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Key Concepts in Colour

Preliminary Physics Topic 2

Electrical Energy in the Home

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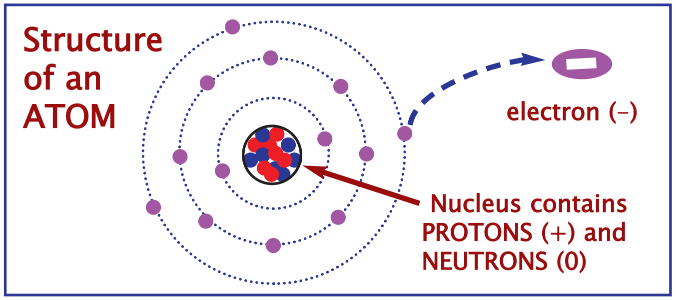
Electrical Energy in the Home

First, Some Revision:

WHAT IS ELECTRICITY?

To answer that, you need to be reminded about atoms:



Atoms consist of a central nucleus in which are:

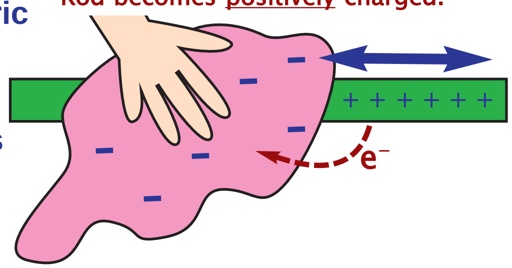
Protons (+ve) & **Neutrons** (neutral).

In orbit are tiny **Electrons** (-ve).

Both protons and electrons have a property we call "Electric Charge", which is responsible for all the things we know as "Electricity" and "Magnetism".

Normally, every atom has exactly the same number of protons and electrons, and therefore the same amount of (+ve) and (-ve) electric charge.

Electrons rubbed off perspex rod. Rod becomes positively charged.



However, it is relatively easy to separate electrons from atoms,

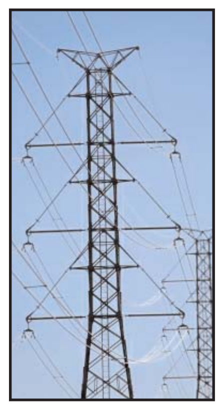
and then things get interesting...

STATIC ELECTRICITY ("Static" = not moving)

If different materials are rubbed together, friction can often remove electrons from one and deposit them on the other. The result is that each substance is left with an electric charge.

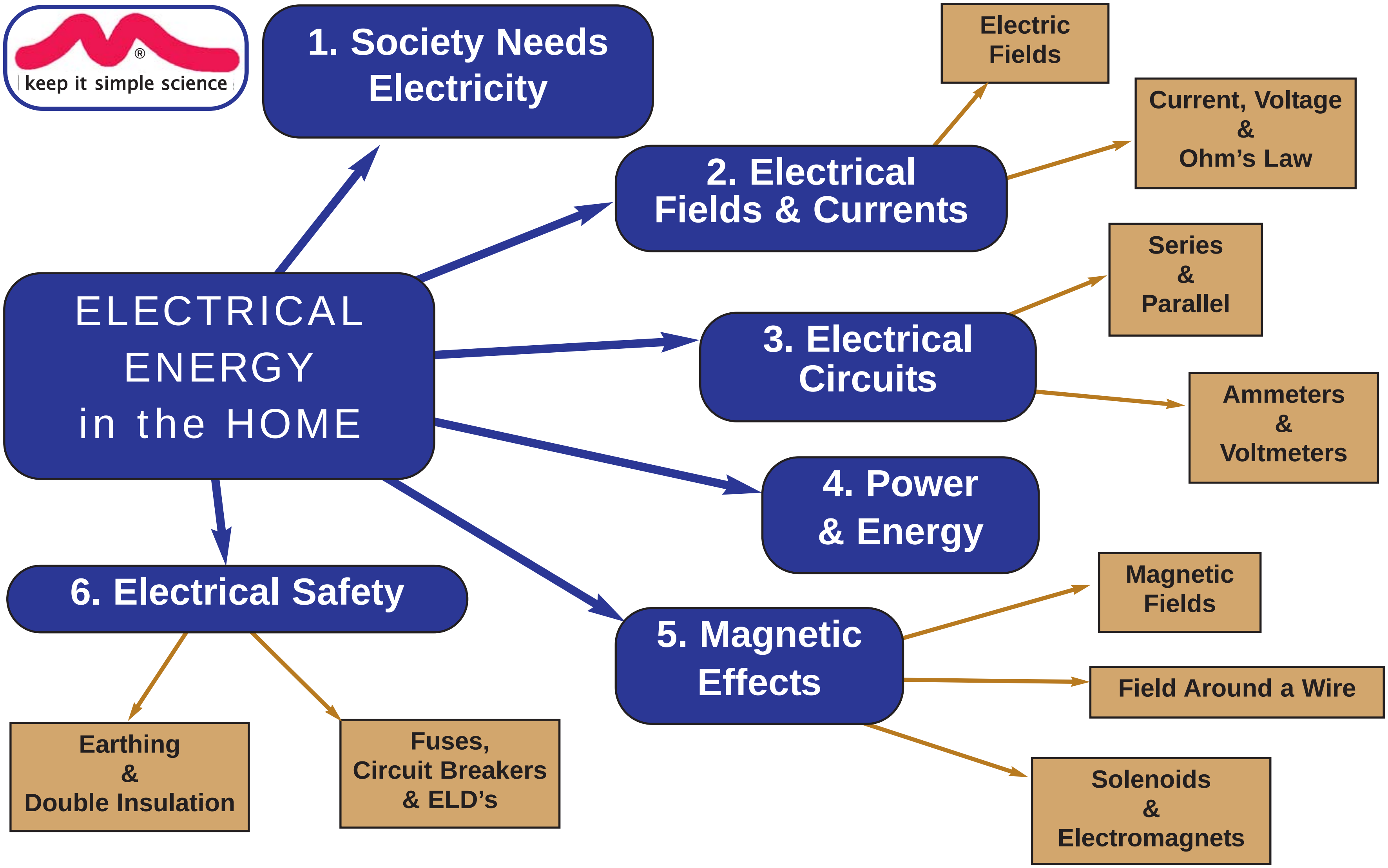
Charged objects can attract or repel each each other and cause all sorts of weird things to happen.

CURRENT ELECTRICITY
("Current" means moving/flowing)



Electrons can also flow through Conductors, such as metal wires.

and that's when electricity gets very useful...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ELECTRICAL ENERGY in the HOME
1. Society Needs Electricity
2. Electrical Fields & Currents
Electric Fields
Current, Voltage & Ohm's Law
3. Electrical Circuits
Series & Parallel
Ammeters & Voltmeters
4. Power & Energy
5. Magnetic Effects
Magnetic Fields
Field Around a Wire
Solenoids & Electromagnets
6. Electrical Safety
Earthing & Double Insulation
Fuses, Circuit Breakers & ELD's

1. SOCIETY NEEDS ELECTRICITY

We are so used to having electrical appliances and getting things done with the flick of a switch that it's easy to forget that it wasn't always like that.

Energy Sources in History

Our distant ancestors had only their own muscles and the warmth of the Sun to provide energy to do anything.

Slowly that changed. Each new energy source gave more power, more wealth, better living conditions and more opportunity for humans to survive and control their environment.

500,000 BC: control of fire. Heating & cooking.

10,000 BC: domestication of animals... animal power improves the transport of people and goods, plowing, etc.

3,000 BC: wind and water power.... sailing boats, windmills, etc.

(approx) 1750 AD: burning of coal begins to replace wood. Steam engines invented... machinery, trains, steam ships, etc. This was the "Industrial Revolution".

1780-1800: scientific investigations of the strange properties of electricity... the conflicting theories of Galvani and Volta (see later...), but electricity remains a scientific curiosity made in small amounts by batteries.

