ELECTRICITY

(Basic Principles)

Objectives

This course is aimed at those with little or no previous knowledge of electricity.

It's aims are, therefore, to provide:

An introduction to electricity.
A basic understanding of what it is & where it comes from.
Electrical measurement & unit terminology.
A basic understanding of the part played by magnetism.
An overview of Power Generation & Supply.
Basic electrical safety.

Introduction to Electricity

Regulations.
What is electricity?
Terms & Units.
Basic Principles.
Generation & Distribution.
Safety.

Regulations

Health & Safety At Work Act (1974).

Electricity At Work Regulations (1989).

B.S. 7671 (I.E.T. Wiring Regulations 2018).

Electrical Supply Regulations.

IEC 60079 (Selection, Installation & Maintenance of Electrical Apparatus in Potentially Explosive Atmospheres).

DSEAR (2002) (Dangerous Substances & Explosive Atmospheres Regulations).

Electricity at Work Regulations (1989)

Includes the following for equipment & working:

Safe construction, maintenance & work systems.

Equipment capability, environments, insulation, earthing, connections, circuit protection, isolation, making dead, live working, working space, responsibilities, competence.

Covers ALL aspects at ALL voltage levels.

B.S. 7671: 2018

Requirements for Electrical Installations

IET Wiring Regulations (Eighteenth Edition)

Requirements for design erection and verification of new electrical installations, also additions and alterations to existing installations that have been installed in accordance with previous editions.

Basic Principles 1

What is Electricity?

What is electricity?

A source of energy

Essential to modern life

Extremely dangerous

invisible, no smell, no sound

About 10 – 12 fatalities in industry/year

What is electricity?

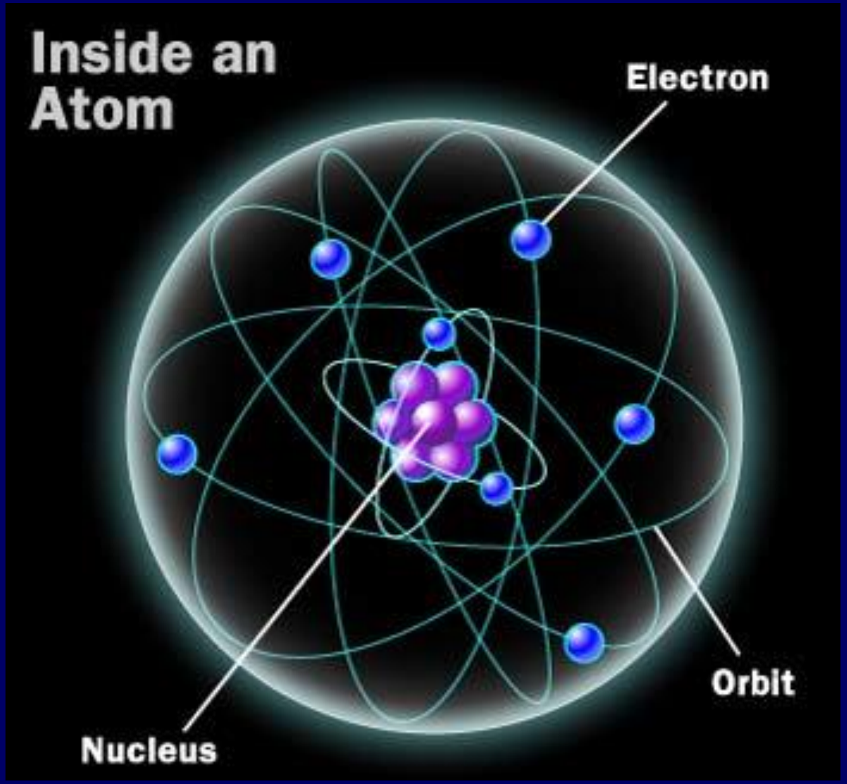
All materials are made up of atoms.

Each atom consists of a **nucleus (*protons & neutrons*)**

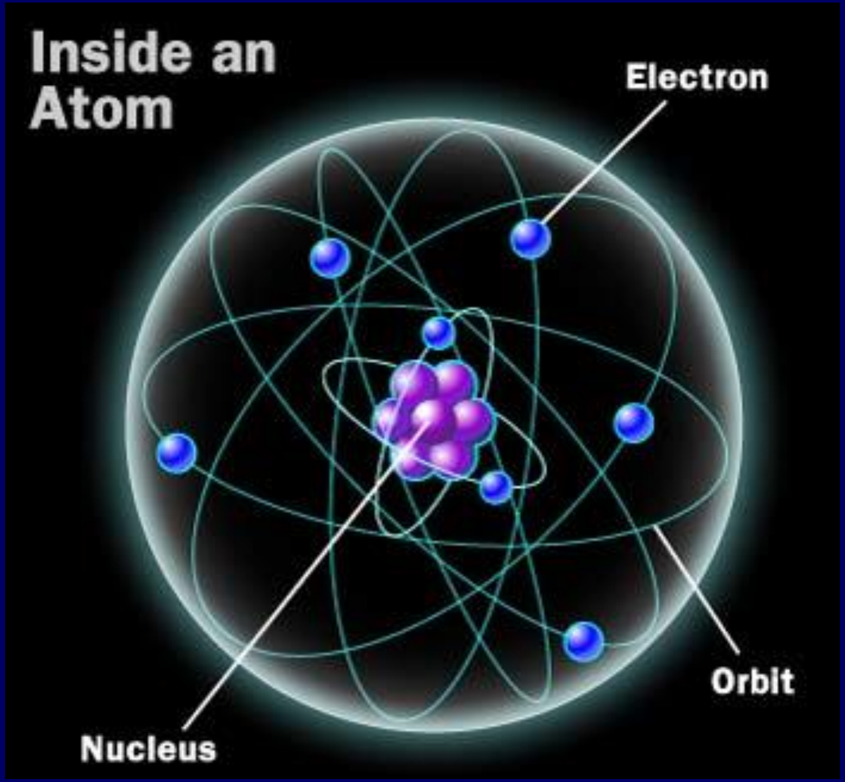
& orbiting ***electrons***.

Protons carry a **positive** charge whilst **electrons** carry a **negative** charge.

Elements may be identified by their different numbers of Protons (*atomic number*).



What is electricity?



The materials whose **electrons detach easily** & move around, (*"free electrons"),* are known as **electrical conductors.**

Those materials whose **electrons** are **tightly bound** to the atoms are frequently used as electrical **insulators.**

The Electron

Discovered by J.J. Thompson in 1897.

Carries the basic unit of charge.

Is the carrier of electric current in conductors.

It's behaviour in semi-conductor materials, led to the development of solid-state microelectronics.

Where does it come from?

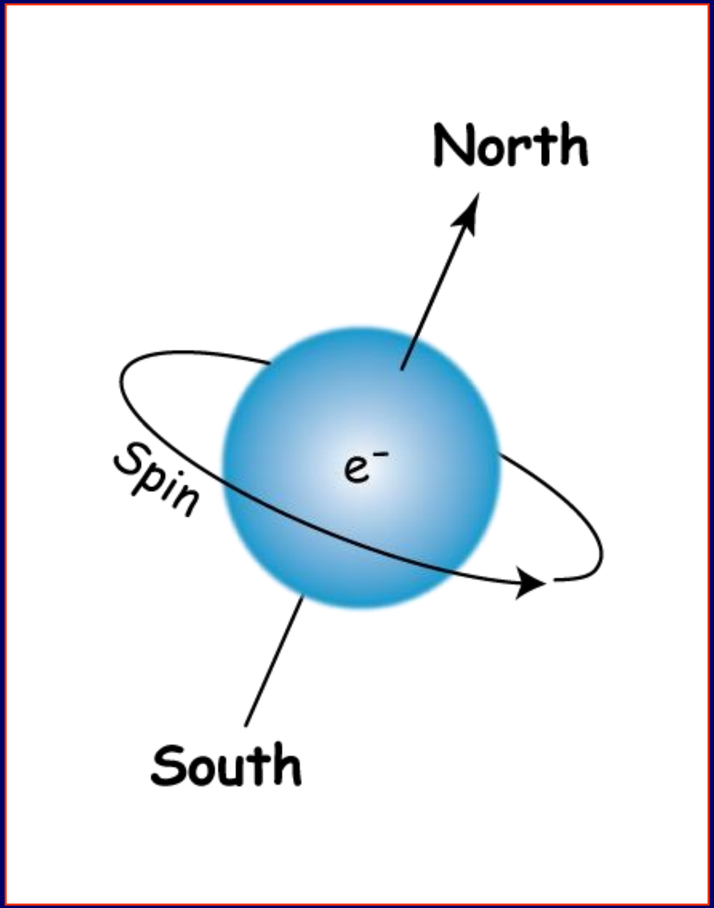
The electron is like a *magnetic dipole*, a miniature magnet, with a north end and a south end.

It spins on its axis, giving rise to current in the direction of rotation.

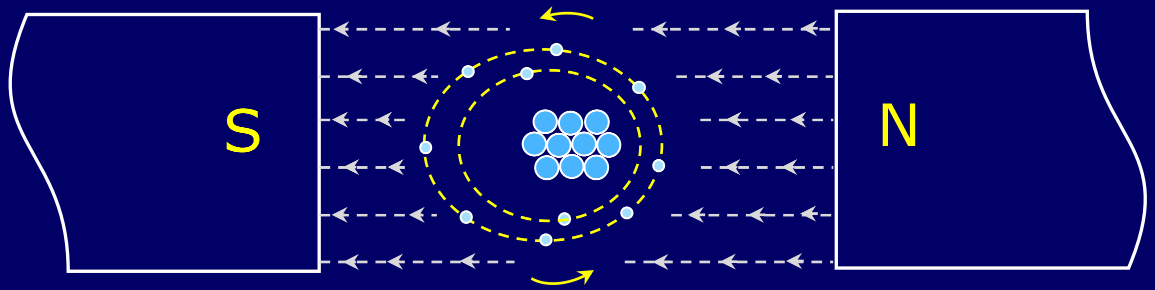
If you move a magnet near a conductor, the magnetic field will cause electrons in that conductor to move to other atoms.

When a conductor is connected to an energy source the **-ve charged electrons** will be **attracted to the +ve source** by transferring, or flowing, between atoms.

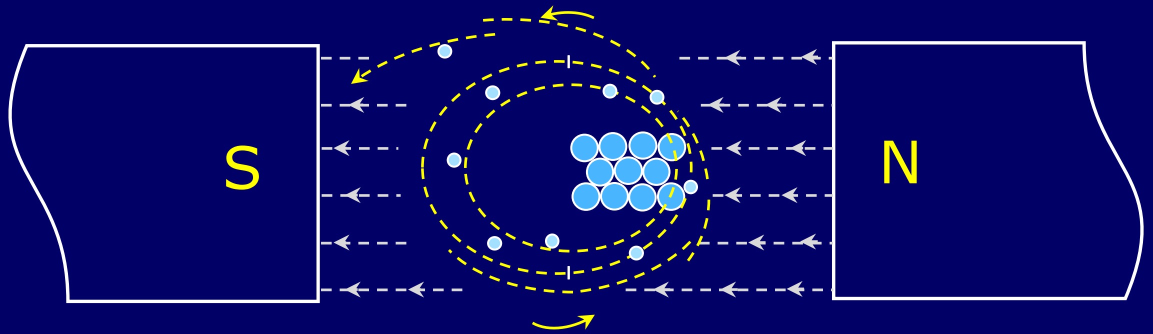
This **electron movement** is known as the **current** & it creates another magnetic field around the conductor and also produces heat within the conductor.



