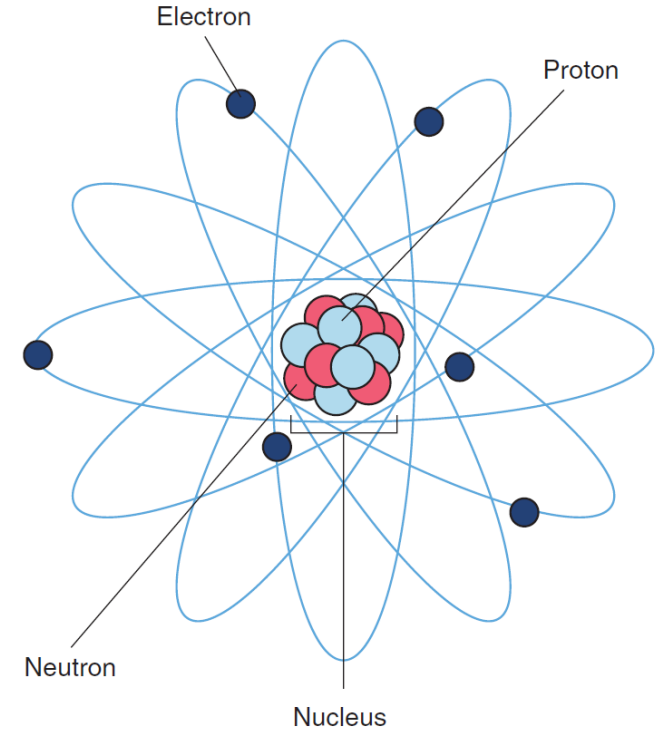# Electric Vehicle - Basic Electrical and Electronics

Basic electrical principles

- The atom consists of a central nucleus made up of protons and neutrons. Around this nucleus orbit electrons, like planets around the sun.

- The neutron is a very small part of the nucleus. It has equal positive and negative charges and is therefore neutral and has no polarity.

- The proton is another small part of the nucleus, it is positively charged.

- The neutron is neutral and the proton is positively charged, which means that the nucleus of the atom is positively charged.

- The electron is negatively charged. It orbits the nucleus and is held in orbit by the attraction of the positively charged proton.

Electron

Proton

Neutron

Nucleus

Conductors and Insulators

- When atoms are in a balanced state, the number of electrons orbiting the nucleus equals the number of protons.

- The atoms of some materials have electrons that are easily detached from the parent atom and can therefore join an adjacent atom.

- These atoms move an electron from the parent atom to another atom (like polarities repel) and so on through material. This is a random movement and the electrons involved are called free electrons.

- Materials are called conductors if the electrons can move easily. In some materials it is extremely difficult to move electrons from their parent atoms. These materials are called insulators.

Conductors
Metals conduct electricity

Copper   Silver   Gold
Aluminium   Iron   Mercury

INSULATORS
Materials that do not conduct electricity
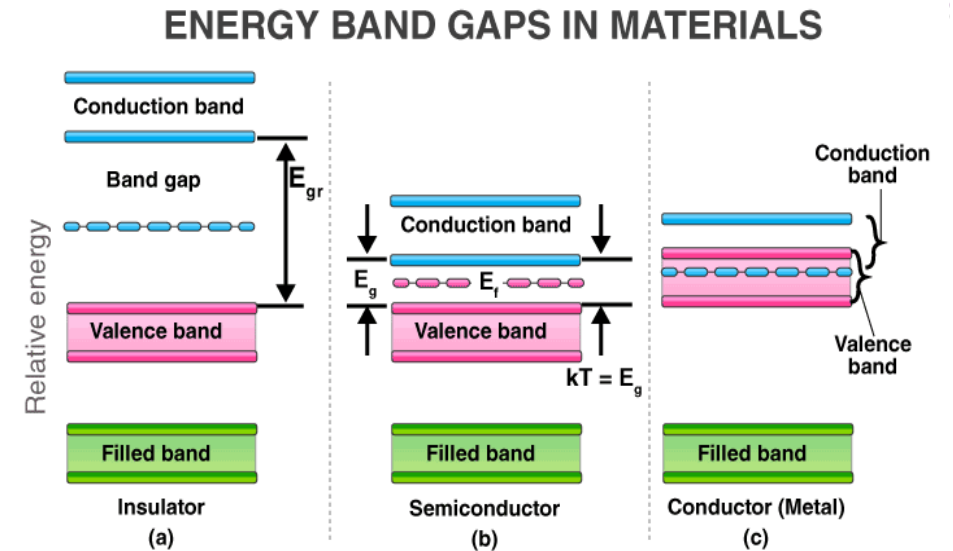
Plastic   Rubber   Cotton   Wood

Semiconductors

- Semiconductors are the materials which have a conductivity between conductors (generally metals) and non-conductors or insulators (such as ceramics).