1830's: discovery of how to generate electricity using a "dynamo" (generator). Practical amounts of electrical power become possible, but it was still only used for scientific research.

1880-1910: a flood of inventions such as the light bulb, telephone, gramophone and radio created a demand for electricity to be made available on a large scale.

By 1950, all industrialised nations had become totally converted to, and dependent on electricity for domestic power.

Continued next slide...

SOCIETY NEEDS ELECTRICITY (cont.)

The Impacts of Change

As the sources and available amounts of energy have changed, so has human society.

When only human muscles, animal power and wood burning was available, most people lived in rural areas and grew their own food. "Cottage Industry" was widespread, with people manufacturing clothing, shoes, furniture, etc on a small scale in their own homes.

Life was simple and people worked hard. If there was any leisure time, people entertained themselves with their own music, singing and dancing.

The "Industrial Revolution" changed that by the invention of mass-production in huge factories. Cottage industry collapsed, and many country people were forced to move to cities and find jobs in the factories.

INDUSTRIALISATION & URBANISATION

Modern factories are now powered by electricity instead of coal & steam engines, but the trend continues... the jobs and opportunities (and the "bright lights") still attract country people to the cities.

People now enjoy a lot more leisure time, but how they spend it has changed totally. Electricity makes it possible to go to a movie, watch TV, listen to CD music or Twitter on the internet.

Electricity powers the computers and other equipment that have revolutionised our banking, businesses and communication systems.

Electricity in peoples' homes has resulted in many "labour-saving" and convenience appliances... washing machines, diswashers, vacuum cleaners, microwaves... even the electric toothbrush!

Increasing access to energy, especially electricity, has had a huge impact on human society.

Power Supply in Remote Places

Despite our society's massive usage of electricity, there are still many remote locations (e.g. in central Australia) where it is impractical to link small communities to the main power grid.

These places must use things like:

Diesel Generators

A diesel powered engine drives an electric generator.

Solar Cells

A solar cell converts sunlight directly to electricity which can be stored in batteries for night use.

Wind turbines

generate electricity from the power of the wind.

A remote community equipped with solar cells and wind turbines for electricity.

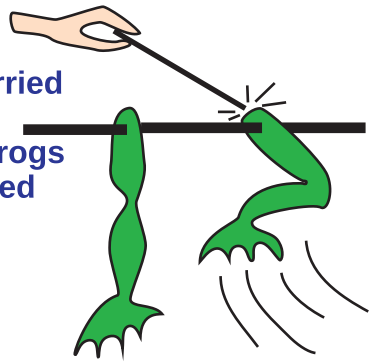
Arguably, this is how all homes should be powered, remote or not!

Volta v Galvani

THE DEBATE ABOUT ELECTRICITY

Back in the 18th century there was great disagreement about what electricity actually was, and where it came from.

From 1780 Luigi Galvani carried out a series of experiments in which freshly dissected frogs legs "twitched" when touched by different metal hooks and wires.
Galvani believed that electricity came from the frog as "animal electricity", a sort of fluid that was connected with the "life force".



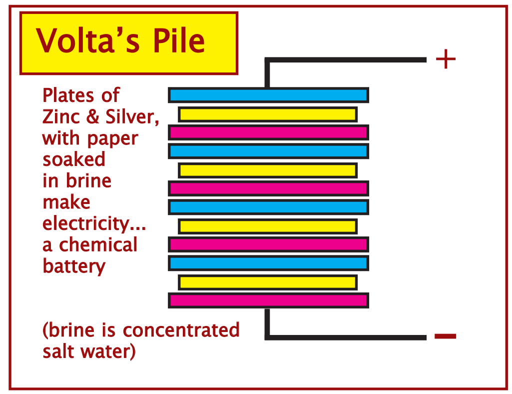
Many did not agree with Galvani. Alessandro Volta suggested that the electricity making the frog muscles jump was produced by chemical reactions in the metals and fluids present. His experiments of 1794 supported his idea.

The debate raged between the supporters of each theory, until 1800 when Volta made huge amounts (for that time) of electricity from a series of metal plates with paper soaked in salt water in between.. and not a frog in sight.

This settled the debate!

Although he turned out to be wrong, Galvani's idea sparked (sorry!) tremendous interest in the study of electricity, so he did contribute to scientific progress.

The basic electrical meter for detecting and measuring electricity is called a "galvanometer" in his honour.



Volta's "Pile" was the forerunner of modern batteries. For many years it was the best way for scientists to make electricity in the laboratory for further study.

In recognition of his great contribution, we name the electrical unit, the "volt" in honour of Alessandro Volta.

Activity 1

The following activity might be completed by class discussion, or your teacher may have paper copies for you to do.

ELECTRICITY & SOCIETY

Student Name ....

1. What was the main source of energy for industry before electricity?

2. Electricity was known (to scientists) for a hundred years before it began being used in practical ways in society.
What happened to cause it to start being used?

3. (For class discussion)
Why do you think electricity has become so widely used?

4. In the history of the discovery of electricity:
a) where did Galvani think the electricity came from in his experiments?

b) where did Volta think it came from?

5. what was Volta's "Pile" and why was it crucial in the scientific study of electricity?

2. ELECTRIC FIELDS & CURRENTS

Electrostatic Charges and Fields

Electrical charges push or pull each other... there are forces between them:

SAME CHARGES REPEL

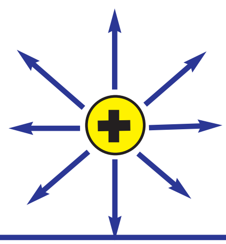
DIFFERENT CHARGES ATTRACT

The forces are best explained by imagining that each electrical charge is surrounded by a "FORCE FIELD". Any electrical charge that is placed within the field will experience a force.

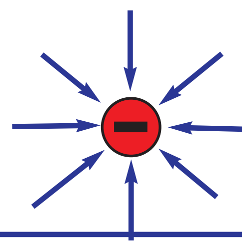
By definition, the direction of the force field lines is the direction a positive (+ve) charge would move if placed in the field.

SHAPES OF FIELDS AROUND POINT CHARGES

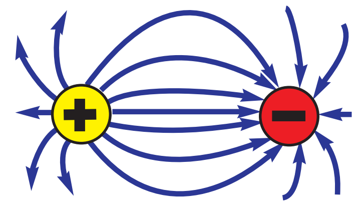
POSITIVE



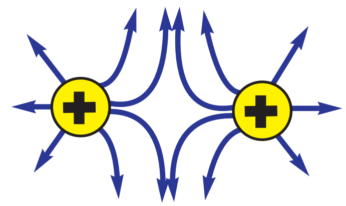
NEGATIVE



FIELD SHAPE BETWEEN TWO OPPOSITE CHARGES.
(attracting each other)



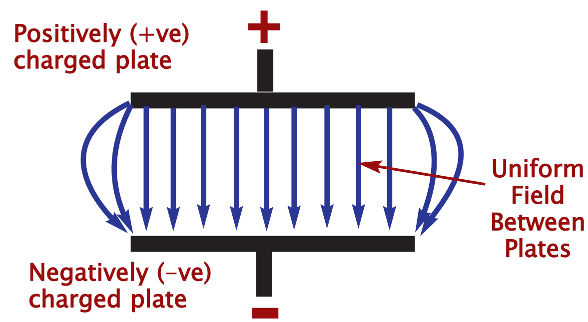
ELECTRIC FIELD BETWEEN TWO IDENTICAL CHARGES.
(repelling each other)



These fields are irregular and the strength of the field varies from place to place.

The only electrical field that is quite regular and has the same strength at each point is the

FIELD BETWEEN TWO CHARGED PLATES



MEASUREMENT OF ELECTRICAL CHARGE & FIELD

The unit of electric charge is the Coulomb (C).
1 coulomb of charge is a very large amount, so "microcoulombs"(μC) are commonly used.

$1\ \mu C = 1 \times 10^{-6}\ C$

("Coulomb" is named in honour of a French scientist.)