Atoms & magnetism



Neon (Ne) 10 - under the influence of a magnetic field the negative electrons are attracted towards the opposite pole however, although their orbit is distorted, no electrons break away. This type of atomic structure forms the inert gases such as helium, neon & argon which are all stable.



Sodium (Na) 11 - under the influence of the same magnetic field, the lone electron in the third ring is broken away from its orbit by the attraction to the opposite pole. This type of atomic structure forms many of the metals & are used as conductors.

Conductors and Insulators

Elements with only **one electron** in the outer-most orbit are the best ***<u>conductors</u>*** (Gold, Silver, Copper).

Elements with **8 electrons** in the outer-most orbit are the best ***<u>insulators</u>*** (Neon, Argon, Radon – all inert gases).

Silicon & Germanium have **4 electrons** in the outer-most orbit & are **"Semi-conductors"** negative temperature co-efficient.

Summary

Conductors conduct electricity.

Insulators don't ?????

Metals conduct.

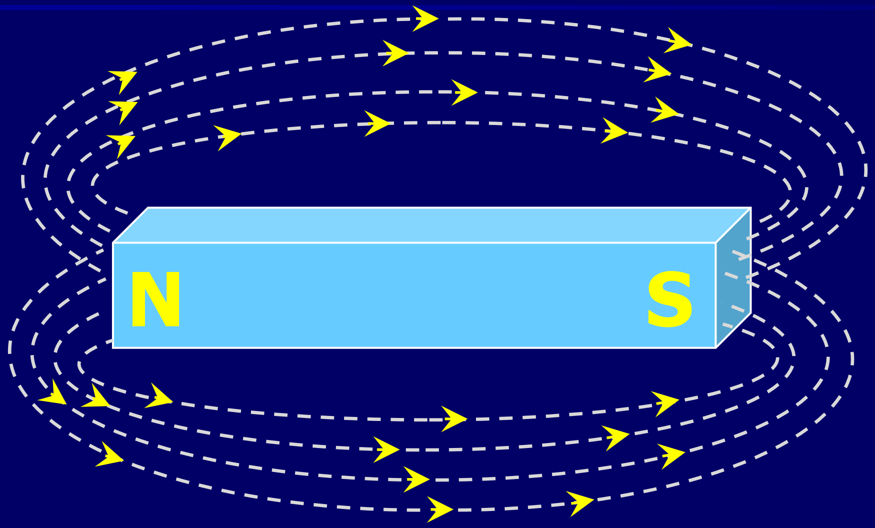
Some liquids conduct.

Wood, plastic, air, oil and some ceramics do not conduct electricity (most of the time).

Basic Principles 2

Magnetism

Rules of Magnetism

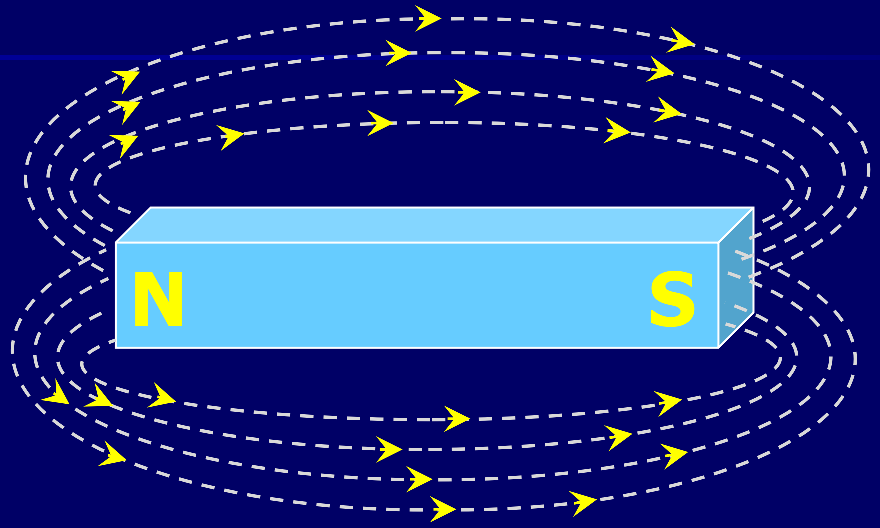


Magnets are materials containing permanent magnetic fields flowing in and around the material which is normally a mixture of Iron (Fe) Cobalt (Co) and Nickel (Ni).

They will only adhere to other materials that contain these elements.

D

Rules of Magnetism



Lines of flux are imaginary and move from **North to South externally**.

Each line forms a closed loop and move South to North internally.

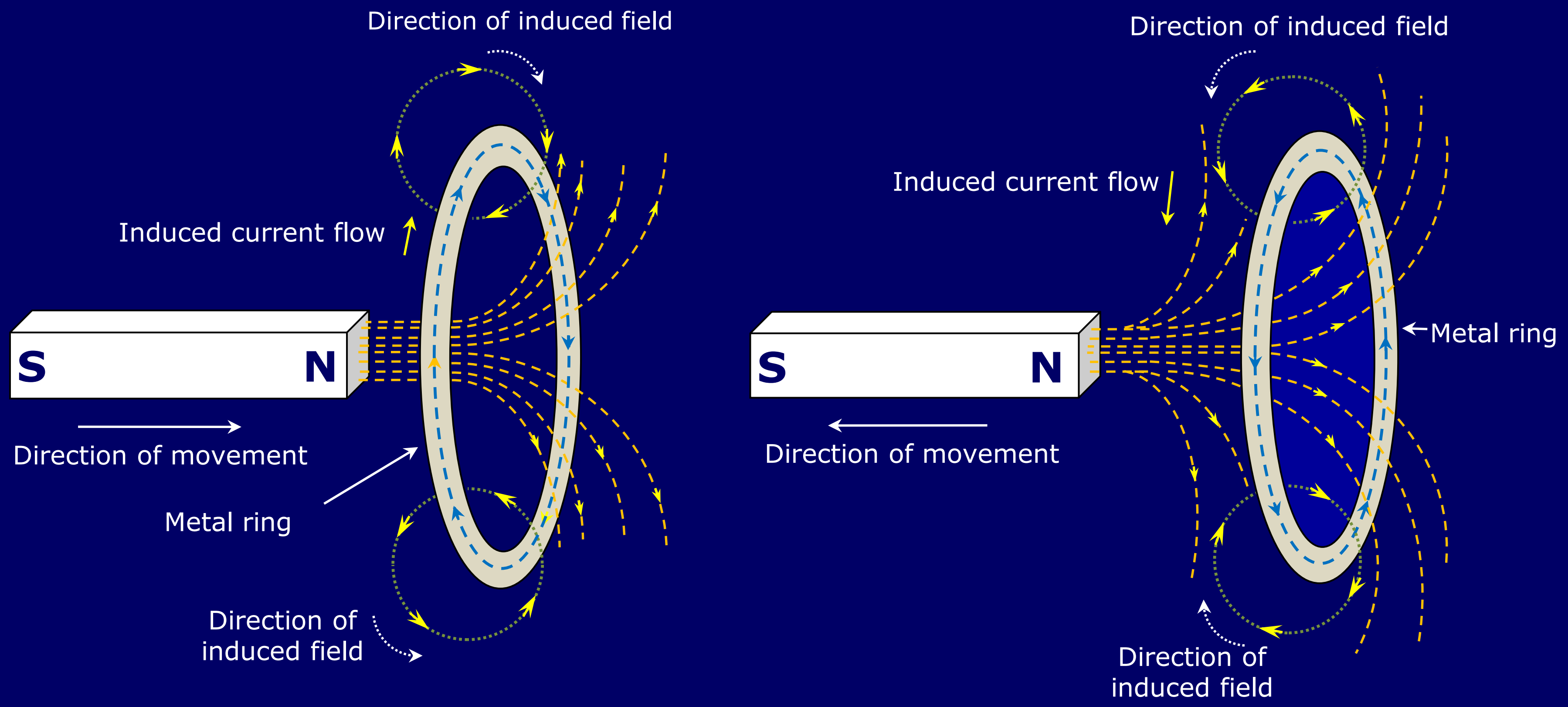
These **lines never intersect**.

The direction of the flux will determine the attraction or repulsion.

Opposites attract, Likes repel.