- Semiconductors can be compounds such as gallium arsenide or pure elements, such as germanium or silicon.
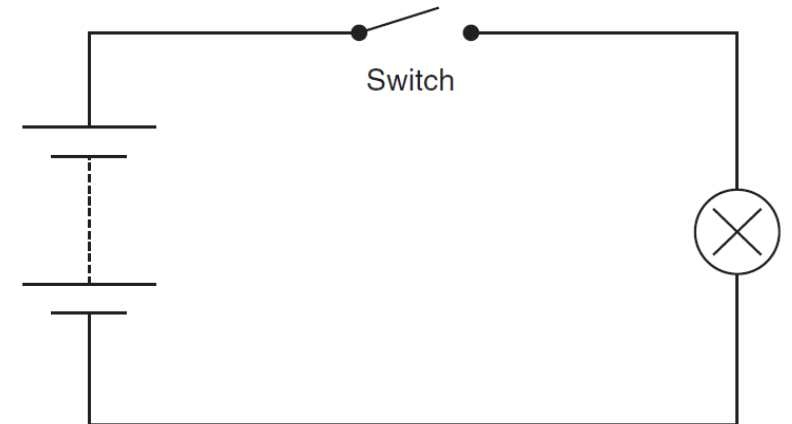
Examples of Semiconductors:

- Gallium arsenide, germanium, and silicon are some of the most commonly used semiconductors. Silicon is used in electronic circuit fabrication and gallium arsenide is used in solar cells, laser diodes, etc.

ENERGY BAND GAPS IN MATERIALS

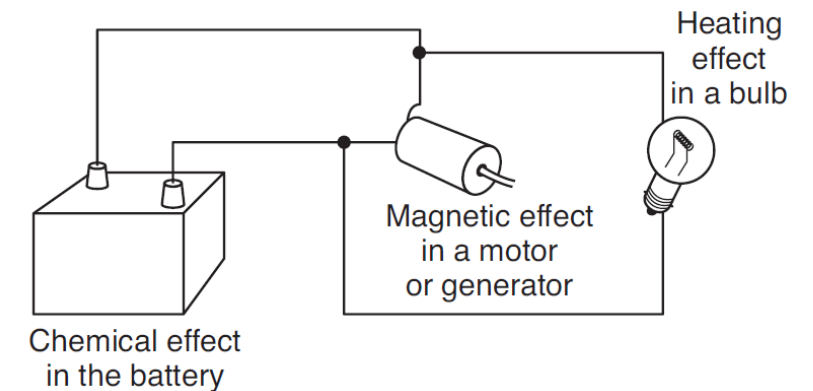# Electron and conventional flow

To cause an electron flow:

▪ A pressure source is needed, e.g. from a battery or generator.

▪ A complete conducting path in which the electrons can move should exist (e.g. wires).

Switch

Effects of current flow

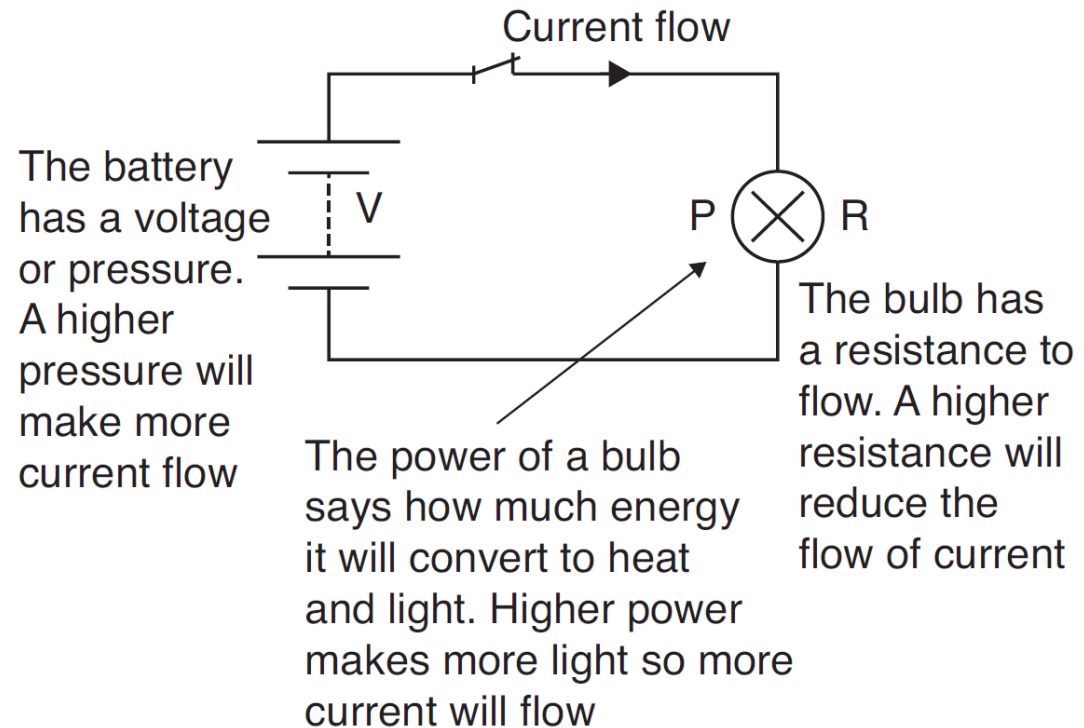When a current flows in a circuit, it can produce only three effects:

- heating
- magnetic
- chemical.

- The heating effect is the basis of electrical components such as lights and heater plugs.

- The magnetic effect is the basis of relays and motors and generators.

- The chemical effect is the basis for electroplating and battery charging.

