4 letters = 1 point
5+ letters = 2 points

Scores
0-5 points = awful
6-10 = average
10+ = amazing

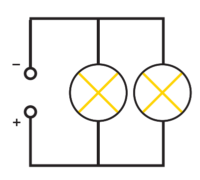
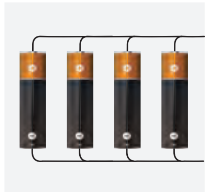
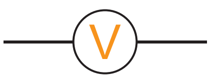
2. Lingo Lattice

All of the answers to the questions are in the lattice below, either as a word or picture. Once you have found each one, there will be one left over, this is the final answer.

Questions

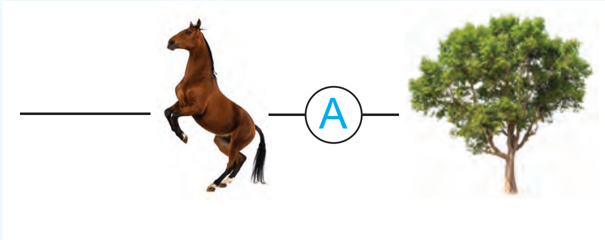
1. What is the symbol for current?
2. What is used in dimmer switches and volume controls?
3. What describes the voltages in a parallel circuit?
4. What device is used to measure voltage?
5. What word means 'flow of charge'?
6. Which of the images shows a parallel circuit?
7. Where would the cells last longer?
8. In which way do you connect an ammeter?
9. What is the voltage output of five 1.6 V cells in series?
10. Which type of current goes back and forth?
11. Which is an example of an insulator?

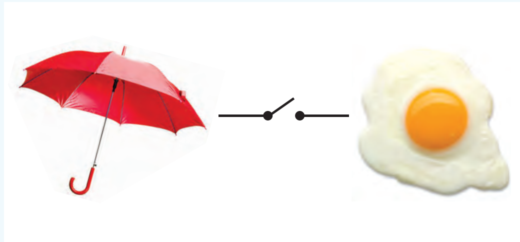
Final Answer

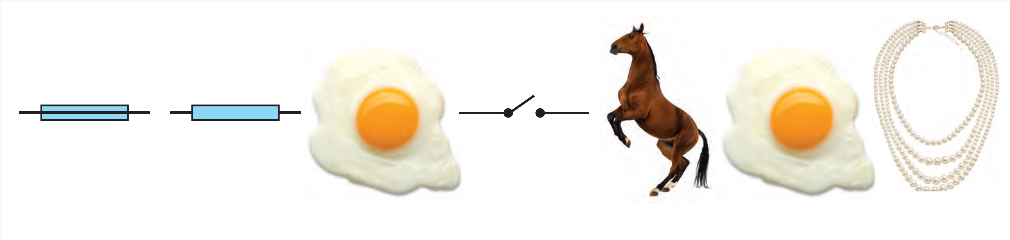
current		8 V
same	series	
	I	1.6 V
alternating	potentiometer	

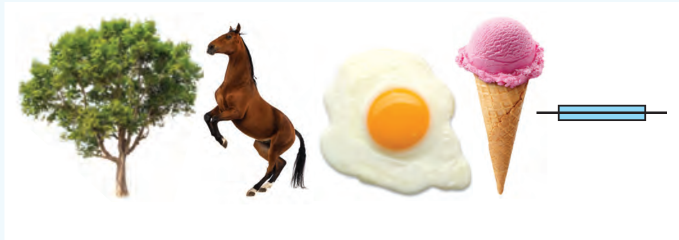
3. Picture Riddle

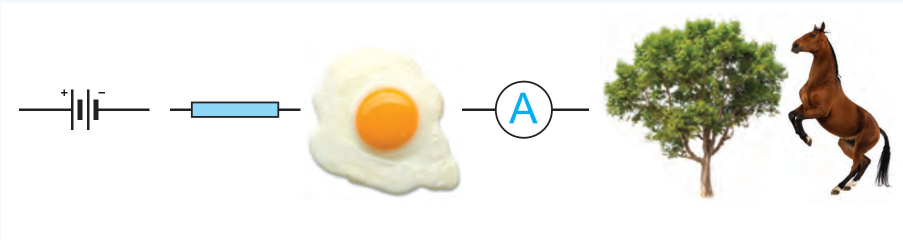
Work out the letter that each picture or symbol represents and use these letters to spell out an electricity joke.