The Electric Field strength is defined and measured as the Force per unit of Charge:

ELECTRIC FIELD = FORCE / CHARGE

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

Electric Field is a VECTOR.
It has a direction as well as a value.

The direction is the way a +ve charge would move

Since force is measured in newtons (N), and charge is in coulombs (C), it follows that the unit of electric field strength is the "newton per coulomb" (NC^{-1})

This means if a charge "Q" experiences an electric force "F", then there must be an electric field present, and its strength is F/Q.

Example Problem 1

When an electric charge "Q" = 6.50×10^{-4} C is placed in an electric field, it experiences a force of 8.15×10^{-2} N. What is the field strength at that point?

Solution: $E = F / Q$

$= 8.15 \times 10^{-2} / 6.50 \times 10^{-4}$

$E = 125\ NC^{-1}$

Example Problem 2

What force would be experienced by a charge of 4.68×10^{-6} C, when placed in an electric field with strength $3.65 \times 10^{3}\ NC^{-1}$?

Solution

E = F/Q, so F = E.Q

$= 3.65 \times 10^{3} \times 4.68 \times 10^{-6}$

$= 0.017082$

$= 1.71 \times 10^{-2}$ N

Electric Current

If electric charges are located on insulators (e.g. plastic) then the charge cannot move and you have static electricity. This can attract things, or repel other same-type charges, such as when your hair stands on end from "static".

If, however, electric charges are located in a conductor (e.g. a metal wire) AND there is an electric field present, then the charges will FLOW THROUGH THE CONDUCTOR because of the force applied to them by the field... this is ELECTRIC CURRENT.

Electric current (symbol I) is defined as the rate of flow of charge, and can be measured in Coulombs per second. ($C.s^{-1}$)

However, we call this unit the "Ampere" ("Amp" for short, symbol "A") in honour of yet another great scientist.

CURRENT = $\frac{\text{CHARGE}}{\text{TIME}}$

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

1 Amp = 1 coulomb per second

Direct & Alternating Current

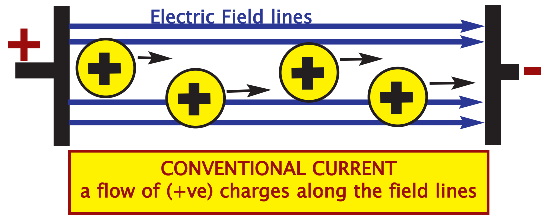
If the electric field is constant, then the charge will flow steadily in one direction. This is called DIRECT CURRENT (DC). Batteries produce DC.

If the field keeps reversing its direction, so does the current. The charges will move back-and-forth. This is called ALTERNATING CURRENT (AC). Generators produce AC. Our "mains" electricity supply is 50 Hz AC... it moves back-and-forth 50 times per second.

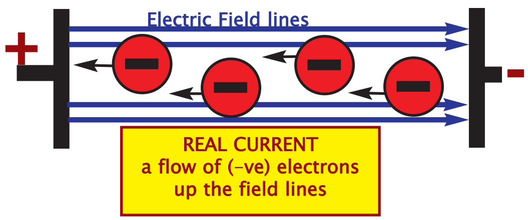
Real & Conventional Current

In the mid 19th century, when scientists figured out that electric current was a flow of electric charges, the obvious question was "is it positives going this way, or negatives going the other way?" Back then they couldn't tell, but realised that in terms of energy flow it was all the same anyhow, as long as everyone was consistent about it.

So, they decided that current is a stream of (+ve) charges flowing with the electric field direction lines.



They had a 50-50 chance and got it wrong!



We now know that electric current in a wire is always the flow of (-ve) electrons in the opposite direction.

However, we still use both descriptions. You must accept that:

"Conventional current" is a flow of (+ve) charge
from (+ve) terminal to (-ve)
AND
"Real current" is a flow of (-ve) electrons the other way.

Voltage

So what makes the charges flow?
An electric field provides a force that acts on each charge. (remember E=F/Q ?)

This "electromotive force" (emf) acts on each charge, giving it ENERGY (measured in Joules (J)). "Voltage" is a measure of how much energy is given to each unit of charge, so...

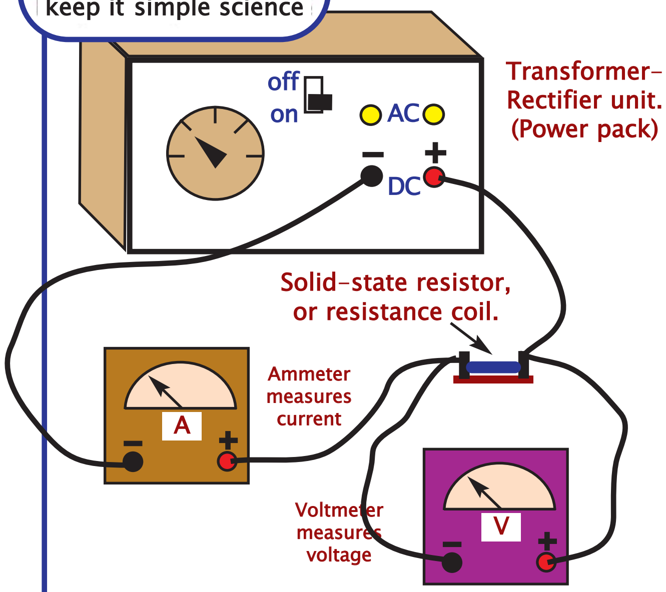
1 Volt (V) = 1 Joule (J) of energy
per Coulomb (C)

So, a 9 volt battery gives 9 Joules of energy to each Coulomb of charge.
A 12 V battery gives 12J to each coulomb of electrons, and so on.

The bigger the voltage, the more energy is available to an electric circuit and the MORE CURRENT FLOWS.

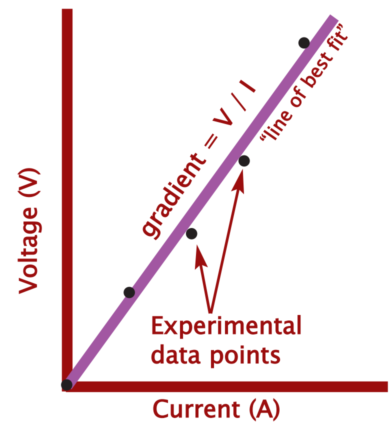
Ohm's Law

Practical Work



You may have carried out a "1st hand investigation" in which you set up a simple electric circuit and meaured the current flow (in Amps) at various Voltage settings. When your data was graphed, it may have looked like this:

The straight line graph shows a direct relationship between voltage & current.



About 1830, Georg Ohm discovered this relationship and established that the gradient of the graph is a constant value for any given resistor. This value is now called the "RESISTANCE", and may be thought of as a value for how the current is being retarded as it flows in the circuit.

The relationship is now called "<u>Ohm's Law</u>"

The unit of resistance is called the "Ohm". The symbol used is the greek letter "omiga" (Ω).

gradient of graph = $\frac{\text{VOLTAGE}}{\text{CURRENT}}$ = RESISTANCE

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

Example Problem 1

What current would flow through a 4.0 Ω resistor if the voltage across the resistor is 10 V ?

Solution: $V = IR$

$10 = I \times 4.0$

$I = 10 / 4.0$

$= 2.5$ A.

Example Problem 2

In an electric circuit, a 5.00 Ω resistor is found to have 2.50A of current flowing through it. What is the voltage across the resistor?

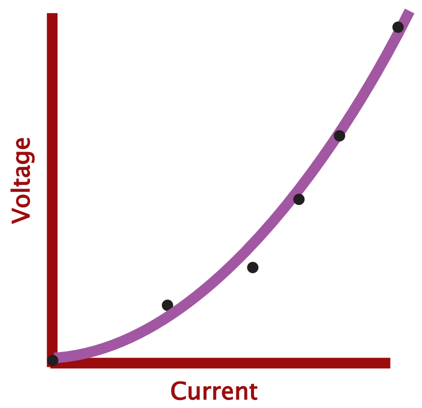
Solution: $V = IR$

$= 2.50 \times 5.00$

$= 12.5$ V

Non-Ohmic Resistance

If you tried the Ohm's Law experiment using a light bulb as your resistor, the graph will come out rather differently:



The curve indicates that the resistance of the bulb keeps changing and does not have a single value. The bulb does not follow Ohm's Law (straight line, single gradient value) and is said to be "NON-OHMIC".