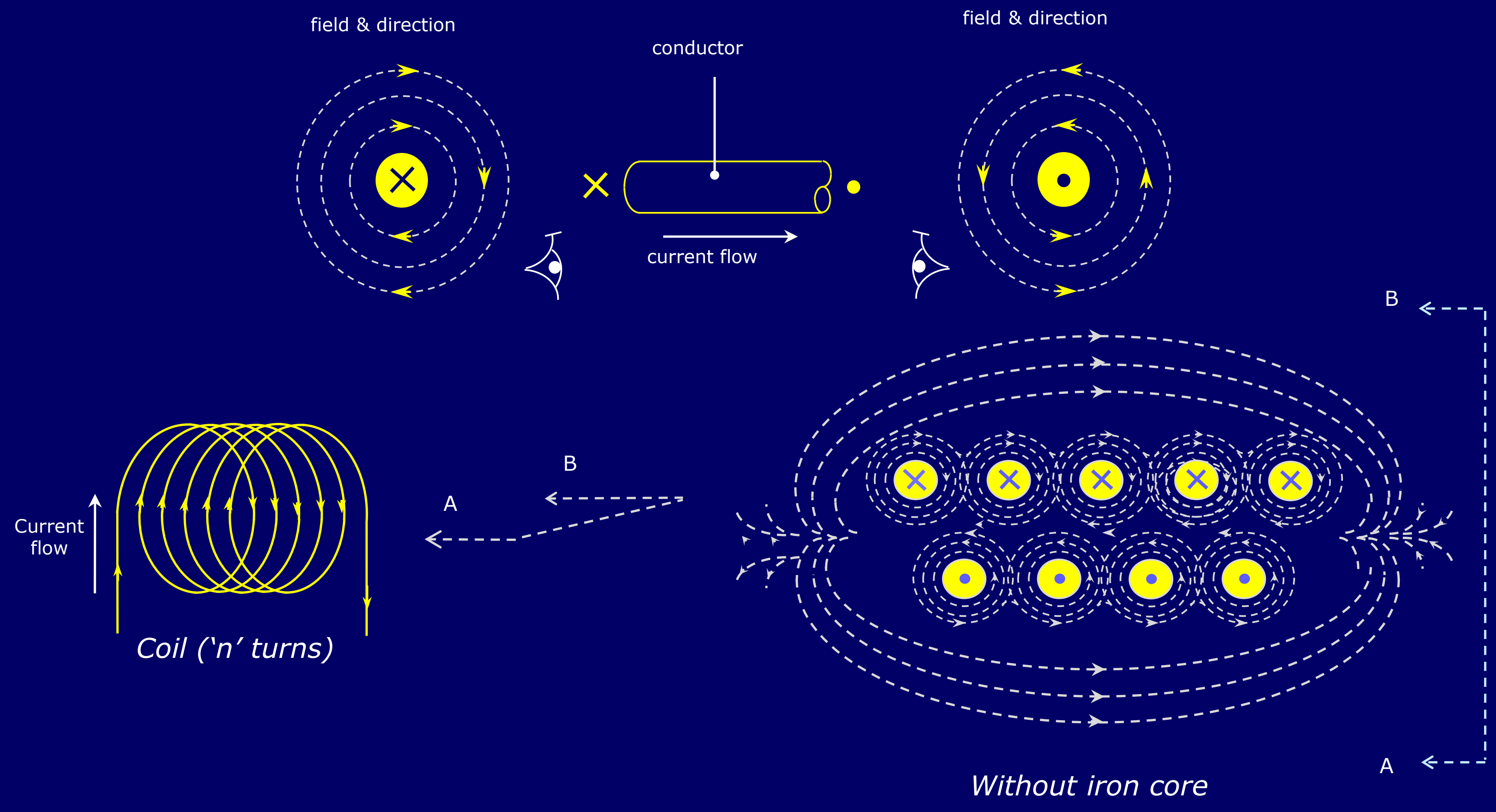
D

Electromagnetic Fields

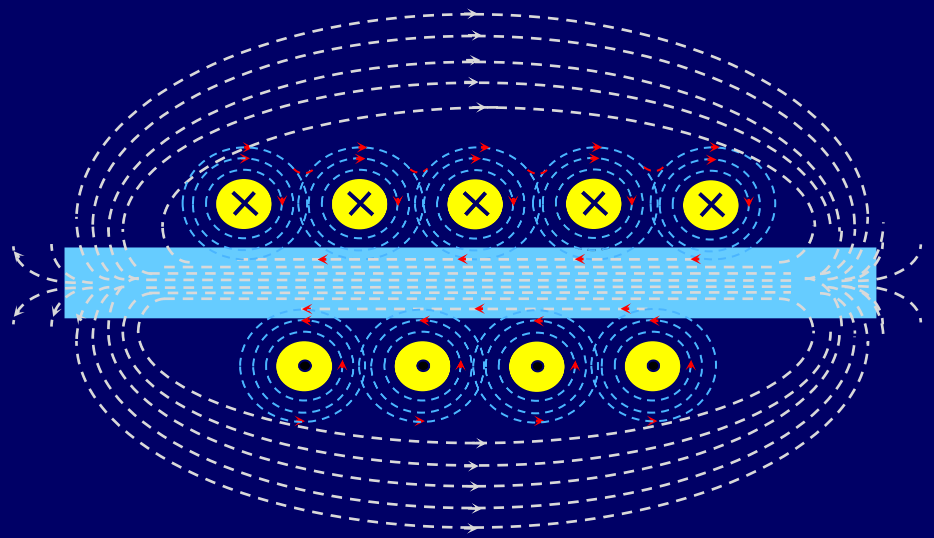


The direction of the induced magnetic field around the ring opposes the field that produced it as a result of movement of the bar-magnet (LENZ's LAW)

Electromagnetic Conventions



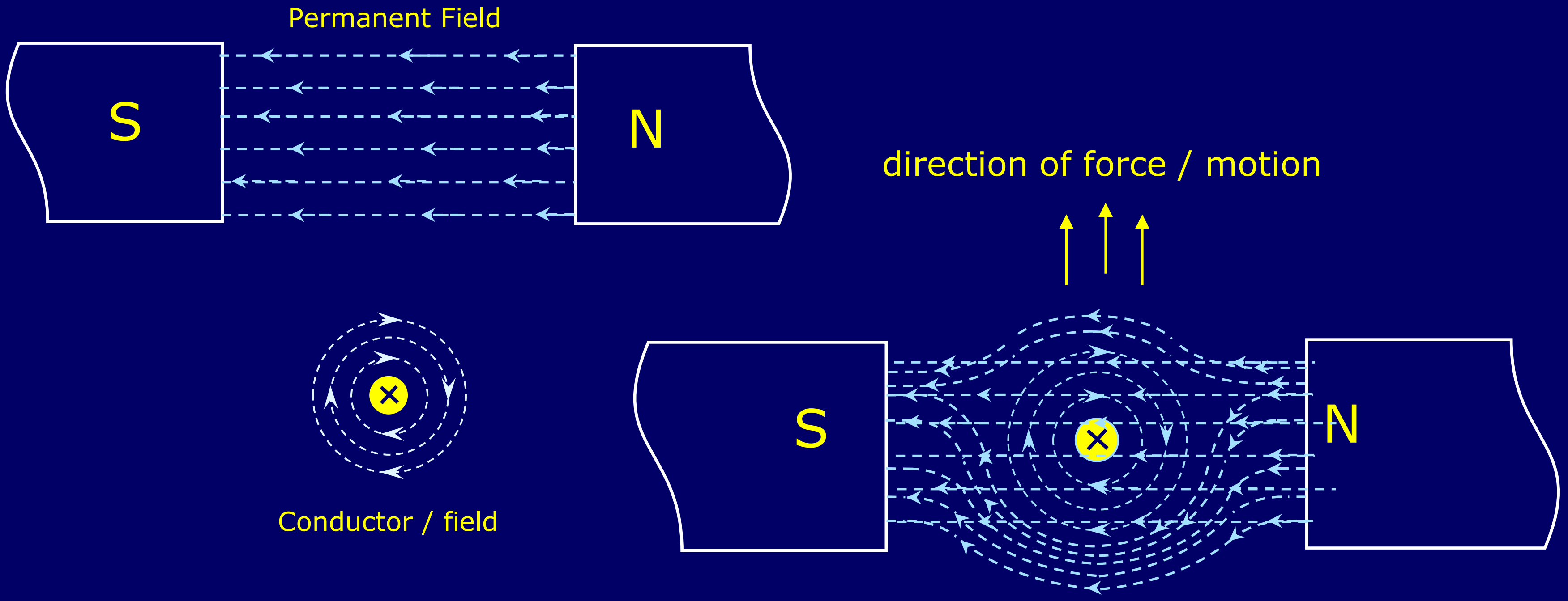
Electromagnetic Fields



With iron core

Electromagnetic Fields

When an electric current flows in a conductor, an external magnetic field is applied around that conductor. If it is then placed within another magnetic field the wire experiences a force perpendicular both to that field and the direction of its own field determined by the direction of the current flow.

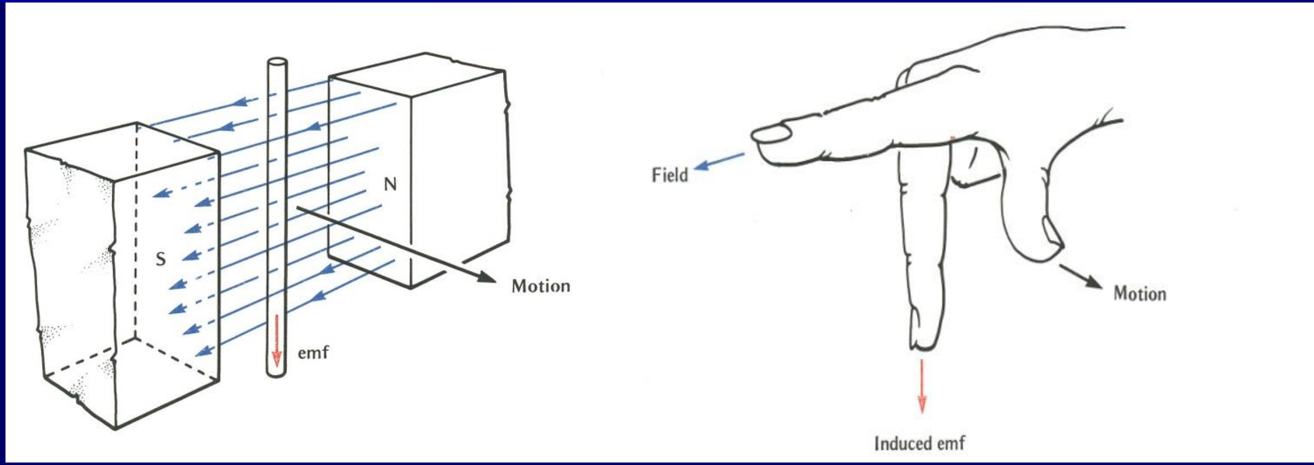


Electromagnetic Fields

There are two "Rules" which may be used to determine the direction of the force exerted on a current-carrying conductor in a motor & the direction of the current flow in the conductors of a generator

These "Rules" are actually visual mnemonics, demonstrated by the use of the left & right hands (due to the differences between cause & effect)

Electromagnetic Fields



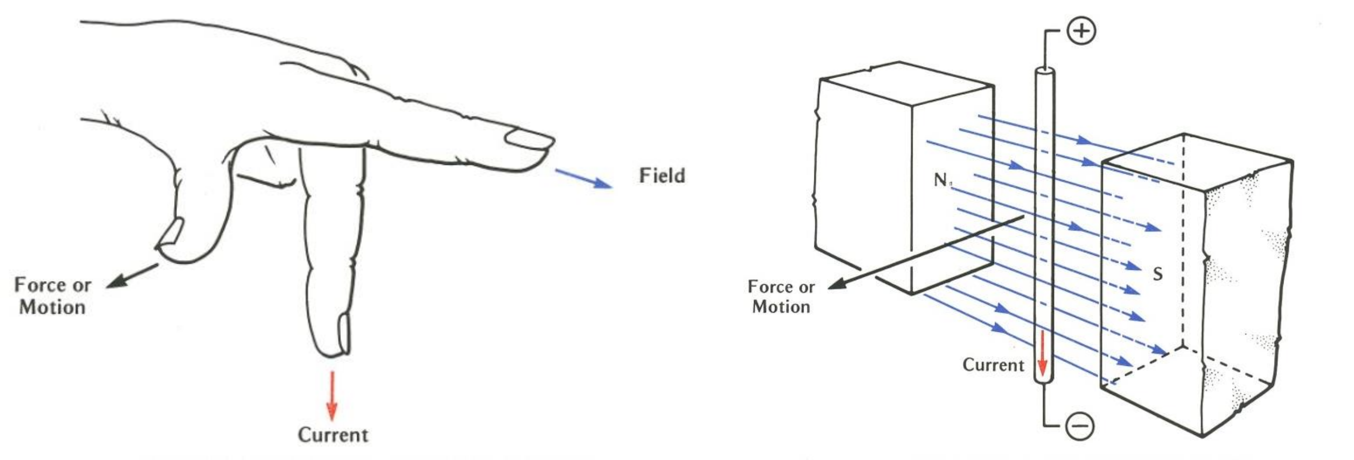
Flemings **Right** Hand Rule (**G**enerators)

Flemings **Right-hand Rule** – used for **Generation** the motion & magnetic field exist, (causes). In a Conductor they lead to the creation of an EMF (Electro-Motive-Force). Which in a closed circuit will produce an electric current in the direction of the force, (effect).

Electromagnetic Fields

Flemings **Left-hand Rule** – used for **Motion** the current field & permanent magnetic field exist, (causes). They lead to the force that creates the motion, (effect).

Flemings **Left** Hand Rule (**Motors**)



Basic Principles 3

Resistance
Voltage
Current

Resistance (R)

Measured in Ohms, Unit Symbol Omega (Ω).

