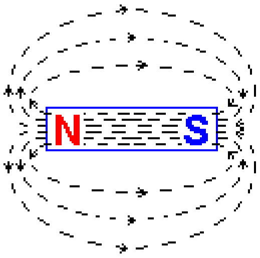
# Electro-magnetism

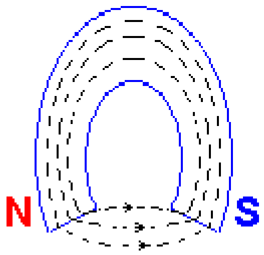
## Magnetic field

This is the area around a magnet or electromagnet where the effects of the magnetic force produced can be felt. Magnetism is represented by unseen lines of flux that form closed loops, as shown in the following diagrams. Some conventions must be remembered:

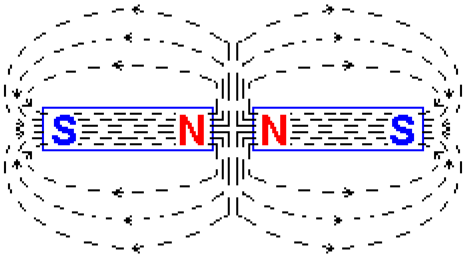
- Lines of flux cannot cross.
- Lines of flux flow externally from the north pole to the south pole.

Flux patterns for various arrangements of permanent magnets are shown below:



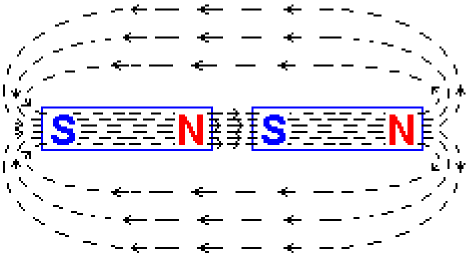




Two permanent magnets – north pole to north pole




Like poles repel.

Two permanent magnets – north pole to south pole



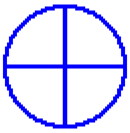

Unlike poles attract.

**Electro-magnetism**

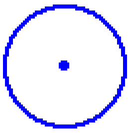
Electricity and magnetism are closely related.

An electrical current flowing through a conductor produces a magnetic field in the form shown below, around the conductor.

In order to help us to establish the direction of the magnetic fields around conductors, we must have a current direction convention, as shown below.



Current flowing into the conductor
(ie away from the observer)

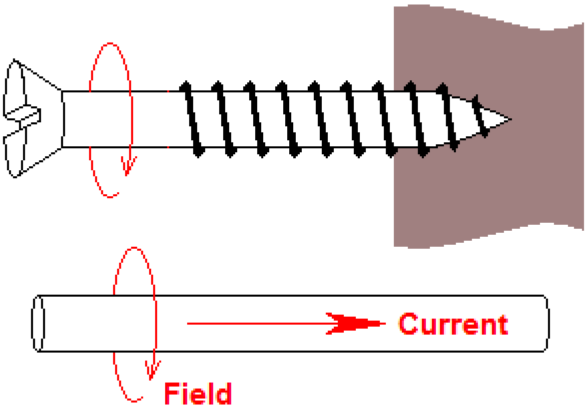


Current flowing out of the conductor
(ie towards the observer)

The direction of magnetic fields around cables can be found by using:

Maxwell's screw rule

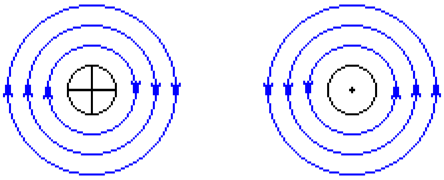
Maxwell's screw rule shows the relationship between the direction of the current flowing and the magnetic field produced by that current.



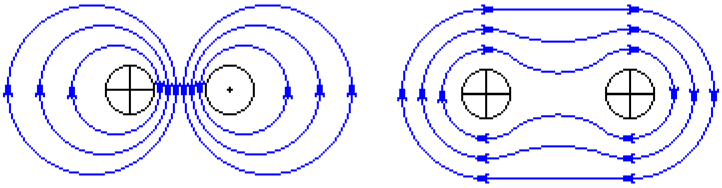

Imagine that you are driving a screw into the conductor in the direction of the current flow. The magnetic field produced by the current will form circular lines around the conductor, in the direction in which you have to drive the screw to advance it.