Conductors & Insulators

A conductor can now be understood as a substance with a very low resistance value, so that current flows through it easily. An insulator as a substance with a very high resistance value which impedes current flow.

Generally, metals are good conductors. Silver & gold are excellent conductors, but we mostly use <u>copper</u> and <u>aluminium</u> for electrical wiring because they are nearly as good as conductors, and a lot cheaper.

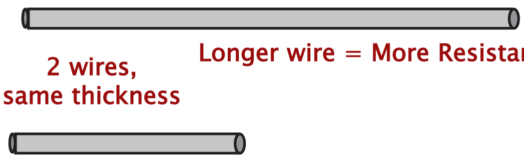
Good insulators include glass, plastic and paper. Although their resistance is very high, it's all a matter of Ohm's Law. If a large enough voltage is applied, even a good insulator can "break down" and allow current to flow.

Contrary to general belief, water itself is NOT a good conductor... the resistance of pure water is very high. However, sea water, bath water or even tap water may have enough dissolved chemicals in it to increase the conductivity (decrease the resistance) to dangerous levels when mains electricity (240 V) is involved.

Factors Affecting the Resistance of a Wire

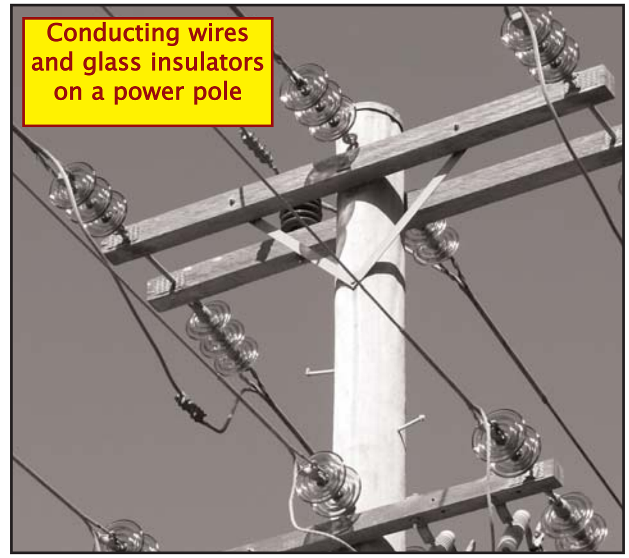
Length

Everything else being equal, the LONGER conductor has MORE RESISTANCE.



Cross-sectional Area

The LARGER the cross-sectional area, the LESS RESISTANCE.

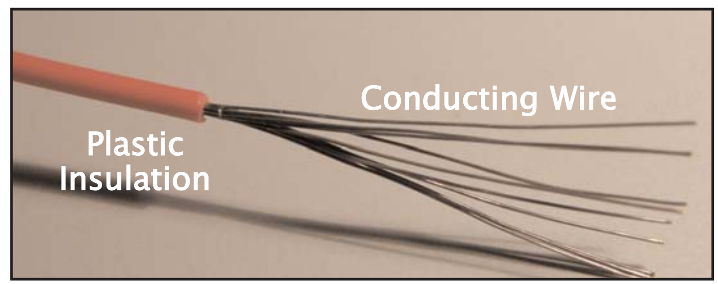


Temperature

Generally in metals, the HOTTER they get, the MORE RESISTANCE they develop.

Type of Material

As already mentioned, metals are mostly good conductors while glass & plastic are poor.

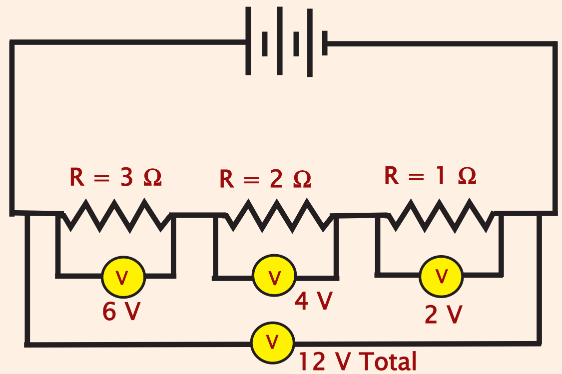


More About Voltage..."Potential Difference"

The "voltage" or "emf" produced by a power source is a measure of how much energy per unit of charge ($J.C^{-1}$) is given to the charges by the electric field.

However, when you measure the voltage across a resistor you are measuring the ENERGY DIFFERENCE (per charge) from one side of the resistor to the other. So, instead of measuring the energy gained by the electrons, you are measuring the energy LOST by the electrons as they push through the resistor. (Energy per unit charge)

You may have measured this "POTENTIAL DIFFERENCE" (P.D.) (or "Voltage Drop") across different resistors in a circuit similar to that shown in the diagram.



You will have found that:

- the higher the Resistance, the greater the P.D, because more energy is lost by the charges.
- the sum of the P.D.'s around the circuit is equal to the total voltage for the entire circuit.

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Activity 2

The following activity might be completed by class discussion, or your teacher may have paper copies for you to do.

FIELDS & CURRENTS

Student Name ....

1.
a) What happens to an electrically charged object or particle if it is placed in an electric field?
b) How is the direction of the field defined?
c) How is the strength of the field defined?
d) What are the units of electric field strength?

2.
a) What is the definition of electrical "current" and what is the unit?
b) Explain the difference between "real" and "conventional" current.

c) What do "AC" & "DC" stand for? Explain the difference between them.

3. What is "voltage"?

4. What do we call the ratio between the voltage and current in a circuit and what unit is used?

5. What is the difference between an "ohmic" and "non-ohmic" resistor?

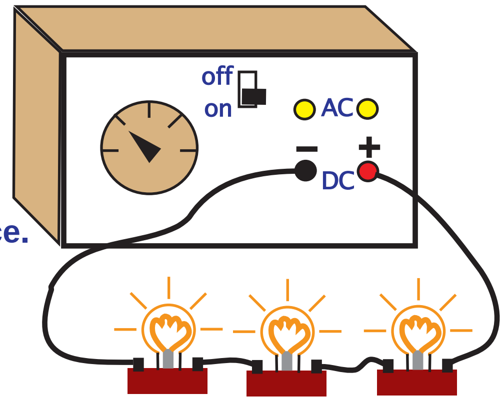
3. ELECTRICAL CIRCUITS... SERIES & PARALLEL

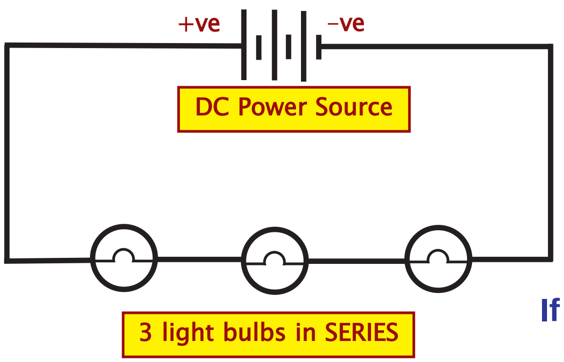
In your home, each electrical circuit usually supplies power to several lights or power points.
For example a "light circuit" might have 6 lights connected, each able to be switched on/off separately.
How are these lights in one circuit connected?
There are 2 basic ways to connect multiple components into a single circuit... in SERIES, or in PARALLEL.

Series Circuits

In a series circuit the components are connected one after the other, in a single pathway for the current..

The electricity has no choice. All the current must flow in the single path through all the bulbs.