All circuits & components possess electrical resistance, based on the type of material(ρ), it's length(L) and CSA(A) plus external influences. Often in practice a circuit requires a specific value of resistance. A component designed to have a specific value of resistance is called a Resistor.

It is impractical to have an infinite range of resistor values, and so manufacturers produce resistors within a range of preferred values, such as 10Ω, 15Ω, 22Ω, 33Ω, 47Ω, 68Ω, ….. & so on in multiples of 10.

Multiplication Units

A summary of typical decimal multiples and sub-multiples is:

Multiplication Factor		Symbol	Prefix
$x10^{12}$	(1,000,000,000,000)	T	Tera
$x10^{9}$	(1,000,000,000)	G	Giga
$x10^{6}$	(1,000,000)	M	Mega
$x10^{3}$	(1,000)	K	Kilo
$X10^{-3}$	(1/1,000)	m	milli
$X10^{-6}$	(1/1,000,000)	µ	micro
$X10^{-9}$	(1/1,000,000,000)	n	nano
$X10^{-12}$	(1/1,000,000,000,000)	p	pico

Resistance (R)

British Standard BS 1852 Resistor Code

For the value of a resistor the multiplication factors are determined by a pre positioned letter or symbol:

R or Ω	⇒ x 1	⇒	Unity (One)
k	⇒ x 1,000	⇒	Thousand
M	⇒ x 1,000,000	⇒	Million

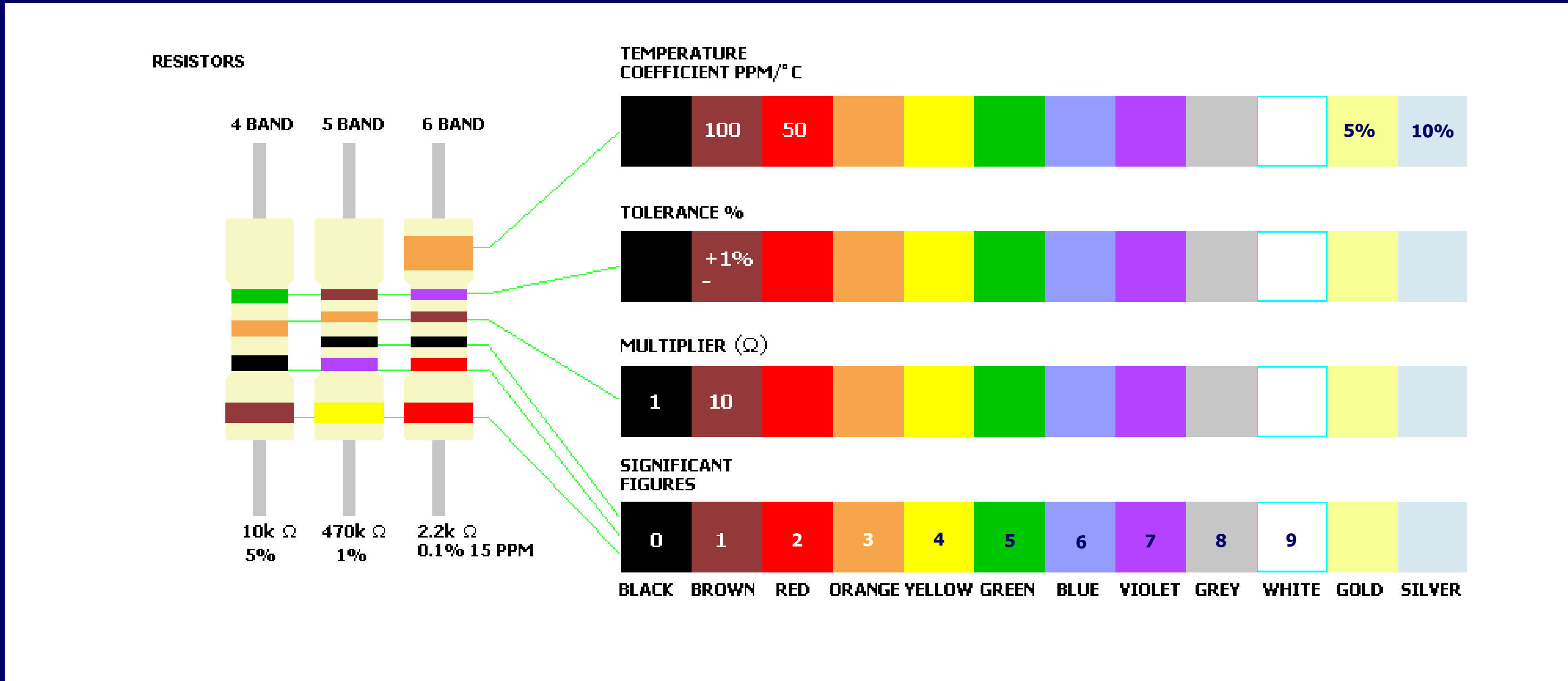
Therefore a Resistor coded 56R or 56Ω would be 56 ohms
& a 68000Ω resistor would be coded 68kΩ

Also a 5R6 or 5Ω6 coded Resistor would be 5.6 ohms
& a 6800 ohm resistor would be coded 6k8 or 6.8kΩ

Resistance (R)

For smaller carbon film type resistors we utilise:

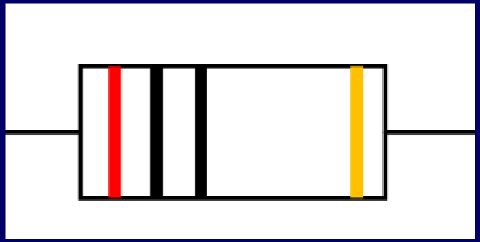
A STANDARD COLOUR CODE



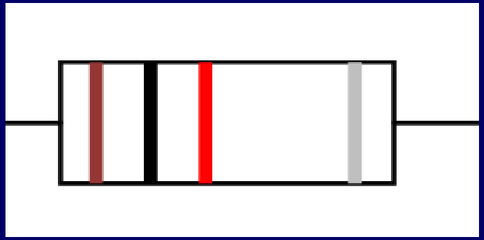
A

Resistance (R)

4 Band Colour Code

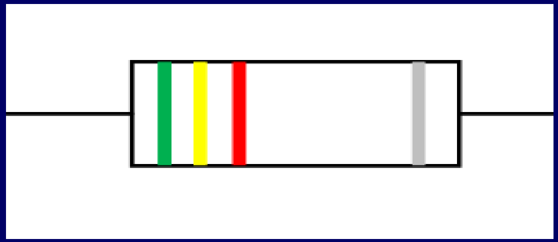


20Ω +/- 5%



1000Ω +/- 10%

1KΩ +/- 10%



5400Ω +/- 10%

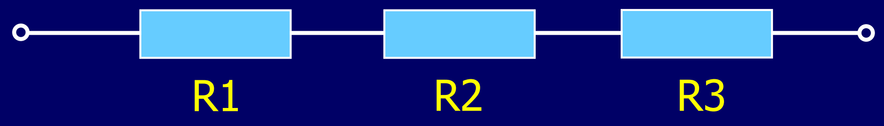
5.4KΩ +/- 10%

5K4Ω +/- 10%

A

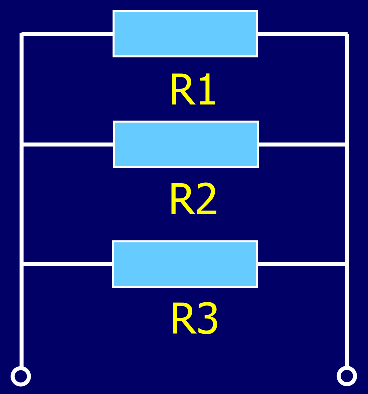
Calculating Resistance (R)

To calculate values of resistance:



Resistors connected in series:

$$R_T = R1 + R2 + R3 + \ldots..$$



Resistors connected in parallel:

$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots..$$

The total resistance of a network of parallel resistors is less than that of the lowest individual resistor.

Voltage (V)

Measured in Volts, Unit Symbol (V).

Between two points in an electric field, the difference of their electric potentials is known as the potential difference.

This difference is proportional to the electrostatic **force** that tends to push electrons from one point to another.

Voltage is measured between two points using the ground as a stable (unchanging) reference point.

Voltage is a property of an electric field, NOT individual electrons.

Voltage Nominal

The Voltage by which an installation (or part of an installation is designated).

The following ranges of nominal voltage (rms values for A.C.) are defined in BS7671 as:

- **Extra Low.** Not exceeding 50V A.C. or 120V ripple free D.C. whether between conductors or to earth.
- **Low.** Exceeding extra low but not exceeding 1000V A.C. or 1500V D.C. between conductors
- **High.** Normally exceeding low voltage.

Voltage (V)

<u>**Common Nominal Voltages (UK)**</u>

For single phase supplies

(i.e. 1 Live, 1 Earth, 1 Neutral per supply)

50 volts RMS, 110 volts RMS, 230 Volts RMS

For three phase supplies

(i.e. 3 Lives, 1 Earth, 1 Neutral per supply)

400 Volts RMS

Current (I)

Measured in Amperes , Unit Symbol (A).

Conducting materials contains large numbers of mobile or "free" electrons which move about randomly (due to thermal energy changes), but there is zero current flow.

When a conductor is attached across the terminals of a power source, the Voltage places an electric field across the conductor.

Current (I)

If the free electrons of the conductor are attracted from the negative terminal towards the positive terminal **in one direction** under the influence of the field, this is known as

Direct Current (DC).

The free electron is, therefore, the current carrier in a typical solid conductor.

When current flows it also creates a magnetic field (around that conductor) & heat through friction (in the conductor).

Current (I)

The movement of these electrons is known as the **CURRENT** & is measured in **Amperes (A).**

One Ampere = 6.241×10^{18}
electron movements per second

The **“pressure”** applied to the electrons is referred to as the **VOLTAGE** & is measured in **Volts (V).**
This pressure can be switched from positive to negative creating a current flow in one direction then the other, this is known as

Alternating Current (AC)

Current (I)

In summary, current is:

- the movement of electrons
- best in soft metals
- measured in Amperes or Amps
- symbolised by ‘A’ (e.g. a 13A fuse)

Metals such as copper, silver, gold and aluminium lose electrons in abundance so a charge can be transferred easily.

Copper is the most common conductor material, primarily due to cost.

