ELECTRICITY

HOW IS ELECTRICITY PRODUCED?

All electricity is produced from other sources of energy.

Hydroelectricity – is produced from the stored energy of water held back by a dam. As the water runs downhill from the dam through a pipeline to the power station, it turns water turbines. The turbines turn generators which produce electricity. The energy conversions are as follows:

Stored energy → moving energy (kinetic) → electrical energy

Fuel burning power station

The chemical energy in fuels e.g. coal, oil, gas or uranium (nuclear energy) is converted into heat energy which heats water into steam. The steam turns steam turbines and they turn generators.

Stored energy → heat energy →kinetic energy – electrical energy

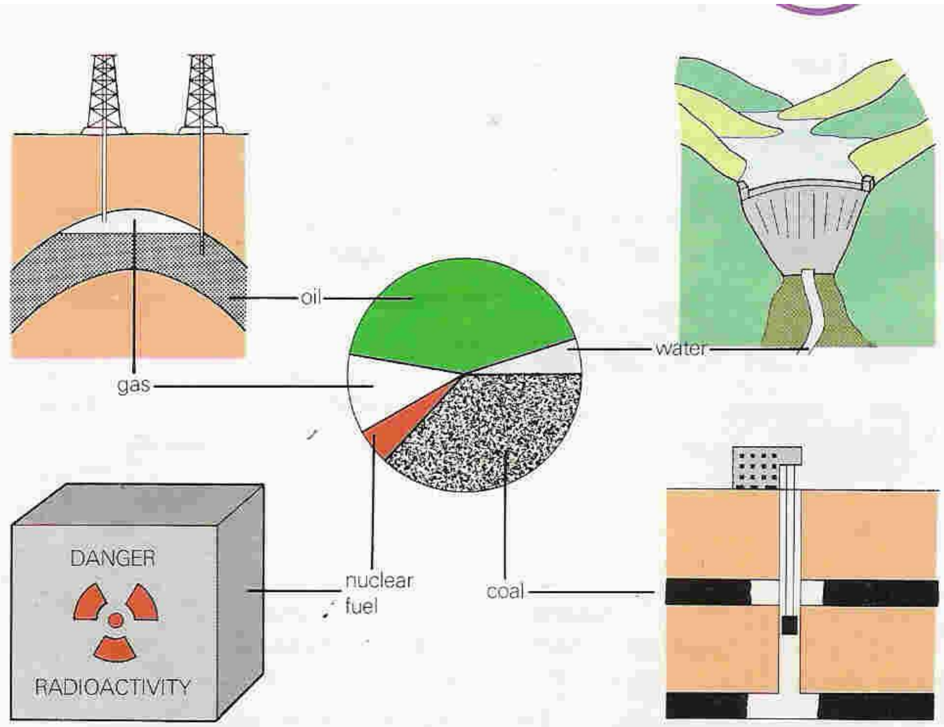
See the diagrams for these stations on the next page.

Conductors and Insulators

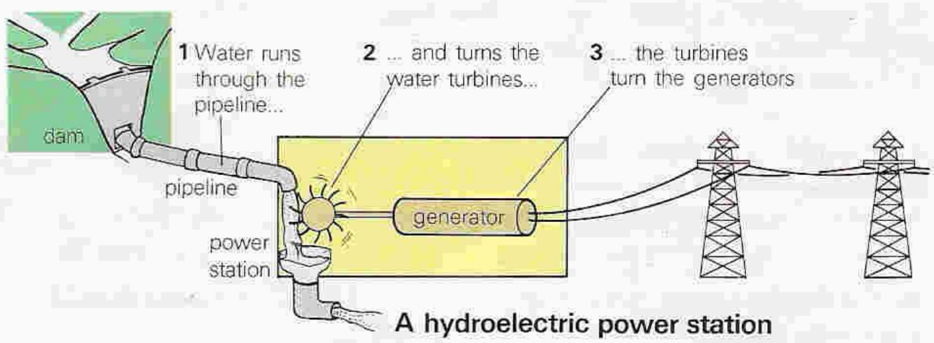
Materials which conduct electricity are conductors, those which do not are called insulators. The table below lists good conductors and insulators.