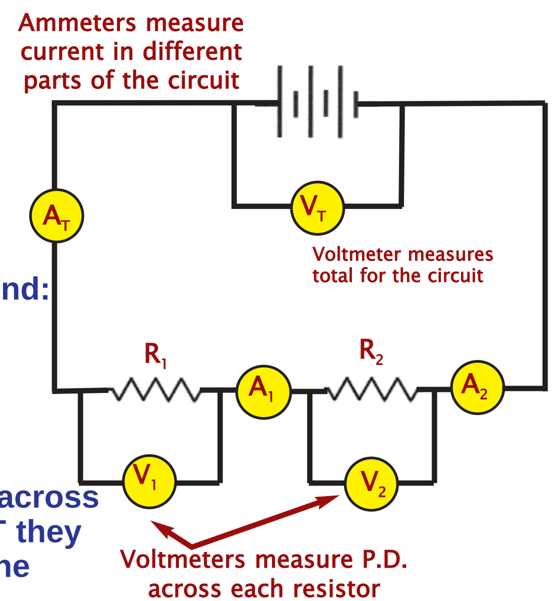


All the current must flow through all the bulbs

The light bulbs are either all on, or all off. They CANNOT be switched independently. If one bulb "burns out" the circuit is broken and they all go out.

You will have done laboratory work to measure the voltages and currents in different parts of a series circuit:

The diagram shows a circuit for measuring voltages and current in different parts of a series circuit.

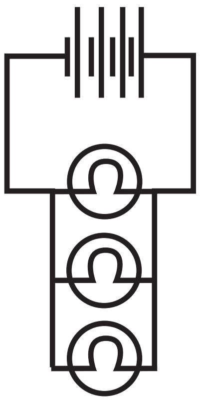


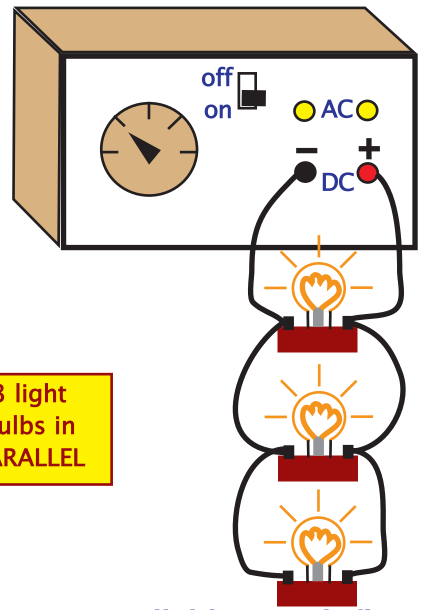
What you may have found:

- Current is the same throughout the circuit. (in this circuit $I_T = I_1 = I_2$)
- Voltages are different across different resistors., BUT they add up to the total for the circuit. (in this circuit $V_T = V_1 + V_2$)
- Ohm's Law is obeyed for each resistor, AND for the entire circuit.

Parallel Circuits

In a parallel circuit the components are arranged in separate “branches” of the circuit.



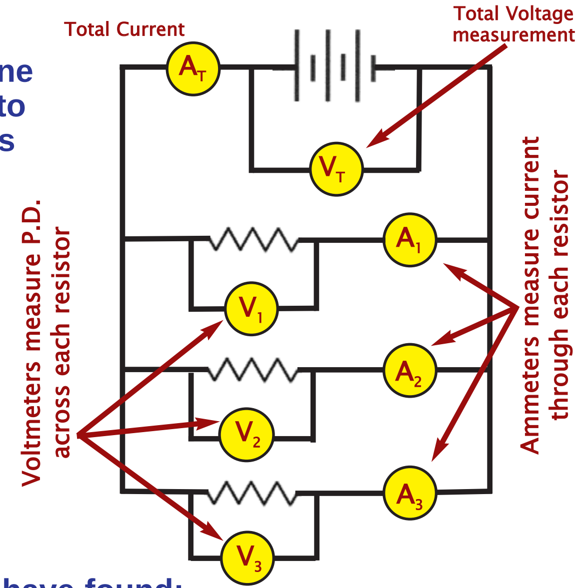


3 light bulbs in PARALLEL

At each “branch” the current divides and flows through ONE bulb only.

Each bulb can be switched on/off separately, and if one “burns out”, the others continue to work.

You will have done laboratory work to measure voltages and currents in different parts of a parallel circuit:



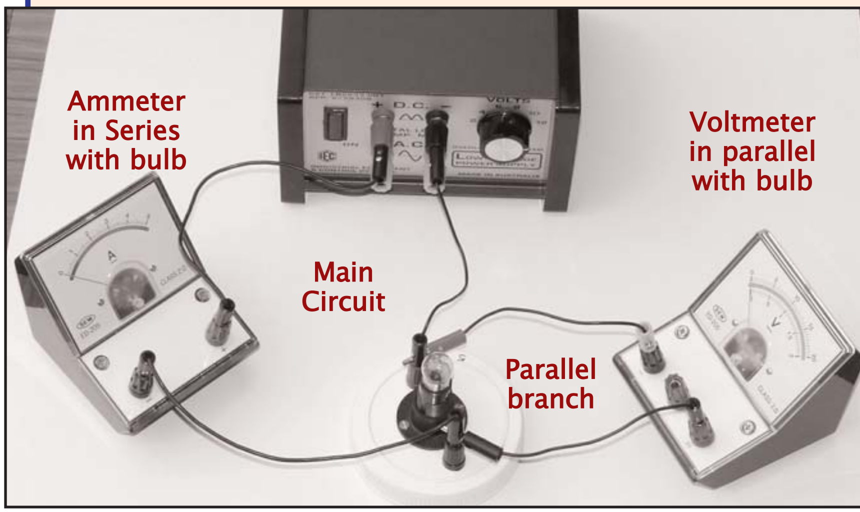
What you would have found:

- Voltages are all the same across each resistor. (in the circuit above $V_T = V_1 = V_2 = V_3$)
- Currents are different in each “branch”, but add up to the total current. ($I_T = I_1 + I_2 + I_3$)
- Ohm’s Law is obeyed in each “branch”, AND for the entire circuit.

Ammeters & Voltmeters

Ammeters measure the current (flow of charge) and so they must be placed in SERIES with the component you wish to measure current flow through. They have very low resistance, to allow current through easily.

Voltmeters measure the Potential Difference across a component, and must be placed in PARALLEL with it. Voltmeters have extremely high resistance and must NEVER be placed in series.



Electrical Circuits in the Home

A typical modern home is wired to contain a number of separate circuits. Each circuit may contain many lights or power outlets and all of them are wired in parallel.

WHY ALWAYS PARALLEL CIRCUITS?

If you have several components on the same parallel circuit:

- they can be switched on/off independently.
- if one "burns out", the others keep operating normally. (In series circuits, it's one off - all off)
- The total resistance of the parallel circuit is less, and more usable POWER can be delivered to each light or appliance.

WHY NOT JUST ONE CIRCUIT?

If all the lights and appliances in your home were on just one parallel circuit, and everything was switched on at the same time, the current flow in the main circuit line would be enormous.

This would be very dangerous. High current levels can cause wires to get hot, melt their insulation and perhaps start a fire.

Series & Parallel Circuit Calculations

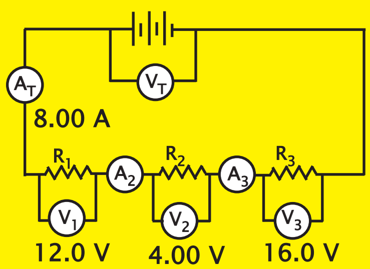
Example Problem 1 Series Circuit

Ammeter A_1 reads 8.00A.

a) What current flows through A_2 and A_3 ?

b) Find the resistance of each resistor R_1, R_2 & R_3.

c) Predict the reading on voltmeter V_T.