Ohm's Law

German physicist Georg Simon Ohm studied the relationship between:

- Potential Difference (V)
- Amperes (A)
- Resistance (Ω)

"the current through a conductor between two points is directly proportional to the potential difference across the two points, and inversely proportional to the resistance between them"

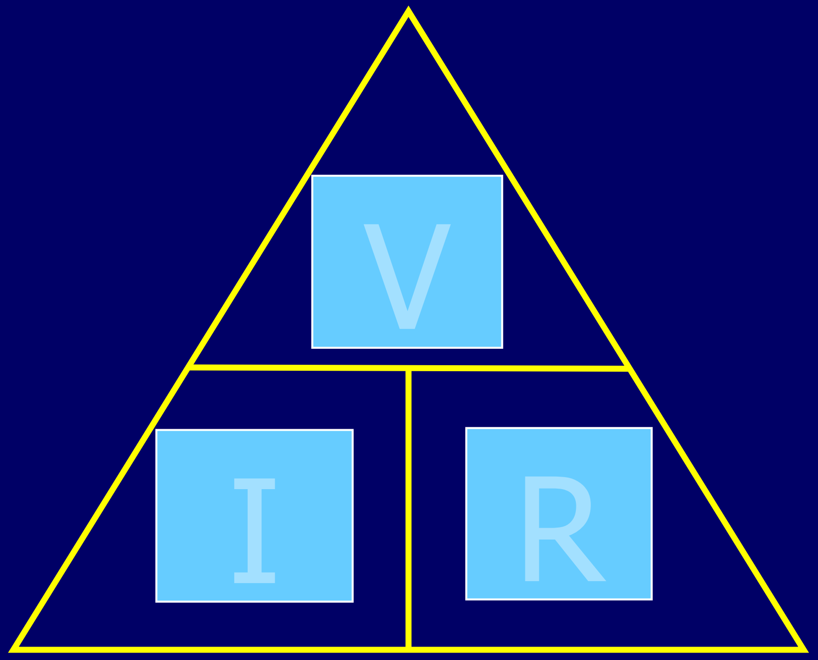
Ohm’s Law

His findings became known as **<u>Ohms Law</u>** where:

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

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

$$V = I \times R$$

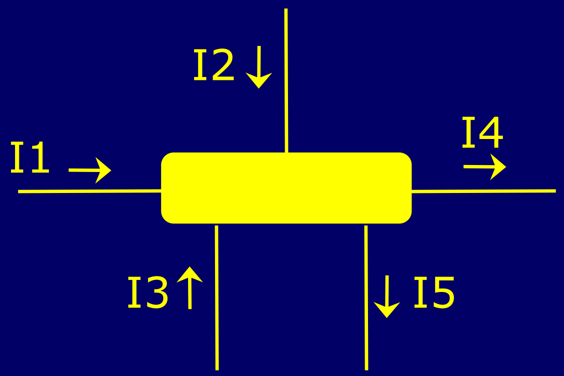


Kirchoff's Laws

Kirchoff's 1st Law

Law of current

"at any junction in an electrical circuit, the sum of the currents flowing into that junction is equal to the sum of currents flowing out of that junction. The algebraic sum of these currents must, therefore, be zero".



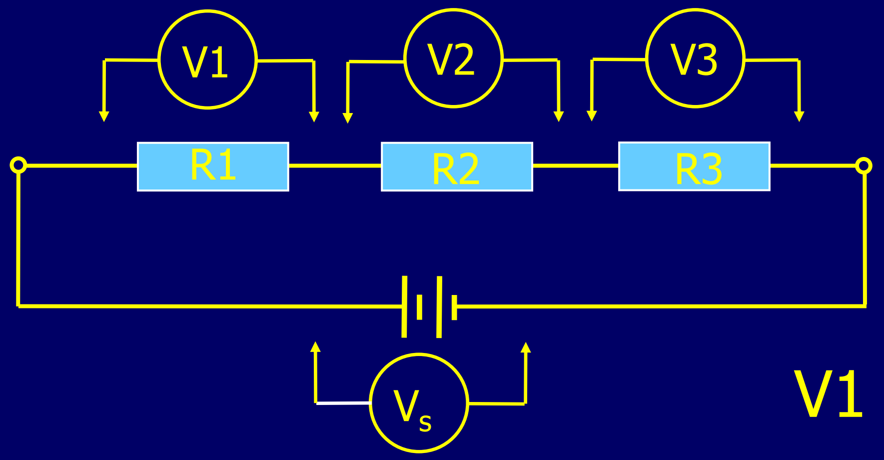
$$I1+I2+I3 = I4+I5$$

Kirchoff’s Laws

Kirchoff’s 2nd Law

Law of voltage

“the algebraic sum of the potential differences (voltage) around any closed circuit is equal to the force (source of supply) acting upon it”



$$V1 + V2 + V3 = V_s$$

Analogy

For example:
We can compare the electrical circuit (voltage, current & resistance) to one of water (pressure & flow).

Horizontal pipe – water does not flow, raise one end, water flows out because of pressure difference hence creating a flow.

The flow can be restricted by introducing a resistance, e.g. decreasing the diameter of the pipe.

The larger the diameter of the pipe the greater the level of flow available, also if you increase the pressure, the greater the flow.

Basic Principles 4

Power

Power (P)

Measured in Watts, and is a product of Volts and Amps

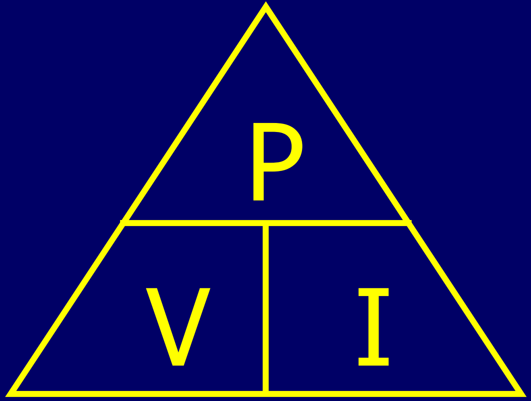
Resistance in electrical wiring consumes power.

Increasing the current or the voltage will result in higher power.

1 Watt = 1 Joule / sec

If current (A) is pushed through a resistor of value RΩ, the power dissipated will be:

Power = $I^2R = V^2/R$ (Watts)



Power Analogy

Using the water analogy, Power in an electrical circuit may be compared as follows:

Take a hose & point it at a waterwheel - the power generated by the wheel can be increased in two ways:

i. Increase the pressure of the water coming out of the hose – water hits the wheel with greater force & the wheel turns faster generating more power.

ii. Increase the flow rate – the wheel turns faster because of the weight of the extra water hitting it.

Power (P)

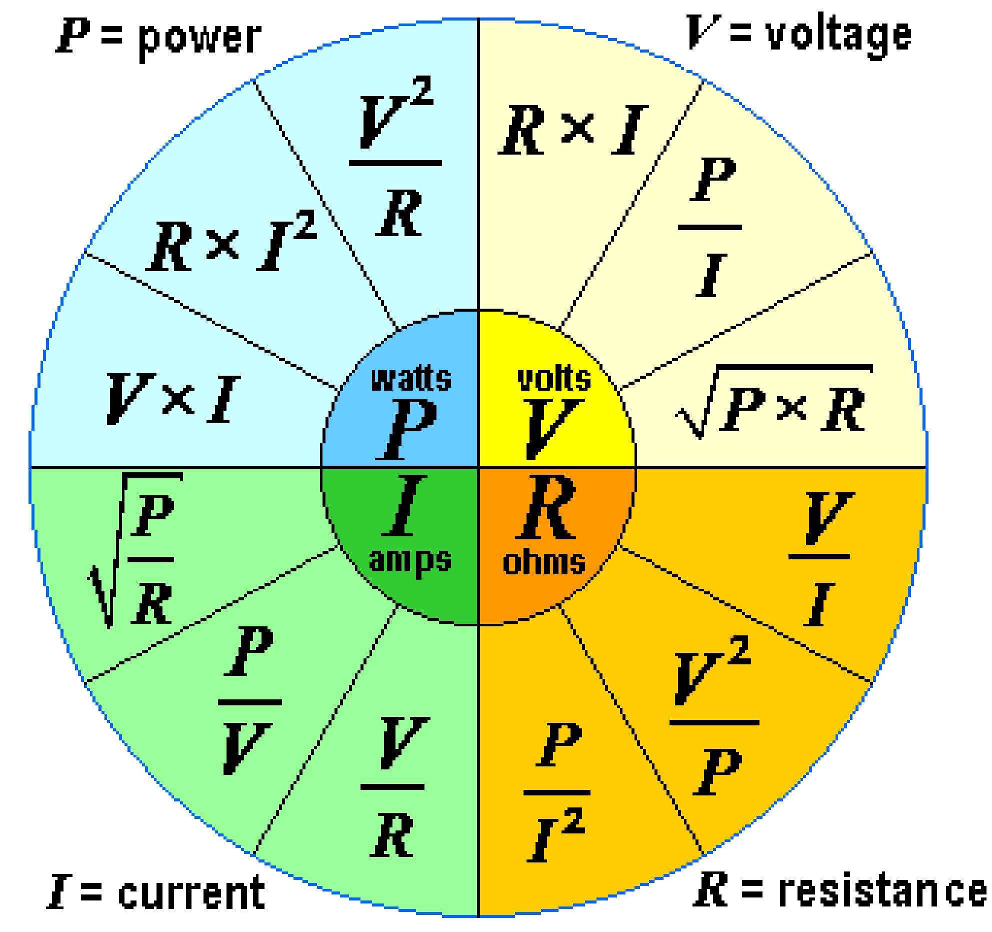
Electrical power is measured in Watts but priced in units of kilo-Watt Hours (kWh) i.e. the amount of kilo-Watts multiplied by the hours of use.

1 Horse Power = 746 Watts = 550 ft-lb/sec.

Q. What happens to the power or energy delivered to a Resistor?

A. The power or energy is dissipated as heat.

In Summary


P = power
V = voltage
I = current
R = resistance
watts
P
volts
V
I
amps
R
ohms
$\frac{V^2}{R}$
$R \times I^2$
$V \times I$
$R \times I$
$\frac{P}{I}$
$\sqrt{P \times R}$
$\sqrt{\frac{P}{R}}$
$\frac{P}{V}$
$\frac{V}{R}$
$\frac{V}{I}$
$\frac{V^2}{P}$
$\frac{P}{I^2}$

Sources of Power

Battery DC

Mains Supply (AC)

Portable Generators

Solar panels

Wind & Wave Generators

Basic Principles 5

Capacitance
&
Inductance

Capacitance (C)

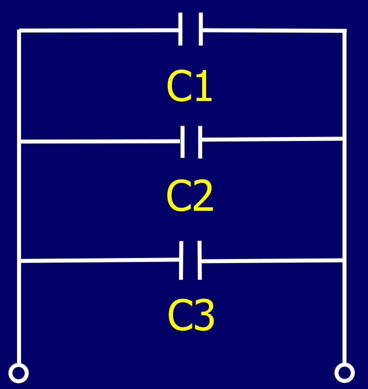
When a potential difference exists on two separate conductive materials a static electric field will develop between them. Any nonconductive material in the space between them then becomes what is known as the dielectric. This situation causes a positive charge to collect on one material and negative charge on the other.

The term “capacitance” is used to define the ratio of the electric charge on each conductor to the potential difference between them. $C = Q/V$

A capacitance of one Farad means that one Coulomb of charge on each conductor causes a voltage of one Volt across the device.

Calculating Capacitance (C)

To calculate values of capacitance:

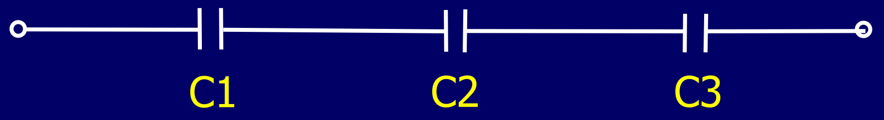


Capacitors connected in parallel:

$$C_T = C1 + C2 + C3 + \ldots..$$

Capacitors connected in series:

$$\frac{1}{C_T} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} + \ldots..$$



The total capacitance of a network of series capacitors
is less than the capacitance of the capacitor having the lowest capacitance.