GOOD CONDUCTORS	CONDUCTORS BUT NOT VERY GOOD ONES	INSULATORS
ALL METALS	Human bodies	Dry air
INCLUDING	Frog's legs	Plastic
Copper	Dirty water	Balloons
Silver	Salty water	Nylon socks
Gold	Damp air	Wood
Mercury	Sweaty hands	Rubber
	Cows on electric fences	Distilled water
Carbon	silicon	

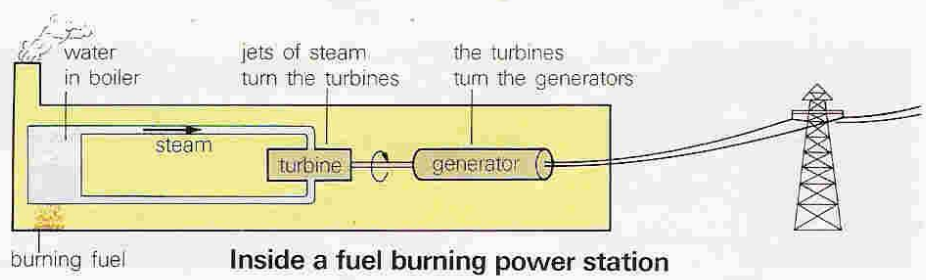
Conductors carry electricity either because they have loose electrons within their structures that can move in a current or they have charged particles.



Where the world's energy comes from



A hydroelectric power station

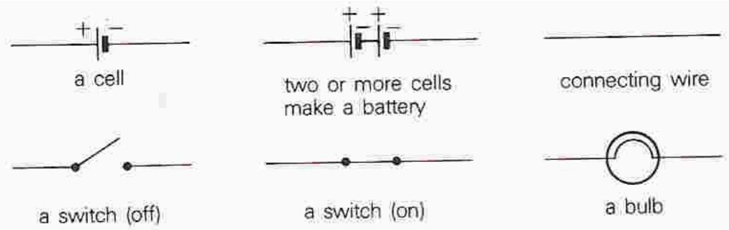


Inside a fuel burning power station

CURRENT

An electric current is a flow of electrons. In the past it was believed that current moved from a positive connection to a negative connection. It is now known that electrons move from negative to positive but the convention is still to draw an arrow going from positive to negative.

The following symbols are used when drawing circuits.



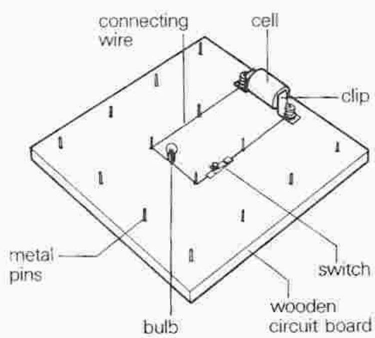


Figure 1 A simple electric circuit can be built on a circuit board.

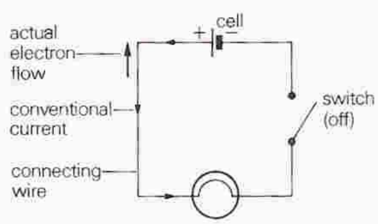


Figure 2 This circuit diagram is a map of the circuit in Figure 1.

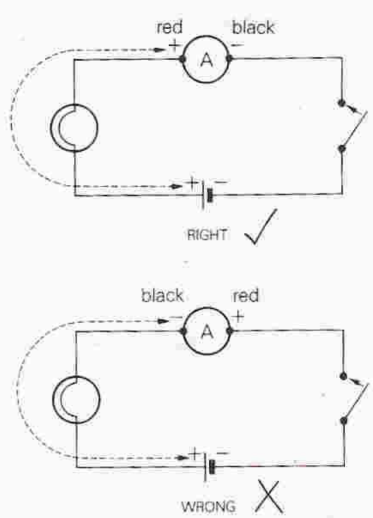


Figure 3 The red connection on an ammeter must be joined to the positive connection of the cell.