Heating
effect
in a bulb

Magnetic effect
in a motor
or generator

Chemical effect
in the battery

Fundamental Quantities

Voltage = Current × Resistance
(V = IR) or (R = V/I) or (I = V/R)

Power = Voltage × Current
(P = VI) or (I = P/V) or (V = P/I)

Current flow

The battery has a voltage or pressure. A higher pressure will make more current flow

V

P ⊗ R

The bulb has a resistance to flow. A higher resistance will reduce the flow of current

The power of a bulb says how much energy it will convert to heat and light. Higher power makes more light so more current will flow

Describing electrical circuits

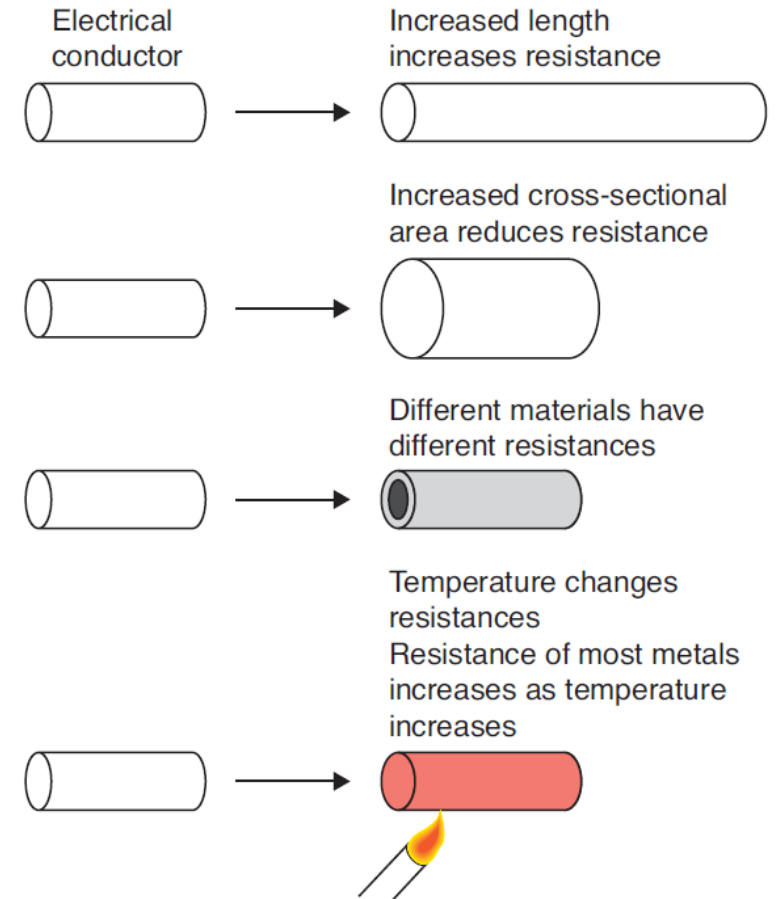**Open circuit -** This means the circuit is broken, therefore no current can flow.

Short circuit - This means that a fault has caused a wire to touch another conductor and the current uses this as an easier way to complete the circuit.

High resistance - This means a part of the circuit has developed a high resistance (such as a dirty connection), which will reduce the amount of current that can flow.
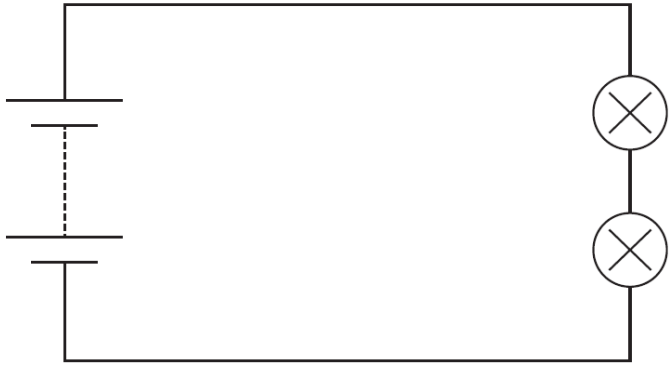
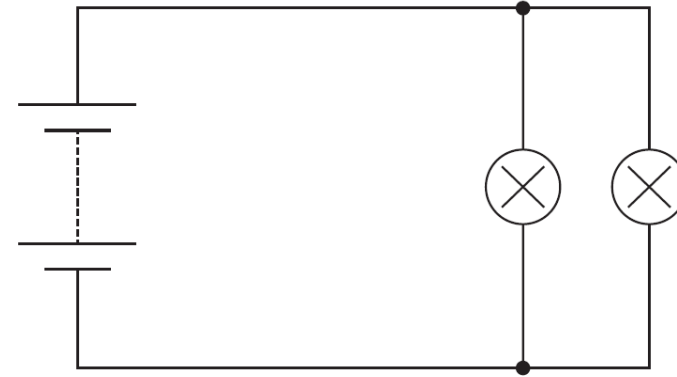# Factors affecting the resistance of a conductor

- Length – the greater the length of a conductor, the greater is the resistance.

- Cross-sectional area – the larger the cross sectional area, the smaller the resistance.

- The material from which the conductor is made – the resistance offered by a conductor will vary according to the material from which it is made. This is known as the resistivity or specific resistance of the material.

- Temperature – most metals increase in resistance as temperature increases.