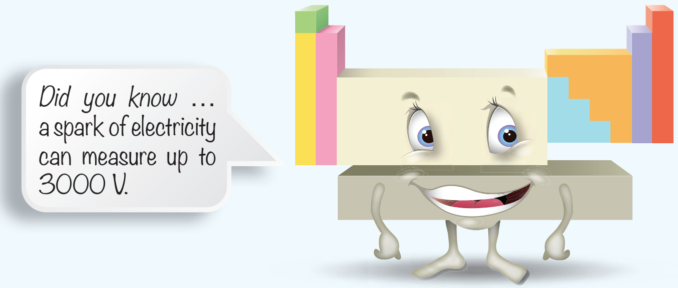


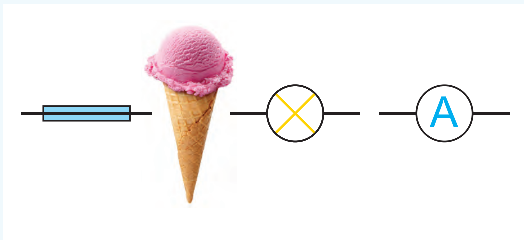






?





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4. Six Word Scramble

Use the clues to work out what the 6 key science words are and then spell the word in the grid by colouring in the squares that make up the word. Use different colours for each answer.

TOR	ECT	TA	RY
DU	GE	CTOR	CON
SE	SIS	TTE	BA
RE	FU	VOL	DIR

Clues

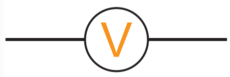
a. A safety device that melts with excess current. (4) __________
b. A substance that allows electricity to flow through it. (8) __________
c. Current that flows in one direction only. (6) __________
d. Two or more cells working in series. (7) __________
e. A device that reduces the current in a circuit. (8) __________
f. A measure of the difference in energy across a component. (7) __________

5. Topic Word Find

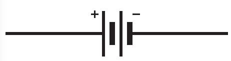
There are twelve electrical words or phrases hidden in the word find below. Write the name of the symbol underneath each one and circle each as you find them in the word find.

S	M	O	D	E	D	B	E	W	C	I	D	O	D	N	P
M	P	S	S	I	I	E	O	H	P	E	I	E	Y	P	O
R	A	T	O	W	L	R	E	C	V	E	E	L	D	R	L
R	E	M	D	I	R	S	S	T	R	E	P	L	W	Y	M
T	E	O	M	R	J	Y	E	I	T	P	U	I	L	R	L
R	L	W	D	E	W	N	E	W	U	R	R	S	H	E	D
L	S	W	H	C	T	I	W	S	N	E	P	O	B	T	C
E	D	E	L	S	N	E	R	D	T	A	M	D	A	T	L
R	O	T	S	I	S	E	R	E	L	B	A	I	R	A	V
C	R	T	T	T	W	T	M	S	S	E	L	I	E	B	M
B	W	L	S	O	P	T	O	O	E	J	Y	D	S	W	N
A	N	E	P	E	L	M	M	L	A	R	O	E	C	D	L
C	I	C	P	O	E	O	E	C	O	I	E	I	L	D	A
C	D	S	V	I	P	E	I	S	D	R	D	P	N	R	L
M	E	R	Y	T	A	P	I	I	M	I	D	E	S	E	W
T	O	E	W	R	Y	O	E	T	R	R	O	E	E	B	D

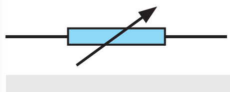

5, 6 letters



9 letters



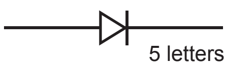
7 letters

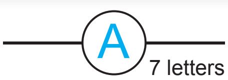

8, 8 letters

2, 5, 6 letters


4, 6 letters

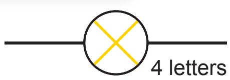
6, 6 letters

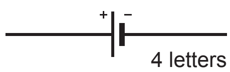

5 letters



7 letters

4 letters


4 letters



4 letters