Inductance (L)

As discussed earlier, currents can be produced in conductors that move in a magnetic field, this is termed **Inductance** (Faradays law), yet we also know that current flow produces its own field which will give rise to another magnetic field which will create another current and therefore another field in opposition (Lenz' Law).

Inductance is given the mathematical symbol L, and is measured in units called the henry* (H) named after the American Physicist Joseph Henry (1797-1878)

** Although the henry is given the symbol (capital) H, the name henry, applied to the unit of inductance, uses a lower-case h.*

Inductance and Inductors

Current flowing in a wire creates a magnetic field, arranging the wire into a coil creates an INDUCTOR.

When current flows through a coil the fields combine to make a much stronger field.

In an A.C. circuit the field value will be constantly changing hence a changing Electro Motive Force will be induced.

The value of this induced E.M.F. and the amount of induced current it produces in a conductor will depend on the rate of change of the magnetic field (frequency) - the faster the flux of the field changes, the greater the induced E.M.F. and therefore it's consequent current.

Inductance and Inductors

A back E.M.F.(also called a counter E.M.F.) is an E.M.F. created across an inductor by the changing magnetic flux around the conductor, produced by a change in current in the inductor.

The value of this E.M.F. is usually just below the supply voltage.

The effect of an inductor inducing an E.M.F. into itself is called **Self Induction** (but often referred to simply as Induction).

When an inductor induces an E.M.F. into a separate nearby inductor, this is called **Mutual Induction** & is a property used by Transformers.

Reactance (X)

Because the strength of the magnetic field set up by the original current is dependent on the rate (speed) of change of current (frequency), an inductor reduces the flow of alternating current (AC) more at high frequencies than at low, this limiting effect produced by the induced E.M.F. will be greater at higher frequencies because the current and therefore the flux is changing more rapidly the name given to this effect is **Inductive Reactance (X_L).**

Capacitance also has an effect on current flow in an AC circuit but has the inverse effect of Inductance i.e. current is more restricted at lower frequencies, this affect is called **Capacitive Reactance (X_C).**

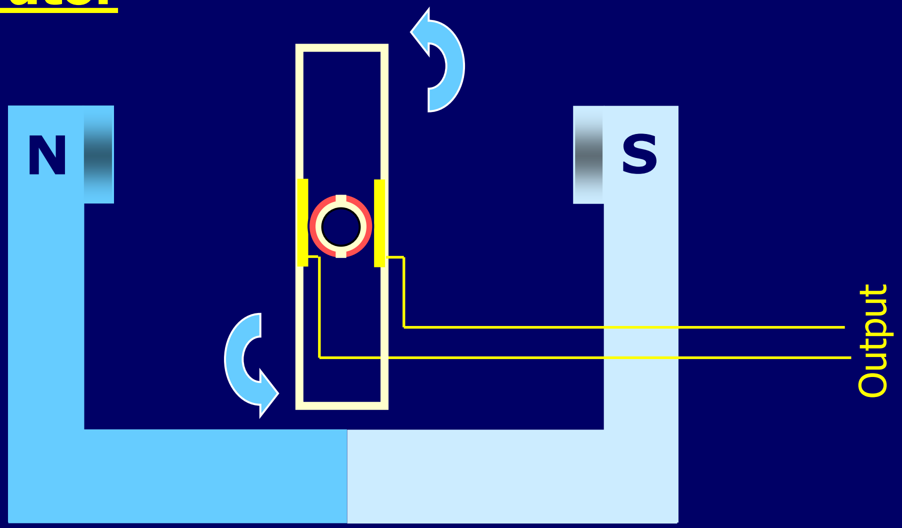
Impedance (Z)

This is the total opposition to current flow in an AC circuit or the changing level of a DC circuit and is a combination of the conductor material **Resistance,** through the effects of material type (Resistivity), length, cross sectional area and the effects of **Inductive** and **Capacitive** reactance based on ambient temperature and the change in supply **frequency** of AC.

Generation & Distribution

Generation

Simple Generator



As the wire rotates through the magnetic field, the field applies “pressure” hence electrons are exchanged & travel in the direction of the field.

Generation

Electricity may be generated by using the following:

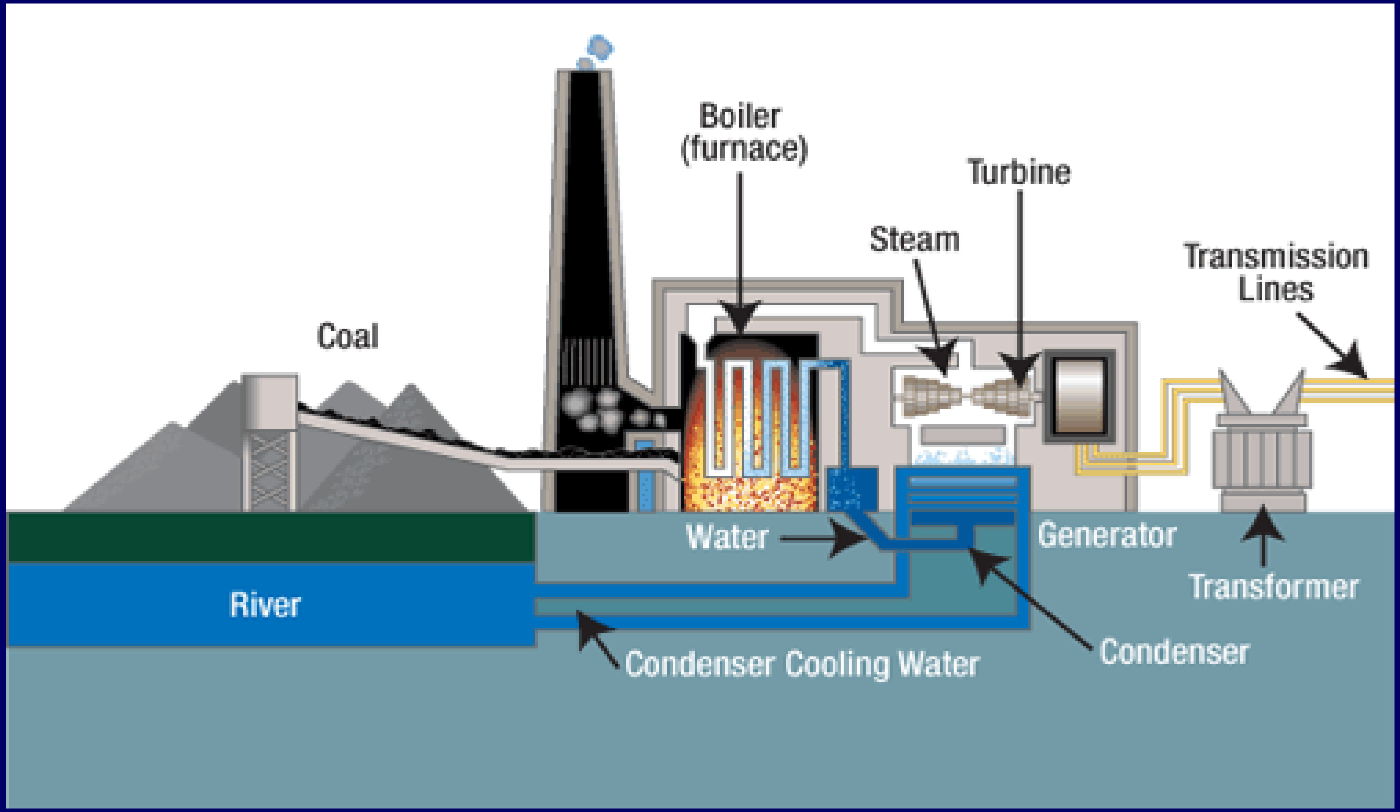
Fossil fuel resources
Coal, Gas & Oil

Nuclear

Renewable Energy
Wind Farms, Wave Energy, Geothermal, Pumped Storage, Solar

Generation

Fossil fuelled power plants operate by burning the fuel to heat water & produce steam to turn the turbine



Generation

The turbine is attached to the generator shaft, coils attached to the generator shaft are connected to a D.C. supply & become electro-magnets.

The rotating coils induce a high voltage in the fixed coils which surround them, generated voltages vary between 16kV & 25kV at 50 Hz.

Voltage is transmitted to “Step-up” transformers for supply to the National or Super Grid systems.

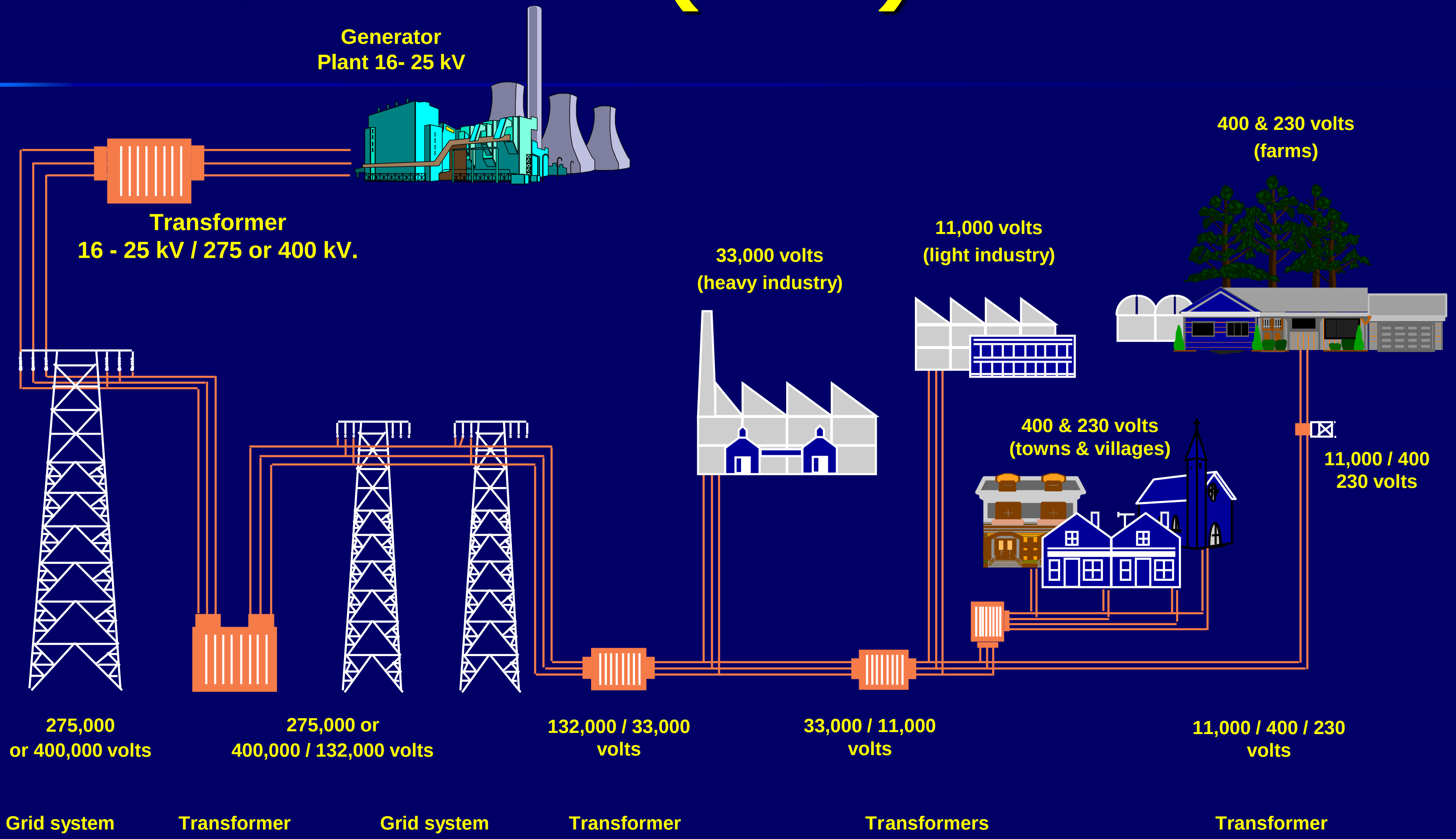
Generation

Choice of transmission voltage depends upon the length of the line.