Electrical conductor

Increased length increases resistance

Increased cross-sectional area reduces resistance

Different materials have different resistances

Temperature changes resistances
Resistance of most metals increases as temperature increases
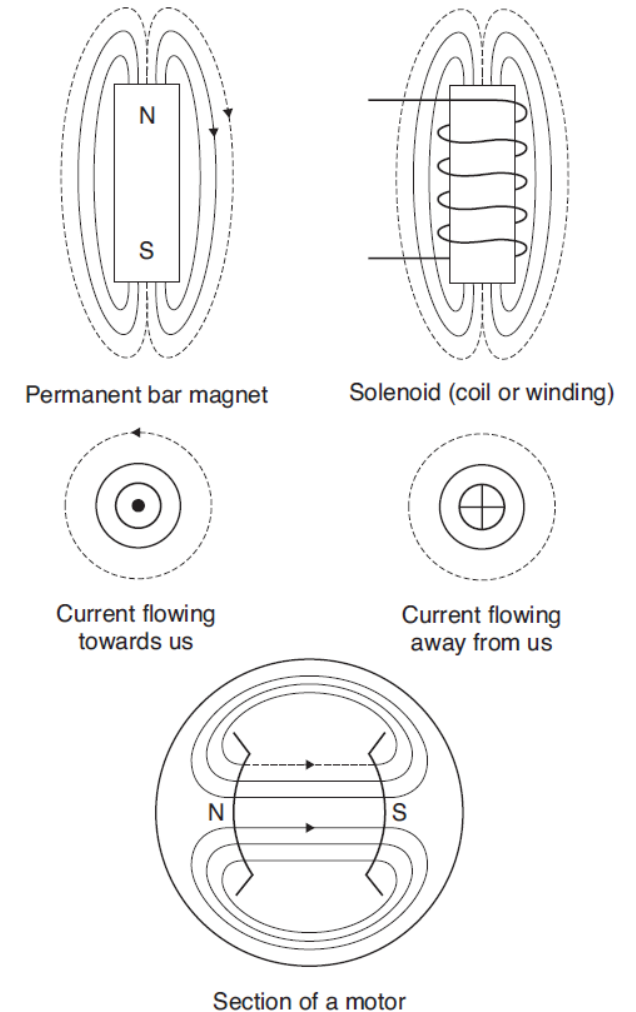
Series and Parallel Circuits

- ➢ Current is the same in all parts of the circuit.
- ➢ The applied voltage equals the sum of the volt drops around the circuit.
- ➢ Total resistance of the circuit (RT) equals the sum of the individual resistance values
  $R_1 + R_2$

- ➢ The voltage across all components of a parallel circuit is the same.
- ➢ The total current equals the sum of the current flowing in each branch.
- ➢ The current splits up depending on each component resistance.
- ➢ The total resistance of the circuit (RT) can be calculated by:
  $1/RT = 1/R1 + 1/R2$ or $RT = (R1 \times R2)/(R1 + R4)$

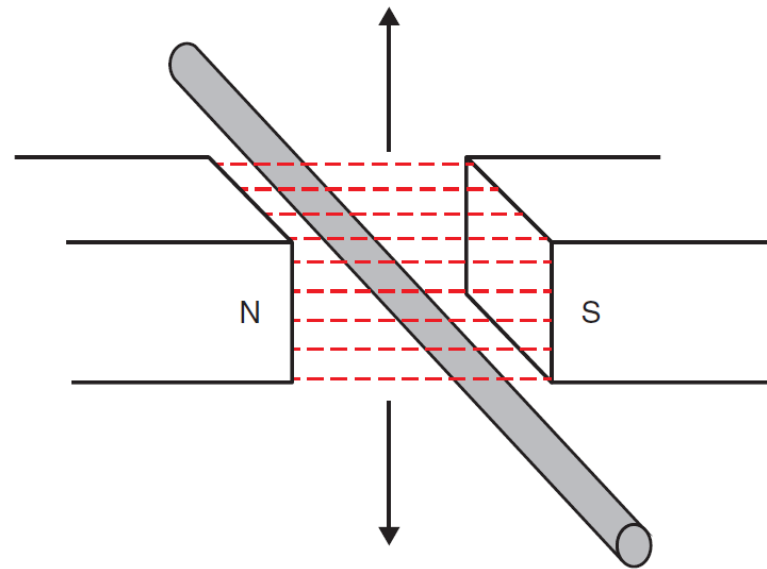# Magnetism and electromagnetism – Some Basic rules

- Unlike poles attract. Like poles repel.

- Lines of force in the same direction repel sideways; in the opposite direction they attract.

- Current flowing in a conductor will set up a magnetic field around the conductor. The strength of the magnetic field is determined by how much current is flowing.

- If a conductor is wound into a coil or solenoid, the resulting magnetism is the same as that of a permanent bar magnet.

Permanent bar magnet

Solenoid (coil or winding)

Current flowing towards us

Current flowing away from us

Section of a motor

Electromagnetic induction

Basic laws:

✓ When a conductor cuts or is cut by magnetism, a voltage is induced in the conductor.
✓ The direction of the induced voltage depends on the direction of the magnetic field and the direction in which the field moves relative to the conductor.
✓ The voltage level is proportional to the rate at which the conductor cuts or is cut by the magnetism.