Solution:

a) 8.00 A flows through both.
(current is the same in every part of a series circuit)

b) Using Ohm's Law: $V = IR$

in R_1: $12.0=8.00xR_1$, $R_1=12.0/8.00 = 1.50\ \Omega$

in R_2: $4.00=8.00xR_2$, $R_2=4.00/8.00 = 0.50\ \Omega$

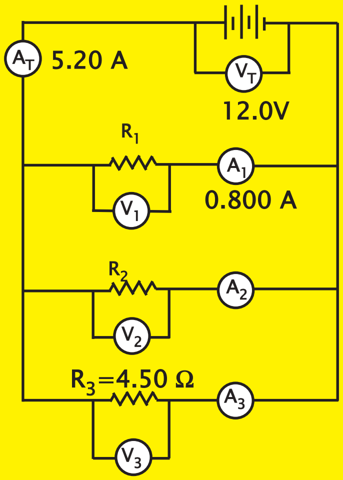
in R_3: $16.0=8.00xR_3$, $R_3=16.0/8.00 = 2.00\ \Omega$

c) $V_T = V_1 + V_2 + V_3$
$= 12.0 + 4.00 + 16.0$
$= 32.0$ V

(in a series circuit, P.D.'s add up to the total)

Example Problem 2 Parallel Circuit

Total voltage = 12.0 V.
Total current at A_T= 5.20 A.
Ammeter A_1 reads 0.800A.
Resistor R_3 has resistance of 4.50Ω.



a) What would be the readings on the other 3 voltmeters?

b) Find the current at A_3

c) Find the current at A_2

d) Find the resistance of R_1 & R_2.

Solution:

a) 12.0 V. (Voltages are the same in every branch of a parallel circuit)

b) $V=IR$ $12.0= A_3 \times 4.50$
$A_3=12.0/4.50 = 2.67$ A

c) Since (in any p'llel crt.) $A_T = A_1 + A_2 + A_3$
$5.20 = 0.800 + A_2 + 2.67$
$A_2 = 1.73$ A

d) $V=IR$

R_1: $12.0 = 0.800 \times R_1$ $R_1=12.0/0.800 = 15.0\ \Omega$

R_2: $12.0 = 1.73 \times R_2$ $R_2=12.0/1.73 = 6.94\Omega$

Activity 3

The following activity might be completed by class discussion, or your teacher may have paper copies for you to do.

CIRCUITS

Student Name ....

1. In which types of electrical circuit (series or parallel):

a) is it "one off, all off"?

b) is the current flow the same in every part of the circuit?

c) can you switch each component on/off independently of all others?

d) is the "voltage drop" the same across each part of the circuit?

e) is the total voltage drop equal to the sum of the individual voltage drops?

f) is the total current equal to the sum of the currents in each "branch"?

2. Imagine you connected 3 identical light bulbs in a series circuit, then re-wired them in parallel. For the same voltage, in which circuit would the bulbs be brighter? Why?

3. Homes are always wired in parallel, but with a number of separate, parallel circuits. Why not just use one circuit with every light and power point in parallel in a single circuit?

4. ELECTRICAL POWER & ENERGY

Electrical Power

"Power" is defined as the rate at which energy is transformed.

Mathematically:

$$\text{Power} = \frac{\text{Energy}}{\text{time}}$$

$$P = \frac{E}{t} \quad \text{or} \quad E = P.t$$

The unit of power should (therefore) be the "Joule per sec" ($J.s^{-1}$) but this unit is called a "Watt" (W), in honour of James Watt who engineered steam engines and discovered a lot about the concept of power.

It can be shown that, in the case of electrical energy:

Power = Voltage x Current
(Watts) (Volts) (Amps)

$$P = VI$$

The Kilowatt-Hour (kW.h)

Measuring energy in joules can be quite inconvenient because 1 joule is a very tiny amount.

For this reason, in everyday life, electrical energy is measured in "kilowatt-hours" (kW.h).

An appliance with a power rating of 1,000 W (=1 kW) if allowed to run for 1 hour will consume 1 kW.h of energy.

On a domestic electricity bill, your home's electricity consumption is measured in kW.h and you pay per kW.h used. Currently you'll pay about 20 cents per kW.h.

Electrical Energy

If you combine the equations $P = VI$ and $P = \frac{E}{t}$

Then, it follows that $VI = \frac{E}{t}$

and therefore,

$$E = V.I.t$$

Electrical Energy (Joules) = Voltage (Volts) x Current (Amps) x time (sec)

This toaster is rated at 800 watts.

How much energy is consumed to make some toast?

Time to cook toast = 1.5 min = 90 s.

$E = P.t = 800 \times 90 = 72{,}000$ J (72 kJ) (This is about 0.02 kW.h... cost about 0.4 cents)

Example Problem

In an electric circuit, a 240 V source causes a flow of current of 8.50 A.

a) What is the resistance of the circuit?

b) What power does the circuit use?

c) How much energy is consumed if this circuit is left on for 3.00 minutes?

Solution:

a) Ohm's Law $V = IR$

$240 = 8.50 \times R$

$R = 240 / 8.50 = 28.2\ \Omega$

b) $P = VI$

$= 240 \times 8.50$

$= 2{,}040 = 2.04\times10^{3}$ W (2.04 kW)

c) $E = V.I.t$

$= 240 \times 8.50 \times (3 \times 60)$ (time must be in sec.)

$= 367{,}200 = 3.67\times10^{5}$ J

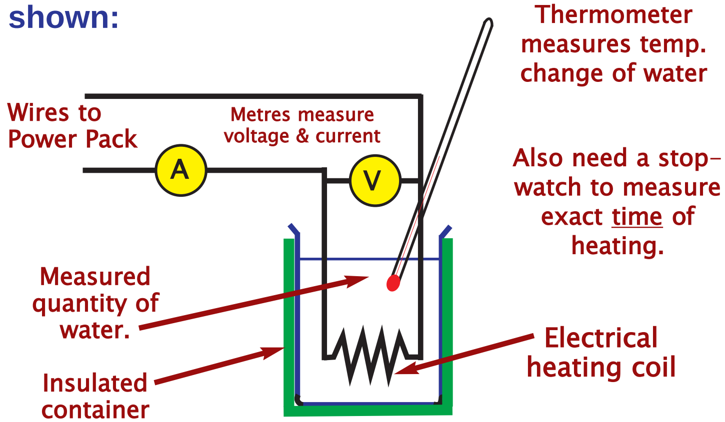
Some Typical Power Consumption Values

Appliance	Power	Time to use 1 kW.h
Light bulb	100 W	10 hours
TV set (small)	400 W	2.5 hours
Elect. Heater	2,000 W	30 min.
Oven (large)	8,000 W	7.5 min.

An Experiment You May Have Done:

Energy Conversion in an Electric Heating Coil

The equipment set-up for a typical experiment is shown:



The "heating coil" is a resistance wire which gets hot when electricity is forced through it.

The energy change is: ELECTRICITY → HEAT

A measured quantity of water is heated for a measured period of time. The current and voltage in the circuit are recorded, as is the temperature change of the water.

From these measurements the amount of electrical energy used by the electric circuit can be compared to the amount of heat energy gained by the water.

Typical Results

Electrical Data

Voltage = 12V
Current = 2.0A
Time circuit ON = 300 s.

Heat Data

mass of water = 100g
start Temp. water = 15°C
end Temp. water = 32°C
change in Temp. = 17°C

How to Analyse These Results

Electrical Energy Used

$$E = V.I.t$$

$$E = 12 \times 2.0 \times 300 = 7,200 \text{ J}$$

Heat Energy Produced

Heat Energy = mass of water x Temp change x 4.2

$$H = 100 \times 17 \times 4.2$$
$$= 7,140 \text{ J}$$

This is because it takes 4.2 Joules of energy to raise the temp. of 1gram of water by 1°C

Therefore, (within experimental error) the electrical energy consumed by the electric circuit is equal to the amount of heat energy produced (and absorbed by the water).

Energy Usage in a Typical Home

Study Your Electricity Account

You should have a good look at the electricity account for your home.