Electrons are pushed through a circuit by a battery (two or more cells). Electrons must have a unbroken pathway and prefer the easiest route. Thus electrons will travel along a thick wire in preference to a thin wire. This is illustrated on the diagram to the left.

Electric currents are measured in amperes (A). The device which measures the current is called an ammeter. An ammeter has two connections: a positive (+) which is red and a negative (-) which is black. The ammeter must be connected the right way round or the needle will move backwards instead of forwards. See diagram on the next page.

Voltage is the driving force or electrical push in a circuit. It is measured in volts (V) with a voltmeter. Voltmeters are connected across a cell or battery.

Resistance, resist the current, a bulb in a circuit for example adds resistance to that circuit. Current can be increased in a circuit by lowering the resistance or increasing the voltage. The reason why electricity flows through thick wires easier than thin wires is because they offer less resistance. Every

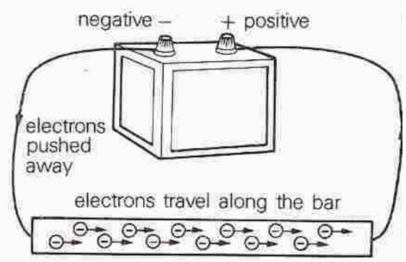


Figure 6 Electrons can be pushed through a metal bar by a battery.

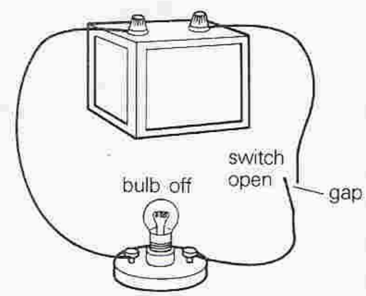


Figure 7 If a circuit is broken, electrons cannot flow.

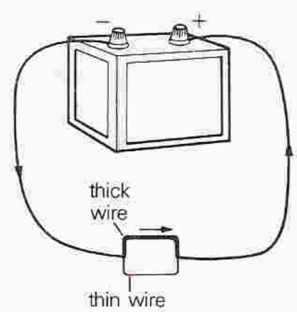


Figure 8 Electrons will travel along a thick wire in preference to a thin wire.

material has an electrical resistance. The greater the material's resistance, the smaller the current which flows through it.

When a current flows through a wire, electrical energy is changed to heat energy. When a current is pushed through a high resistance wire by a large voltage, large amounts of heat are produced.

Resistance is measured in ohms (Ω).

Questions

1. What is an insulator? What is a conductor?
2. Why are electric wires made of copper but coated with plastic?
3. (a) Why do firemen not wear metal hats?
   (b) Fishing near electricity wires is always dangerous, but using a carbon fibre rod makes it even more unsafe. Explain why.
4. Copper has a smaller resistance than nichrome. What does this mean?
5. What can you say about the resistance of (a) a conductor and (b) an insulator?
6. The resistance of a car headlight bulb changes after it has been switched on. The resistance increases as the bulb heats up. How will this affect the current flowing through the bulb? Explain.

SERIES AND PARALLEL CIRCUITS

In a series circuit, the current is the same throughout the circuit. In a parallel circuit, the current splits up when it comes to a junction. The current through the branches add up to the total current in the main part of the circuit. Draw the examples of the two types of circuits.
Also see pages 95 and 96, try all the questions and the questions on page 248

The relationship between current, voltage and resistance is

$V = IR$ where V = voltage in volts, I = current in amperes and R = resistance in ohms.

This equation can be switched around

$I = V/R$ and $R = V/I$

1. A 12 V car battery is connected to a circuit whose total resistance is 6 Ω. What current will flow?
2. A 12 V battery is connected to a circuit. If the current is 2 mA, what must the resistance of the circuit be? Hint you must first convert mA into A.
3. What voltage battery would be needed to send a current of 3 A round a circuit whose total resistance is 4 Ω?