Current flowing through a line results in power losses (I^2R) the higher the voltage the lower the current hence lower power losses.

This saving of losses has to be balanced against the extra cost of HV lines, transformers & switchgear.

Distribution (U.K.)



Distribution (U.K.)

Electricity supplied to homes at 230 volts AC

Large factories at 11000 volts AC or above

Smaller units – three-phase 400 volts AC

Alternates at a frequency of 50 cycles/second (Hz)

Distribution power cables are constructed of a steel core surrounded by the aluminium conductors

Generation

Nuclear power plants produce about 17% of the world's electricity supply & operate by using the heat generated by the splitting atoms to heat water & produce steam.

It has many advantages including:

Can be used for smaller applications, such as powering a ship or submarine.

Is very clean, producing much less emissions than its' fossil fuel competitors.

Generation

The disadvantages of the various methods include:

Fossil fuels, particularly coal & oil, produce large amounts of pollution when burnt, particularly CO^2, which is linked to Global Warming.

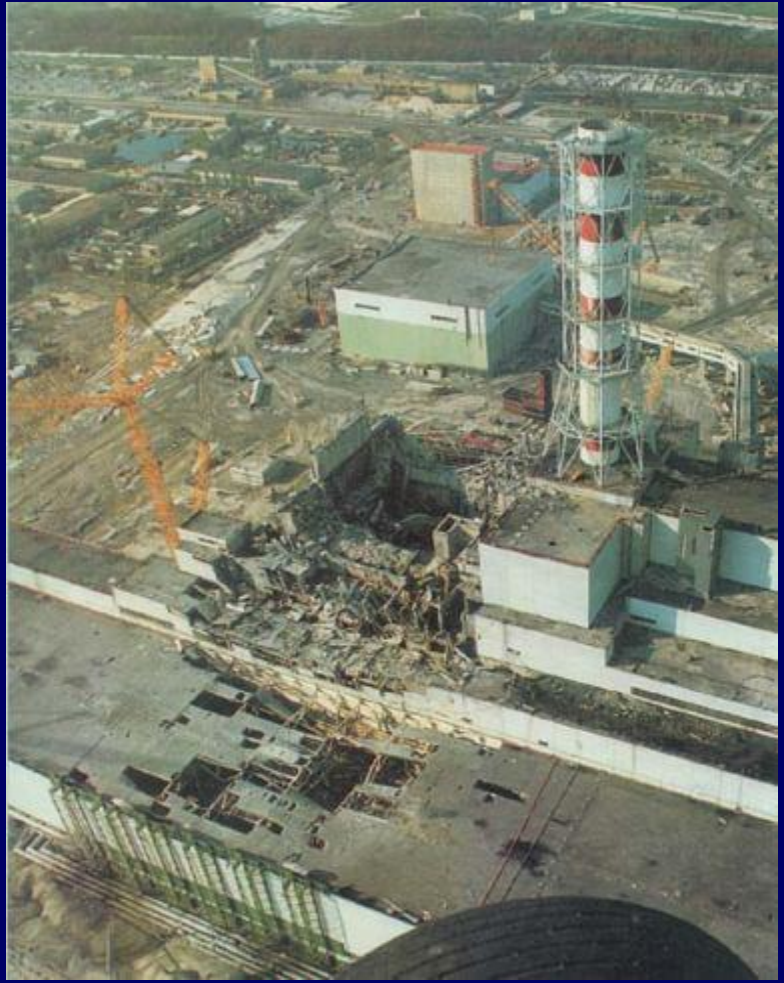
Generation from renewable energy sources can be expensive, is reliant upon the availability of the resource & (at present) is constrained by technology.

Nuclear power produces radio-active waste, some can be re-used however the remainder will take years to degrade & require secure storage facilities, usually underground & away from large populations.

When nuclear power goes wrong, the consequences can be catastrophic.........

The world's worst nuclear accident Chernobyl 26th April 1986

An operation goes badly wrong during the preparation stages …!



Electrical Safety

Effect of electricity on the human body

Electric Shock

- Tingling sensation
- Muscular Contraction
- Asphyxia
- Respiratory Arrest
- Ventricular Fibrillation

Burns

- Surface
- Deep tissue

Electric shock

0.5mA – 6mA   Tingling sensation
Threshold of perception.

10mA – 16mA Muscular contraction occurs
Threshold of danger.

30mA – 60mA & above, Prolonged exposure can be

FATAL

Death can occur in a fraction of a second.

Ventricular Fibrillation

Factors are Current /Time & Physiological Structure of body.

Can occur at **30mA (0.03 A).**

Causes heart to ‘flutter’.

Heart muscle cannot open / close properly.

Does not pump.

Lack of oxygen to brain – DEATH.

Electric Shock - Action

Isolate the supply immediately – dial 999.

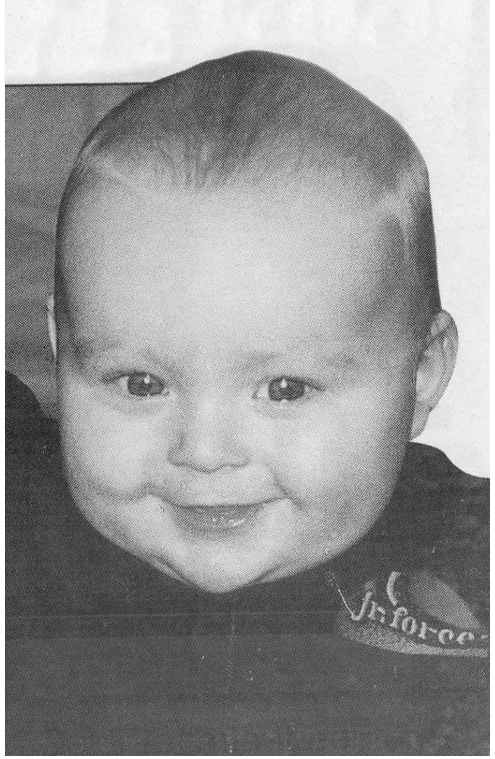
If you cannot isolate the supply DO NOT attempt to touch the casualty.

If attempting to physically remove the victim use non-conducting implements only.

Check for pulse / breathing, give artificial respiration if necessary *

DAILY MAIL, October 27 1999

Killed by a bungler



By ROGER SCOTT

Toddler dies after wiring botch makes house "live"

A TODDLER died in an electrical "house of horrors" after a botched wiring job left every appliance permanently "live".

An electric fire in the house was switched off at the wall and apparently safe. But when 13-month-old Jordan Hawkins reached out and touched one of the elements, he was instantly electrocuted.

Experts called in to investigate the tragedy in Newcastle upon Tyne found the live and neutral cables to the fuse box had been transposed, so a powerful current was still flowing through the fire. In addition every appliance in the house was live.

Moira Mair, the tenant of the house where Jordan died said council workmen had carried out repairs some months previously. But Geoff Atkinson, principle mainten- ance engineer for Newcastle City Council's housing department, said they would have sent only qualified elec-tricians to do the work and they would have noticed if the wires were crossed.

Recording a verdict of misadventure, coroner David Mitford said : "We know why the item was live. It would be nice if we knew how this happened and who was responsible".

He added that he would be writing to the council asking it to check electric wiring in the same street after hearing from witnesses that there had been "problems" in other homes.

DAILY EXPRESS, January 1998

Killed by fairy lights

Tragedy as little angel Cara, 6, is electrocuted in front of the family.

An excited little girl was electrocuted when she switched on Christmas tree lights as her family looked on, unable to help.

The lights, which the family bought 4 years ago, were plugged into a table lamp. To reach the switch, Cara rested her foot on a copper gas fire pipe running along the skirting board.

She was subjected to a full mains voltage shock, possibly due to a loose wire, because her body was earthed by the piping.

Her elder sister Fiona, 14, tried to pull her free but received a minor shock herself.

Police, Electricity Board experts and Trading Standards officers launched an investigation.

Inspector Steve Love, of Humberside police said : "It was a tragic accident which, on the face of it, was peculiar to the circumstances around the lights, rather than a fault with the lights. It was a tragic combination of circumstances".

Electrical Circuits

Electrical circuits

Consist of the following:

A Power Source.

Connecting cables.

Electrical equipment (energy converter).

Electrical circuits (Earthing)

Very important for safety!

Prevents parts of equipment which do not normally conduct electricity (e.g. metal frames or lids), from becoming live in the event of a fault occurring.

All of these potentially conducting surfaces must be connected together at the main earthing terminal to ensure they are all at the same potential.

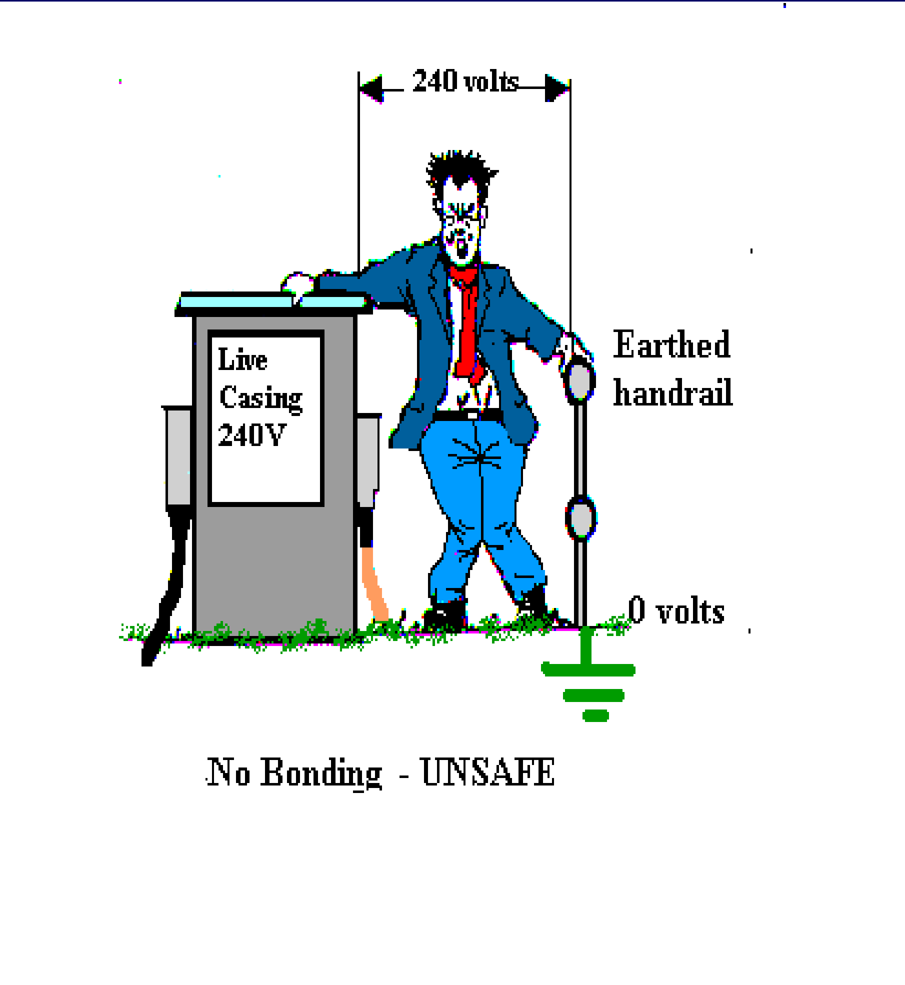
Exposed Conductive Parts

Equipment Bonding

Exraneous Conductive Parts

No bonding.