Mutual induction

If two coils (known as the primary and secondary) are wound onto the same iron core, then any change in magnetism of one coil will induce a voltage into the other.
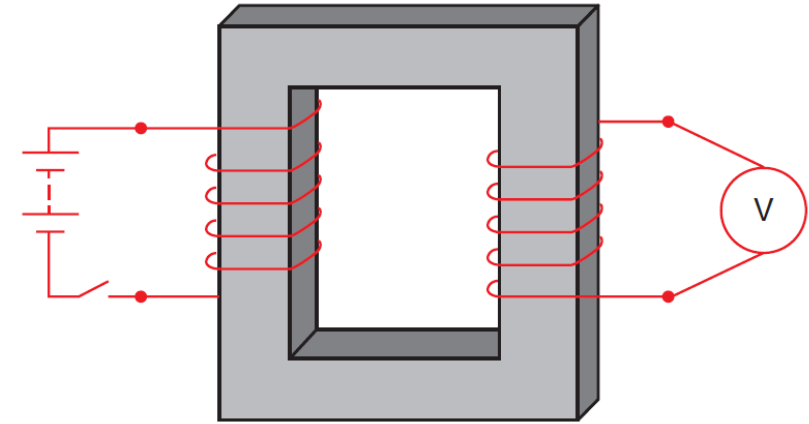
This happens when a current to the primary coil is switched on and off. If the number of turns of wire on the secondary coil is more than the primary, a higher voltage can be produced.

If the number of turns of wire on the secondary coil is less than the primary, a lower voltage is obtained.

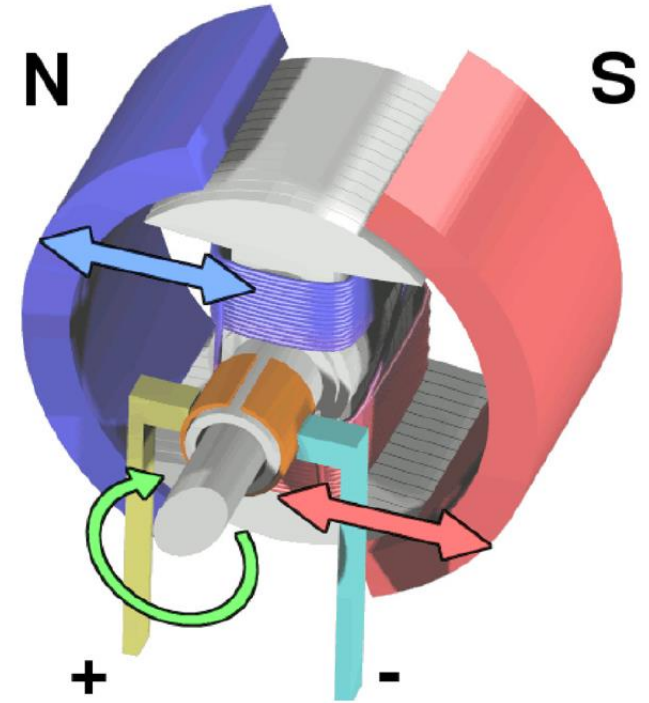This is called 'transformer action' and is the principle of the ignition coil.

The value of this 'mutually induced' voltage depends on:
- The primary current.
- The turns ratio between primary and secondary coils.
- The speed at which the magnetism changes.

Basic motor principle

- Electric motors operate because of the interaction between magnetic fields.

- The magnetic fields can be created by windings or be permanent magnets, but one of them must be electromagnetism.

- The force from the two fields is made to act in such a way as to cause a shaft to turn

Definitions and laws

Ohm's law

For most conductors, the current that will flow through them is directly proportional to the voltage applied to them.

The ratio of voltage to current is referred to as resistance. If this ratio remains constant over a wide range of voltages, the material is said to be 'ohmic'.

R = V/I
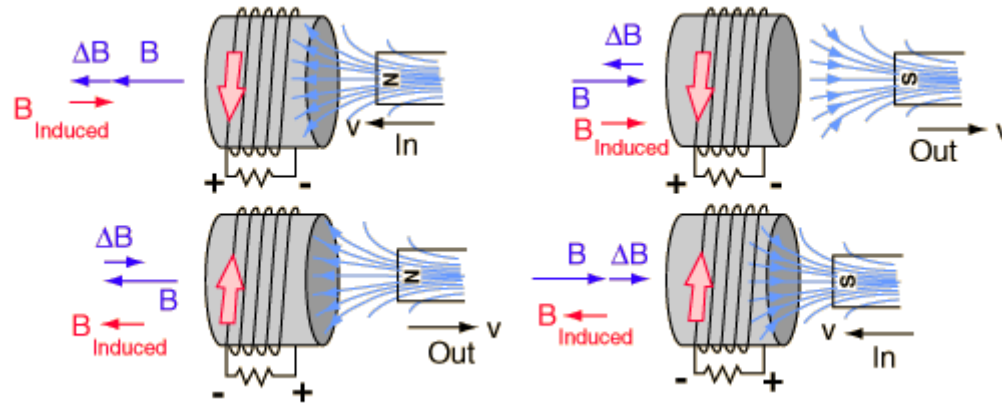I = current in amps,
V = voltage in volts,
R = resistance in ohms.

Lenz's law

The EMF induced in an electric circuit always acts in a direction so that the current it creates around the circuit will oppose the change in magnetic flux which caused it.

Lenz's law gives the direction of the induced EMF resulting from electromagnetic induction. The 'opposing EMF' is often described as a 'back EMF'.