For resistors in series the total resistance equals the sum of all the separate components.
Example

FUSES

The purpose of a fuse is to protect the wiring in a house. If the current flowing through the wires is bigger than they are designed to take, the fuse melts and switches off. This prevents the wiring from overheating, melting its insulation and starting fires. See handout from Starting Science for diagrams of fuses A fuse consists of a short length of thin wire with a low melting point, rather like solder.

Power

In electricity power = voltage x current where power is measured in watts.
To work out the current drawn from the mains you use P = VI.

Example An electric hand dryer rated at 1.1 kW is designed to run off the 110V mains. Suggest a suitable fuse for it.

1.1 kW = 1100 W,   Using our equation   1100 = 110 x I   ∴ current I = 10 A

The wiring to the appliance should be able to cope with a current of 10 A. The fuse should be rated near to its melting point so early failure would be likely therefore a fuse which would blow at 13 A or 15 A would be appropriate.

Circuit breakers are now used instead of fuses. A circuit breaker contains little electromagnets connected in series with the rest of the circuit. If the current gets too high, the electromagnet becomes strong enough to operate a switch to turn it off.

Try this question
An extension cord, rated at 5 A, is bought to run a television set. Your mother unplug the TV set and plugs in the electric iron (110 V, 1.1 kW) instead.
Why is this a bad thing to do? What is likely to happen? What are the dangers?

The third pin in a mains socket is the earth connection. The earth connection is connected by very low resistance wires to a metal plate or rod buried in the soil just outside the house. If an appliance has a metal case and something goes wrong with the wiring, the metal could become live (give you an electric shock). The earth wire allows the current to pass through it instead of through you.

The Kilowatt-Hour of energy

Your electricity bill represents the gives the amount of energy used each month and the amount charged by the supplier. Energy is measure in Joules, but this unit of energy is too small for the company to use. The electric company has their own unit for energy. There unit the kilowatt-hour represent the amount of energy needed to keep a 1 kW appliance running for 1 hour.

A 2kW appliance left on for 3 hours would use 6 kWh (2 X 3) of energy.

Example 1   How much energy would a 3KW appliance use if left on for 15 minutes?
15 minutes = 15/60 = 0.25 hours   energy used = 3 X 0.25 =0.75 kWh

Example 2   How much energy would a 5W appliance use if left on for 7 hours?
5W = 5/1000 =0.005 kW   energy used = 0.005 X 7 = 0.035 kWh

Reading an electric meter

Some meters are digital but most still consist of a series of dials.

Each dial turns in the opposite direction to the one next to it. The meter on the right turns clockwise, the one next to it anti-clockwise, the one next to it clockwise etc. Ignore the red dial when taking readings. Note the number that the pointer has just passed for each meter. If the pointer is half way between 4 and 5 record 4 (the number it has just passed). The meter above therefore reads

60 169 kWh

Take a reading from the meter below

50.5 How to wire plugs

The insulation round the wires in the cord of an appliance will be colour-coded to indicate which is which. These should be the colours:

BROWN: the live wire;
BLUE: the neutral (return) wire;
GREEN AND YELLOW: the earth wire, connected to the metal casing.

A two-pin plug connects just to the live and neutral wires; the extra pin in a three-pin plug is for the earth wire.

Warning! There may be local variations in the colours of the wires in some parts of the Caribbean. If in doubt, ask a qualified electrician.

If you have to wire up a plug for yourself (Fig. 50.7), there are some important things which for safety's sake you must get right. The main ones are these:

1 Firmly connect the right wire to the right pin.

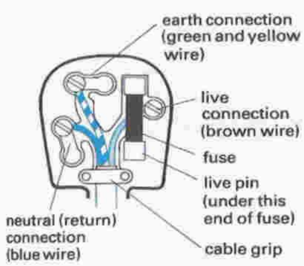


Fig. 50.7 How to wire a plug