**Magnetic fields due to electric current**

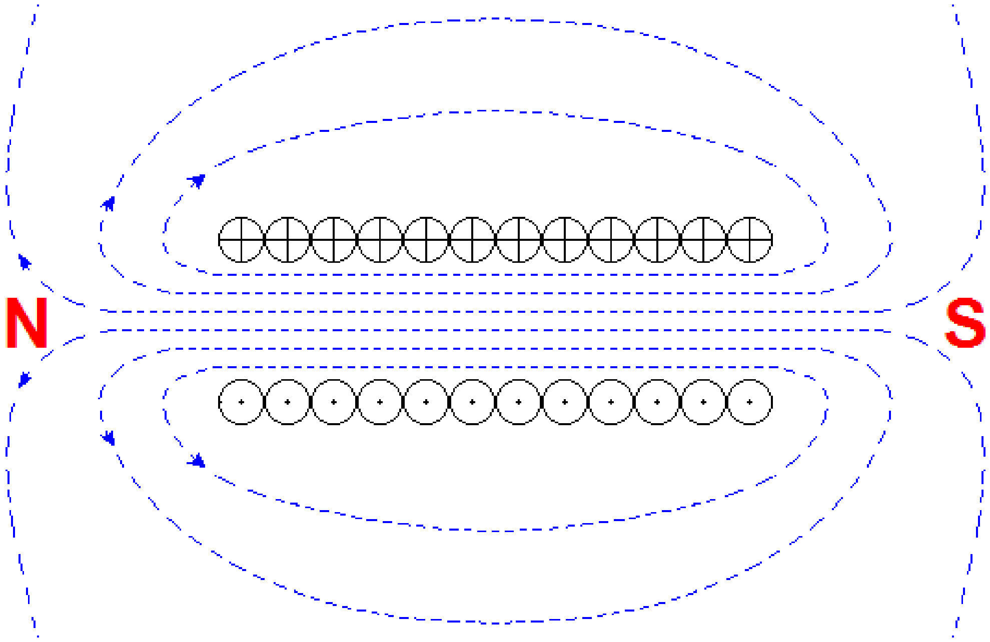
In straight conductors



In a flat coil



In a solenoid




Winding the conductors into a coil/solenoid increases the magnetic effect and produces a magnetic field similar to a bar magnet with north and south poles.

A solenoid is a coil wound into a tightly packed helix. In physics, the term solenoid refers to a long, thin loop of wire, often wrapped around a metallic core, which produces a magnetic field when an electric current is passed through it. Solenoids are important because they can create controlled magnetic fields and can be used as electromagnets. The term solenoid refers, specifically, to a coil designed to produce a uniform magnetic field in a volume of space.

A common use for a solenoid is in a relay (or contactor): an electrically operated switch. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits) or where several circuits must be controlled by one signal. The first relays were used in long-distance telegraph circuits, repeating the signal coming in from one circuit and retransmitting it to another.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor.

There are two quantities relating to magnetism with which we need to be familiar when considering electrical science. These are detailed below.

**Magnetic flux**
The number of magnetic lines of force set up in a magnetic circuit is called magnetic flux. It is comparable to electric current in an electric circuit.

The unit is the Weber (Wb) and it is denoted by the symbol **Φ** in formulae.

**Magnetic flux density**
Whilst the magnetic flux is a measure of how many lines of flux there are, it gives us no indication of how compacted or spread out these lines are. The closer the lines are concentrated, the stronger will be the effect of the magnetic field; flux density is a measure of how compacted these lines of flux are.

Flux density is a measure of the number of lines of flux passing through an area of 1$m^2$ and can be found by:

$$\text{Flux density, B} = \text{flux density (Weber)} \times \text{area } (\text{m}^2)$$

The unit for flux density is the tesla, abbreviated to T.

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