When the magnetic flux changes (ΔB), the magnetic field of the induced emf (BInduced) works to counter the change.

Kirchhoff's laws

Kirchhoff's 1st law:

The current flowing into a junction in a circuit must equal the current flowing out of the junction.
This law is a direct result of the conservation of charge; no charge can be lost in the junction, so any charge that flows in must also flow out.

Kirchhoff's 2nd law:

For any closed loop path around a circuit, the sum of the voltage gains and drops always equals zero.
This is effectively the same as the series circuit statement that the sum of all the voltage drops will always equal the supply voltage.
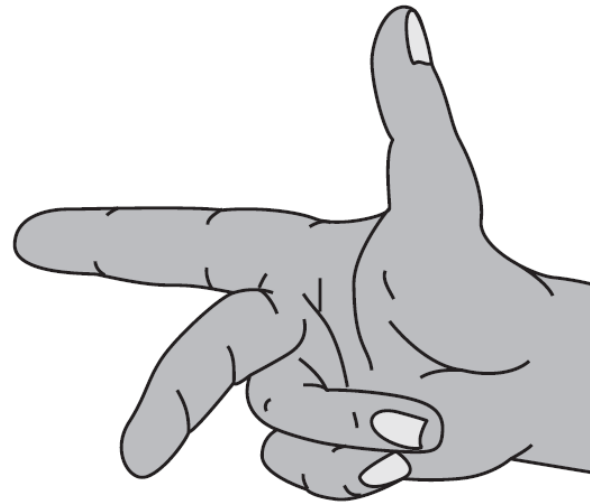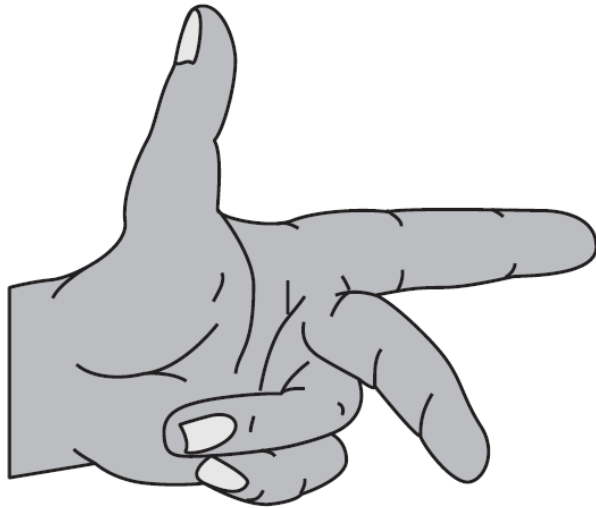
Faraday's law

- Any change in the magnetic field around a coil of wire will cause an EMF (voltage) to be induced in the coil.

- No matter how the change is produced, the voltage will be generated.

- The change could be produced by changing the magnetic field strength, moving the magnetic field towards or away from the coil, moving the coil in or out of the magnetic field, rotating the coil relative to the magnetic field and so on!
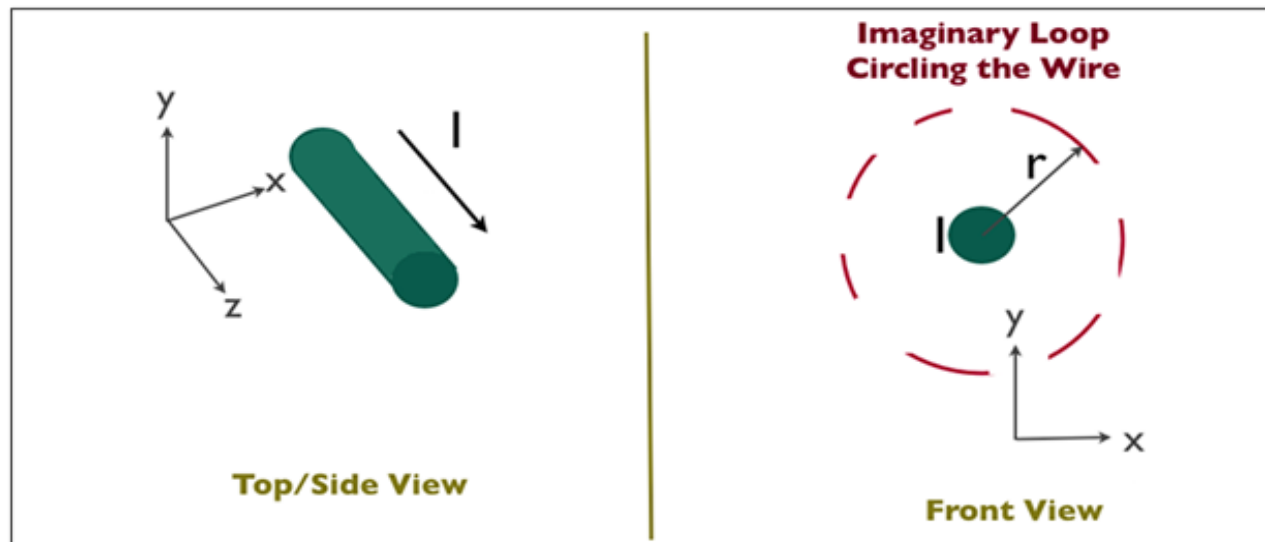
Fleming's rules

- In an electrical machine, the first finger lines up with the magnetic Field, the
- second finger lines up with the Current and the thumb lines up with the Motion.