Person can receive an electric shock if equipment becomes faulty.



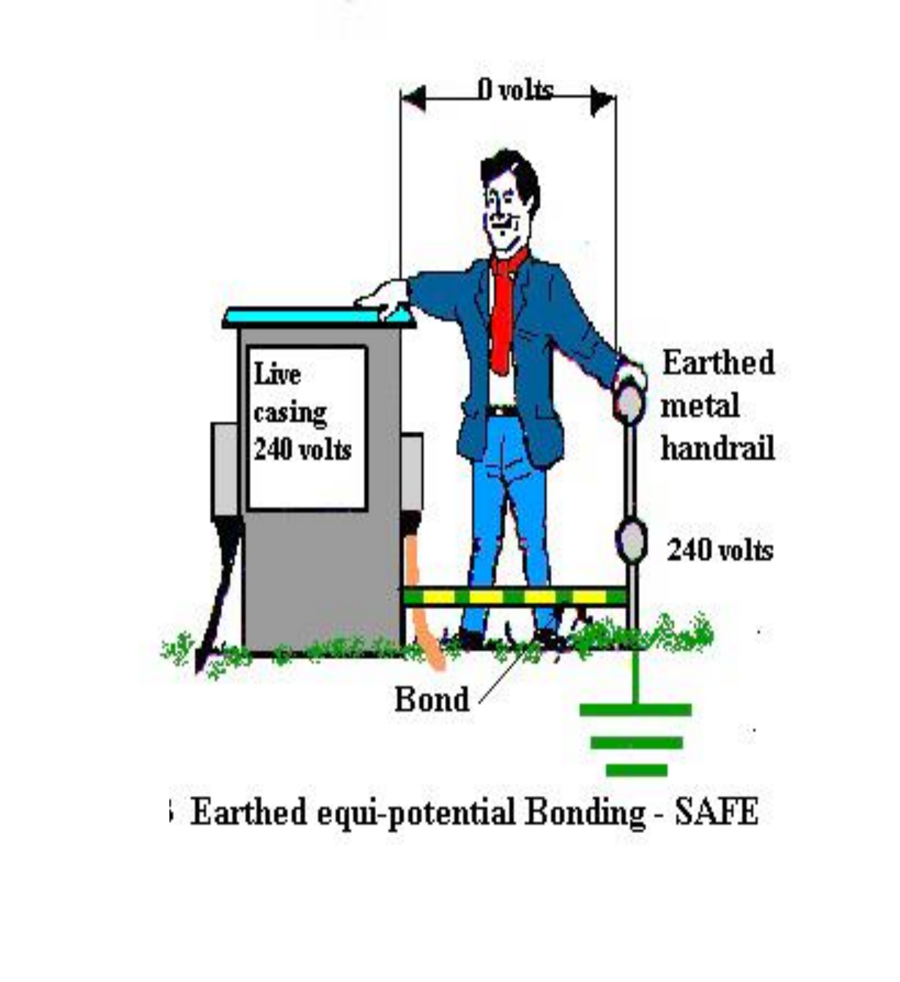
Equipment Bonding

All equipment bonded together

No potential (voltage) difference between live casing and handrail

If case becomes live the protection will operate

This is called **equipotential bonding**



Protective Devices

Fuses

Essential for safety, will cut off the supply at a certain current level (above the rating of the fuse).

Fuse has a ‘fusible’ wire element which heats up when current flows.

Excessive current = excessive heat & wire melts preventing current flow.

Protective Devices

MCB's (Miniature Circuit Breakers).

Protect against circuit current overload.

Two methods of operation – thermal & magnetic.

Three types available for different equipment &/or operating conditions:

Type B	Domestic applications.
Type C	Industrial & commercial Typically, *fluorescent lighting & light duty motors*.
Type D	Industrial & commercial Typically *for circuits that have high in-rush current.*

Protective Devices

RCD

Residual Current Device.

Compares current in Live & Neutral - if different and above a certain value the supply is switched off.

Can only be used in conjunction with other protective devices (MCB's or fuses).

Protective Devices

RCBO

Residual Current Breaker (with overload capability).

Three methods of operation:

Thermal, magnetic, also compares current in Live & Neutral - if different and above a certain value the supply is switched off.

Work on Electrical Equipment

Always follow the electrical isolation procedure

Isolate the supply via a switch that will create an air gap that should not fail & can be locked in the "Off" position.

Lock off to prevent inadvertent switching ON whilst work is taking place.

Test conductors & terminals BEFORE touching (note : you MUST test the test instrument before and after, a Permit-to-work will be necessary).

Ignoring the procedure may be viewed as "Gross Misconduct" & may be used against you in a Court of Law.

Work on Electrical Equipment

Never:

Assume the equipment is safe to work on.

Assume the electrical supply has been switched off / isolated.

Over-ride a device intended for safety (unless specific written permission has been given & all consequent measures taken comply with the Law).

Undertake ANY work without a Permit-to-work.

Safety – Hand-held equipment

Hand-held on-site electrical tools should not be more than 110Vac supplied via a step-down transformer.

Reduced low voltage **(110V)** equipment identified by its colour **(Yellow).**

Step-down transformer has a centre-tapped earth (CTE) on its Secondary winding.

There are no recorded incidents of 55Vac causing serious harm, less than 120V DC is considered to be safe.

Double Insulation

Lots of portable equipment is Double Insulated.

Extra layer of insulating material over live conductors, or potentially live conducting material, to prevent exposure to live parts.

Can mean that an earth conductor is not required – risk reduced by additional insulation &/or built from non-conducting materials.

Fires/Arcs/Explosions

Fires

Overheating by overloading , arcing & sparking, loose connections.

Arcs

Generated during faults / or switching live circuits.
High currents & temperatures - can cause severe burns & damage to equipment (& persons).

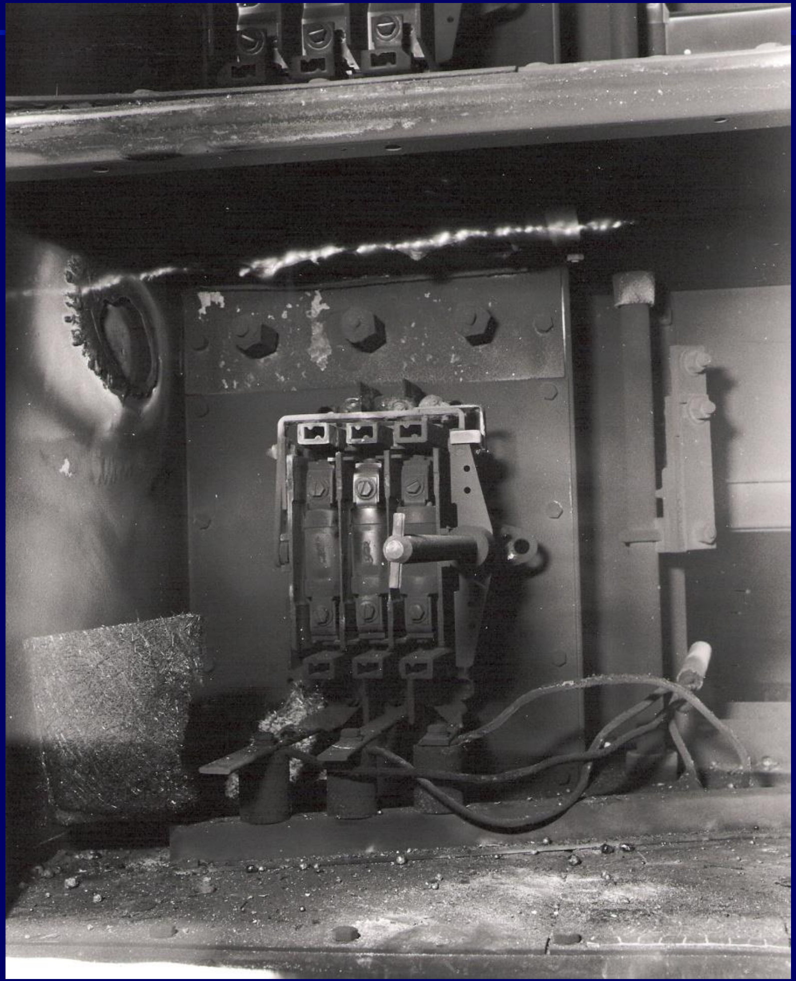
Explosions

Flammable vapours.

Gases.

Dusts.

Electrical Arc & Explosion



Electrical Equipment

Selection

Must be suitable for the intended environment

- Wet, dusty, flammable gases, mechanical strength, corrosive atmospheres.
- Must be maintained in a condition that is suitable for its intended use.
- Failure to select suitable equipment & maintain it often results in incidents at a later date.
- Installation, **use** & maintenance are part of the Electricity At Work Regulations (1989).

Portable Appliances

Many accidents result from 230V portable equipment, inc. pressure washers & vacuum cleaners!

This may be the result of:

- Poor or incorrect selection.
- Inadequate or poor maintenance.
- The most important checks are usually the easiest to do!

Maintenance of Portable Electrical Equipment

Visual Inspections:

Check flexible mains cable for damage to insulation - if the insulation is damaged replace the cable.

If connected via a plug / socket arrangement, check both are secure DO NOT wrap the conductors together and cover with tape.

So called 'Electrical Insulation Tape' will not provide a suitable barrier between you and a potentially fatal electric shock – as has been proven on many occasions.

Check the PAT label is present & within its' Test Date.

Maintenance of Portable Electrical Equipment

Plug:

Check that only the outer insulation has been clamped / gripped – clamping the inner conductor insulation will potentially lead to exposure of live terminals.

Is the fuse the correct rating (instructions should advise correct current value – DO NOT use a nail or any other conducting material).

Check that all 3 pins are present and in good condition.

Check that the plug construction is in good condition.

Maintenance of Portable Electrical Equipment

Portable Appliance Testing (PAT).

Must be completed by a competent person:
Earth bond test.
Insulation test.
On-load test.

Guidance – HSE HS(G) 107 - “Maintaining portable and transportable electrical equipment”.