If your home has an electric hot water system and uses electricity for cooking and heating/air-con then it probably uses at least 10 kW.h of energy per day. If you have gas cooking and/or solar or gas for hot water, your electrical energy usage may be less than this. Your usage may be higher if there are more than 4 people in your household.

Save Energy, Save $$, Save the Planet

Every kW.h of energy you use, releases approx. 1 kg of CO_2 gas from coal burned to generate the electricity.

If your household reduced electricity usage by (say) 10%, you would probably save about $150 per year. More importantly, it would also reduce greenhouse gas emissions by over one tonne.

Simple Strategies to Reduce Electricity Usage

Turn off the lights when you leave a room.
Take shorter showers.
Do NOT leave appliances on stand-by. Turn them off.
Wear warmer clothes in winter & turn heating down.
Replace inefficient light-bulbs with high-efficiency fluorescent or LED lights.
In summer, set your air-con for “cool” instead of “blizzard” and limit its usage.
Take advantage of Government incentives to add insulation and/or solar hot water systems to your home.

Activity 4

The following activity might be completed by class discussion, or your teacher may have paper copies for you to do.

POWER & ENERGY

Student Name ....

1. Define “power” in terms of energy and time.

2. What 2 electrical measurements determine electrical power and what is the unit of power?

3.
a) What is the SI unit for energy?
b) Why then, is the “kilowatt-hour” used for electrical energy?

c) Define the kW.h unit in terms of usage of an electrical device.

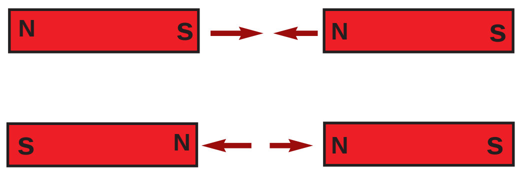
4. List some simple strategies to reduce electricity consumption in your home.

5. MAGNETIC EFFECTS OF ELECTRICITY

Magnetic Fields

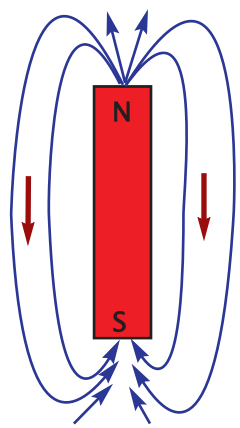
Just as every electric charge acts as if it is surrounded by an invisible "force field", so too for magnets.

Magnets have 2 different "poles", and can either attract or repel each other.



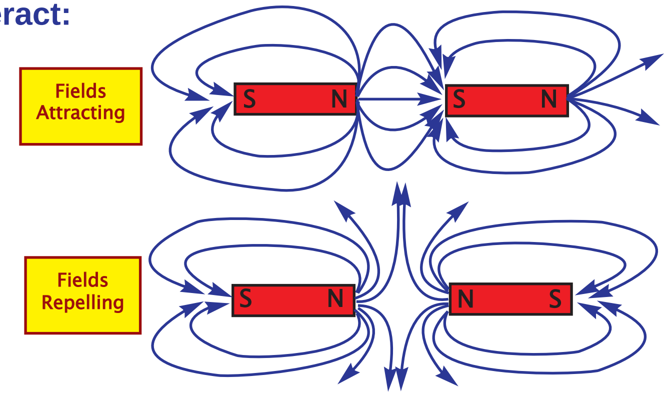
The Earth has a magnetic field, and that is how the poles of any magnet have come to be called "north" & "south".

Each magnet can be imagined to be surrounded by magnetic lines of force... a "magnetic field".



The magnetic field direction is defined as the direction that a small NORTH pole would move if placed in the field. (But you can't ever get an isolated north pole! They always come in north-south pairs)

When 2 magnets are brought near each other the attraction or repulsion is due to the way their fields interact:



IT TURNS OUT THAT MAGNETISM IS CAUSED BY ELECTRIC CURRENTS...

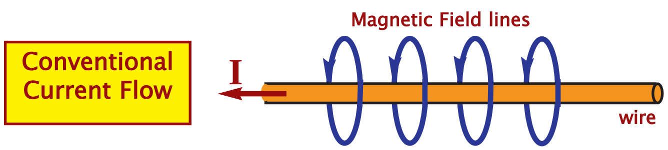
Electric Current Creates Magnetic Fields

It is now known that all magnetic fields are produced by moving electric charges.

In a bar magnet, the charged particles within the atoms move in such a way to produce a permanent magnetic field.

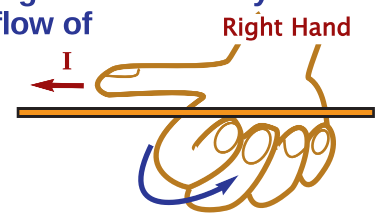
In the Earth's liquid-iron core there are electric currents flowing and creating the huge magnetic field that causes small magnets to point north-south... the magnetic compass.

You may have used small magnetic compasses to "map" various magnetic fields, including the field produced by an electric current flowing along a straight wire:

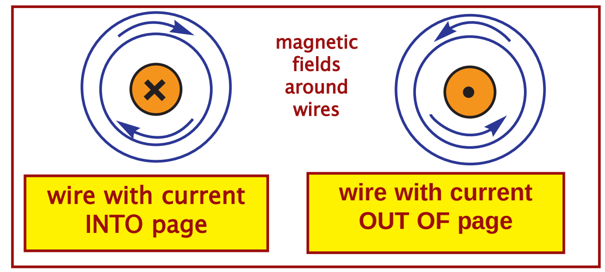


To predict the shape of such a field, use the "Right-Hand Grip Rule". Pretend you are gripping the wire with your thumb pointing the direction of the flow of Conventional current (+ve towards -ve).

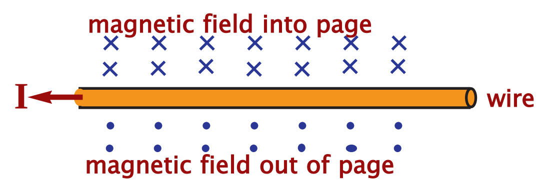
The curling fingers show the direction of the field.



To more easily draw and understand diagrams you must also learn the "arrow" technique to represent currents or field-lines that are perpendicular to the page.



Imagine an arrow coming straight out of the page at you... all you see is its point (•). If the arrow is going down into the page, you only see its feathers (X). Use the R.H. Grip Rule on these diagrams to get the idea.

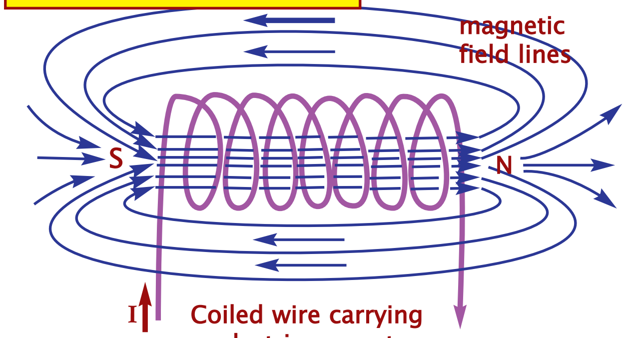


Solenoids & Electromagnets

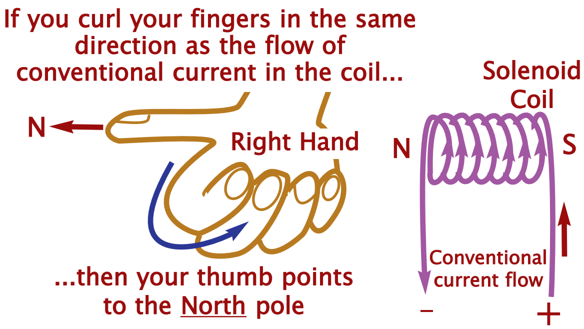
The magnetic field around a straight wire carrying current, is quite weak.