- Fleming's rules relate to the direction of the magnetic field, current and motion in electrical machines.

- The left hand is used for motors, and the right hand for generators (remember gener-righters).

Ampere's law

For any closed loop path, the sum of the length elements × the magnetic field in the direction of the elements = the permeability × the electric current enclosed in the loop.
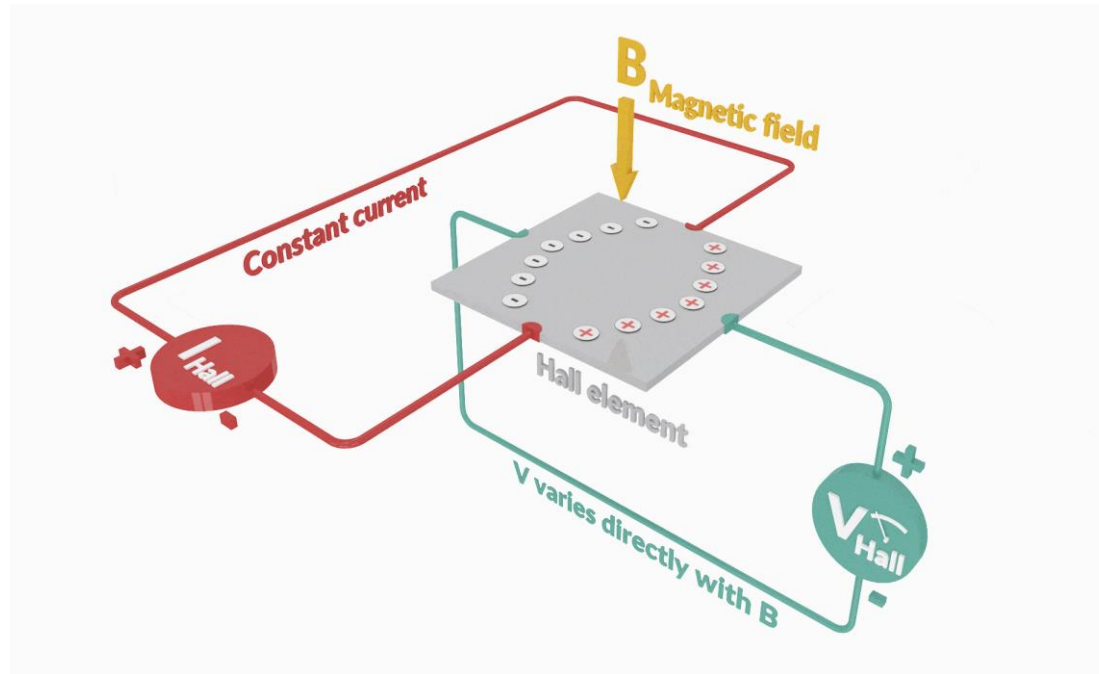
In other words, the magnetic field around an electric current is proportional to the electric current which creates it and the electric field is proportional to the charge which creates it.

Hall Effect Principle

When a current-carrying conductor or a semiconductor is introduced to a perpendicular magnetic field, a voltage can be measured at the right angle to the current path.

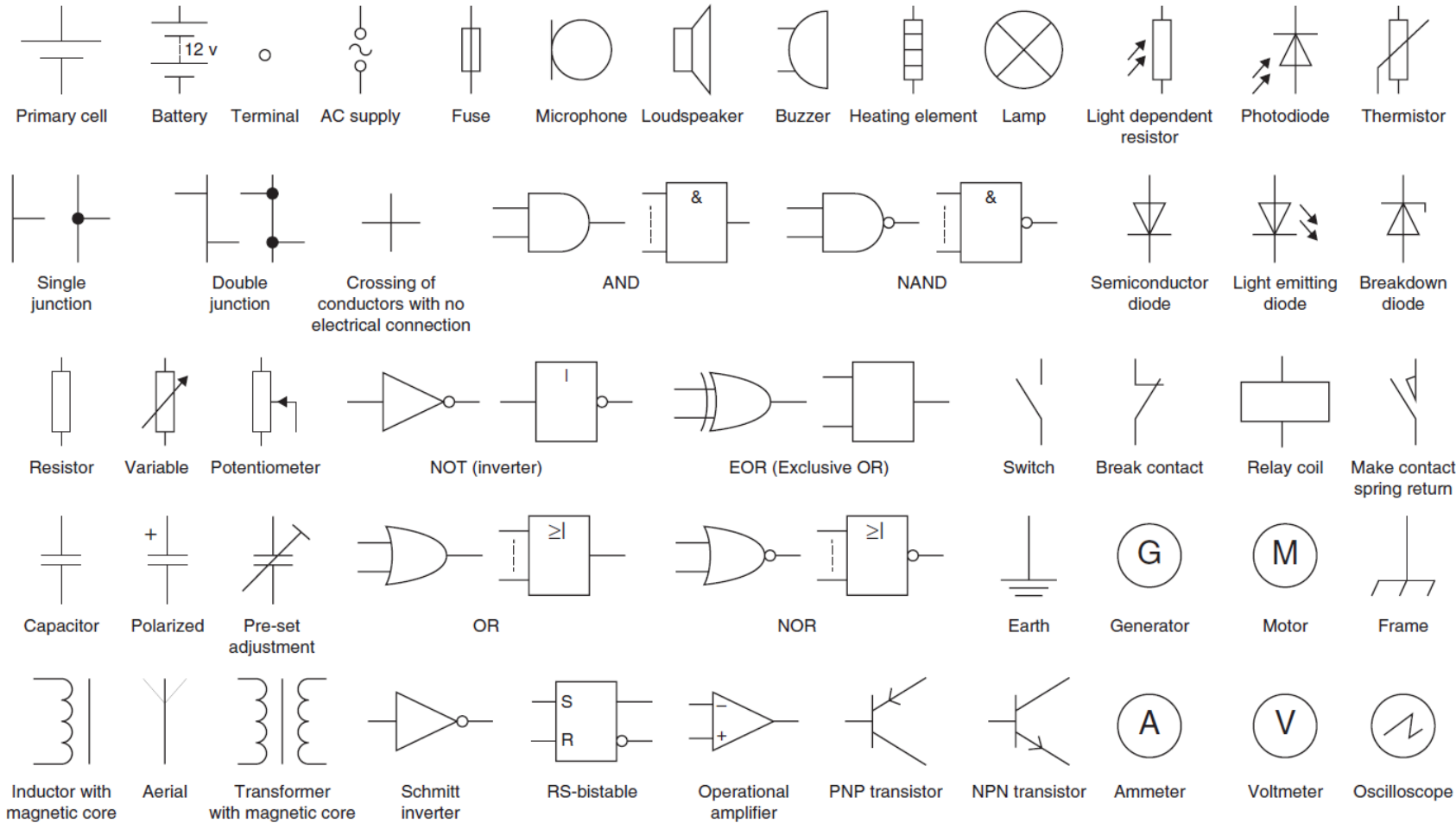This effect of obtaining a measurable voltage is known as the Hall Effect.

Some Definitions and Units

Name	Definition	Symbol	Common formula	Unit name	Abbreviation
Electrical charge	One coulomb is the quantity of electricity conveyed by a current of one ampere in one second.	Q	$Q = It$	Coulomb	C
Electrical flow or current	The number of electrons past a fixed point in one second.	I	$I = V/R$	Ampere	A
Electrical pressure	A pressure of 1 volt applied to a circuit will produce a current flow of 1 amp if the circuit resistance is 1 ohm.	V	$V = IR$	Volt	V
Electrical resistance	This is the opposition to current flow in a material or circuit when a voltage is applied across it.	R	$R = V/I$	Ohm	Ω
Electrical conductance	Ability of a material to carry an electrical current. One Siemens equals 1 amp per volt. It was formerly called the mho or reciprocal ohm.	G	$G = 1/R$	Siemens	S
Current density	The current per unit area. This is useful for calculating the required conductor cross-sectional areas.	J	$J = I/A$ (A = area)		$A\,m^{-2}$
Resistivity	A measure of the ability of a material to resist the flow of an electric current. It is numerically equal to the resistance of a sample of unit length and unit cross-sectional area, and its unit is the ohm metre. A good conductor has a low resistivity ($1.7 \times 10^{-8}\Omega$ m copper); an insulator has a high resistivity ($10^{15}\,\Omega$ m polyethane).	ρ (rho)	$R = \rho L/A$ (L = length; A = area)	Ohm metre	Ω m
Conductivity	The reciprocal of resistivity.	σ (sigma)	$\sigma = 1/\rho$	Ohm^{-1} $metre^{-1}$	$\Omega^{-1}\,m^{-1}$
Electrical power	When a voltage of 1 volt causes a current of 1 amp to flow, the power developed is 1 watt.	P	$P = IV$ $P = I^2R$ $P = V^2/R$	Watt	W
Capacitance	Property of a capacitor that determines how much charge can be stored in it for a given potential difference between its terminals.	C	$C = Q/V$ $C = \varepsilon A/d$ (A = plate area, d = distance between, ε = permittivity of dielectric)	Farad	F

Name	Definition	Symbol	Common formula	Unit name	Abbreviation
Inductance	Where a changing current in a circuit builds up a magnetic field, which induces an electromotive force either in the same circuit and opposing the current (self-inductance) or in another circuit (mutual inductance).	L	$i = \dfrac{V}{R}(1 - e^{-Rt/L})$ (i = instantaneous current, R = resistance, L = inductance, t = time, e = base of natural logs)	Henry	H
Magnetic field strength or intensity	Magnetic field strength is one of two ways that the intensity of a magnetic field can be expressed. A distinction is made between magnetic field strength H and magnetic flux density B.	H	$H = B/\mu_0$ (μ_0 being the magnetic permeability of space)	Amperes per metre	A/m (An older unit for magnetic field strength is the oersted: 1 A/m = 0.01257 oersted)
Magnetic flux	A measure of the strength of a magnetic field over a given area.	Φ (phi)	$\Phi = \mu HA$ (μ = magnetic permeability, H = magnetic field intensity, A = area)	Weber	Wb
Magnetic flux density	The density of magnetic flux, 1 tesla is equal to 1 weber per square metre. Also measured in Newton-metres per ampere (Nm/A).	B	$B = H/A$ $B = H \times \mu$ (μ = magnetic permeability of the substance, A = area)	Tesla	T

Circuit and electronic symbols

End of the Lesson ☺