However, if the wire is wrapped into a helix or coil, the magnetic field in each loop adds to its neighbours to intensify the field.

Magnetic field of a Solenoid



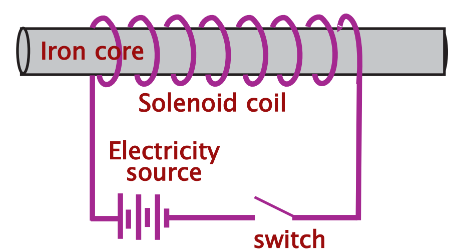
The magnetic field of a solenoid is exactly the same shape as a bar magnet. To determine the polarity of the solenoid (i.e. which end is north and south) once again use a “Right-Hand Rule”.



You may have carried out a laboratory exercise in which you made an electromagnet. This is simply a coil with a bar of iron in the middle. The iron intensifies the solenoid field so that even with quite low currents (e.g. 2 Amps) the magnetic effect is as strong as a small bar magnet.

The big difference, of course, is that the magnetic field of an electromagnet can be switched on and off with the electric current.

A SIMPLE ELECTROMAGNET



AS YOU WILL LEARN IN THE HSC COURSE, ELECTROMAGNETS ARE THE BASIS OF ELECTRIC MOTORS.

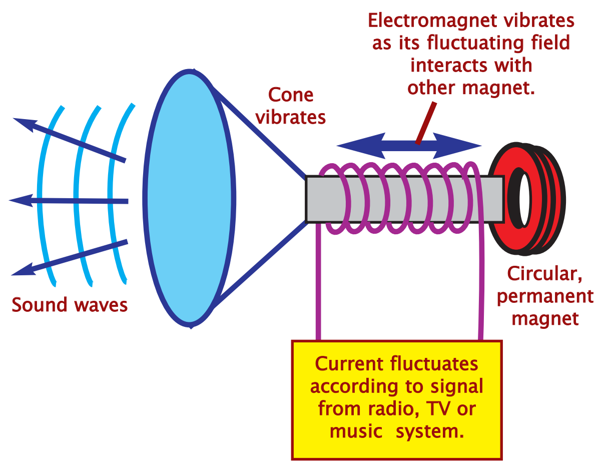
An Application of Electromagnets...

MOVING COIL SPEAKERS

All the electrical devices in your home that you listen to (radio, TV, music system, etc) produce sounds from a "speaker".

HOW? **Electromagnets!**

The electrical current from the radio/TV tuner or music system is modulated according to the signal involved. This means the current fluctuates in a way corresponding to the music, or person's voice, or whatever.



Since the current fluctuates, so does the magnetic field of the electromagnet.

Since there is another magnetic field close by to interact with, the electromagnet vibrates back and forth as its field varies, and the attraction / repulsion of the other magnet varies.

The electromagnet is attached to a cone of stiff plastic which also vibrates, sending compression waves into the air.

As you will remember from the previous topic, compression waves in air are SOUND WAVES.

An electromagnet has converted electrical current into the sounds of a human voice, music, or whatever you want to listen to.

Activity 5

The following activity might be completed by class discussion, or your teacher may have paper copies for you to do.

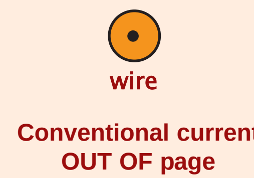
MAGNETIC EFFECTS

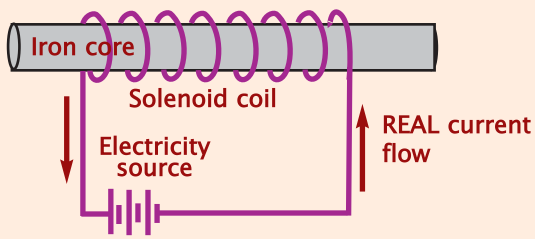
Student Name ....

1. Sketch the magnetic field produced in each case.

a)


b)


c)


d)


2. In a "moving coil" speaker:
a) what produces the sound waves?

b) What makes the cone vibrate?

c) Why does the field of the electromagnet fluctuate?

6. ELECTRICAL SAFETY in the home

The Dangers of Electricity

"Electrocution" is very dangerous. Even a small electrical current (say, 0.1 Amp) from a voltage source as little as 50 V can disrupt nerve signals and send your muscles into spasms. If the muscle involved is your heart, it can go into "fibrillation" where it quivers uncontrollably and does not pump blood properly... a potentially lethal situation. Our mains electricity, at 240V, is well able to kill.

As well as that, badly designed or faulty wiring systems can cause an electrical circuit to overheat, or create sparks which can start a fire. Many house fires are started by electrical faults.

Safety Devices

Fuses

A fuse is merely a short piece of wire with a very low melting point. If an excess of current flow through it, it gets hot, melts and thereby breaks the circuit.

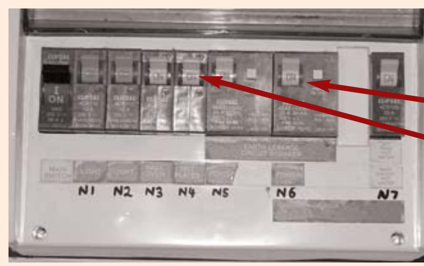
Fuses are designed to be "5 Amp" or "8 Amp" or "15 Amp", etc, according to the maximum current they will allow through, before they "blow". It is vital to replace a burnt-out fuse with the correct one, to avoid a circuit becoming overloaded, and creating a fire risk.

Fuses in house circuits are now "old-fashioned" and have been replaced by more efficient devices:-

Circuit Breakers

Circuit Breakers do the same job as a fuse, but can be "re-set" after a circuit overload causes them to "trip". Therefore, they are much more convenient, as well as more efficient and reliable for interrupting a faulty circuit.

Circuit breakers can work in different ways, but one design involves an electromagnet. If excessive current flows, the magnetic field becomes strong enough to attract an iron switch, which turns the circuit off. Once the fault is fixed, the system can be re-set by pressing a button.



"Fuse-Box" in a modern home. (no fuses at all...)

ELD's & Circuit Breakers. These are the "re-set" switches

More Safety Devices

Earth Leakage Devices (ELD's) are electronic circuit breakers which monitor the current going into, and out of, a circuit. If the current in both directions is the same, no problem.

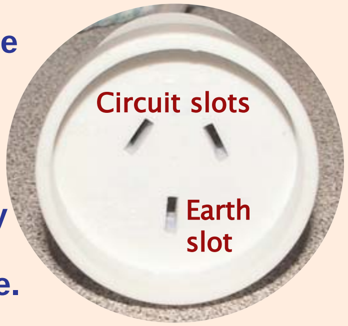
If there is even slightly less current coming out than going in, it means some is "leaking" out , maybe in the process of electrocuting a person. In this case the ELD shuts the circuit off so quickly that the person at risk is not hurt.

Although expensive, ELD's save lives, and they are now compulsory in all new buildings in most cities and towns.

Earthing

Ever wonder why a power point and most plugs have 3 slots/pins? Only 2 are needed for the electric circuit, the 3rd is for the "earth" wire.

So long as nothing goes wrong, the earth wire carries no current and does nothing.



However, if a loose wire or faulty insulation allows an appliance to become "live" with electricity, the current is conducted safely by the "earth wire" down into the ground, rather than through a person touching the appliance.

This flow of current to Earth will usually burn-out the fuse, or "trip" the circuit-breaker or ELD, as well.

Double Insulation

So why do some appliances only have 2-pin plugs, with NO earth connection?

If a fault occurred in a small hand-held appliance (e.g. power drill, hair-drier), even with an earth wire the person holding the appliance would get a shock. So, these appliances are designed so that the electrical circuits within are shielded from human contact by TWO layers of insulation, one being the moulded plastic body of the appliance.

Even if something goes wrong inside, the double layer of insulation ensures that electricity cannot make contact with the person.

For larger appliances, or those in which normal operation does not involve human contact, double-insulation is not practical, so the earth-wire system is used.