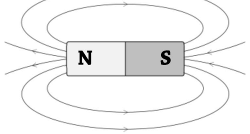
MAGNETISM

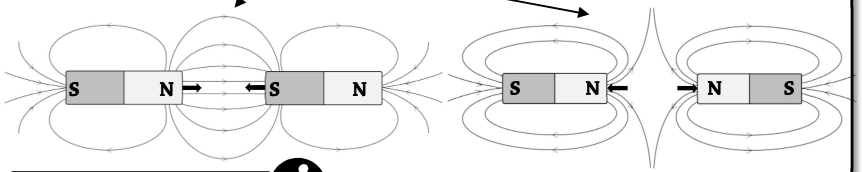
MAGNETS

A magnet is an object that generates its **own magnetic field**. The magnetic field lines start at the north pole (**N**) and loop around to the south pole (**S**) of the magnet.



NOTE
Any field is represented by field lines:
Arrows – give direction of field
Density of lines – give strength of field

When two magnets are brought near each other, their fields interact. Depending on which poles face each other, the magnets will either **attract** or **repel** each other.



NOTE
The force felt between two magnets is a **non-contact** force.

Some objects will constantly have their own magnetic field. These are called **permanent** magnets.

Other objects only gain their own magnetic field by being in the magnetic field of other magnets. These objects are called **induced** magnets and are typically **magnetic materials** which include iron, cobalt and nickel.

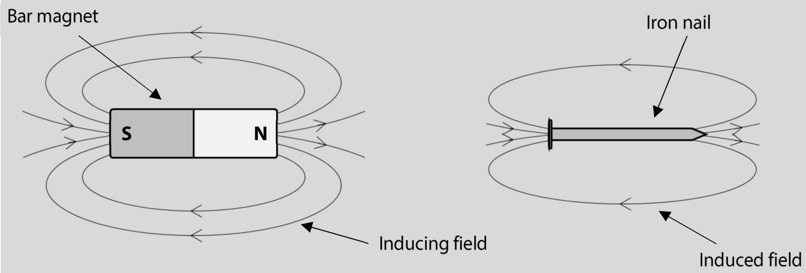
MAGNETIC FIELDS

A magnetic field is defined as the region around a magnet where another magnet or magnetic material experiences a force.

As mentioned above, magnetic fields are represented using field lines. The closer together the lines are, the stronger the field and, therefore, the larger the force. The strongest forces are, therefore, felt closest to the poles.

INDUCING A MAGNET

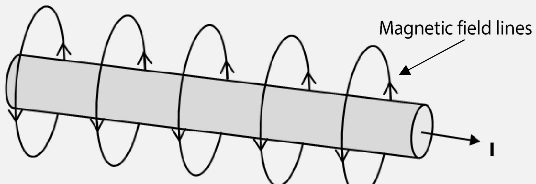
Bringing a magnet near a magnetic material, such as the bar magnet near the iron nail below, will induce a magnetic field in the magnetic material. This field will always result in an attractive force between the two objects.



Once the original magnetic field is removed, the induced magnet quickly loses its induced magnetic field.

ELECTROMAGNETISM

Electricity and magnetism are related. Together, they are called electromagnetism. An example of electricity and magnetism acting together is a wire carrying a current:

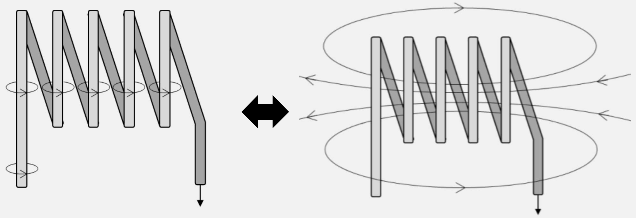


The moving electrons in the current create their own magnetic field. The result is a magnetic field around the current-carrying wire. The field is strongest closest to the wire and weakest far away from the wire.

The strength of the field also increases if the current increases. A magnetic object in the presence of a current-carrying wire will experience a force:

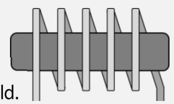
$$force \propto magnetic\ field\ strength \quad \begin{cases} \propto current \\ \propto \dfrac{1}{distance\ from\ wire} \end{cases}$$

The magnetic field strength can also be increased by wrapping the wire up into a coil. The magnetic field around each loop in the coil combines with those of the loops next to it, creating one big field:



This field looks like the field of a bar magnet (see left). A coil of current-carrying wire is known as a **solenoid**.

Placing an iron core within the solenoid induces a magnetic field in the iron, further increasing the resultant magnetic field.



This is known as an **electromagnet**. The magnetic field can be turned on/off by turning the current on/off.

FLEMING'S LEFT-HAND RULE

HT ONLY

As mentioned before, a current-carrying wire has its own magnetic field. If placed in the presence of another magnetic field (say next to a bar magnet), the wire and magnet will exert a force on each other. This is called the **motor effect**.

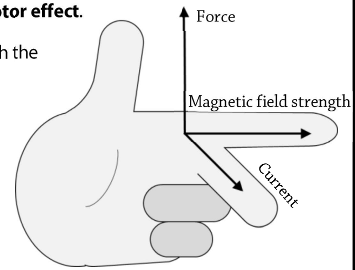
This force can be calculated with the equation

$$F = BIl$$

ES

Key
F – force (N)
B – magnetic field strength (T)
I – current (A)
l – length (m)

Force, magnetic field strength and current are all vector quantities.

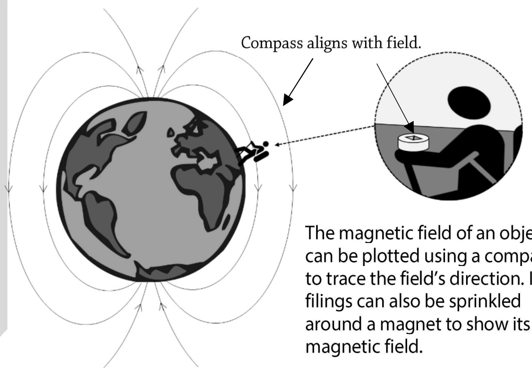


How to use:
Align two fingers / thumb in the direction of the two known quantities. The third finger / thumb points in the direction of the unknown quantity.

NOTE
Magnetic field strength is also called magnetic flux density. It's measured in units of teslas, T. Earth's magnetic field strength is $B_{Earth} \approx 4.5 \times 10^{-6}$ T.

EARTH'S MAGNETIC FIELD

Earth has its own magnetic field due to its iron core. A permanent magnet that is free to move in this field, i.e. a compass, will feel its south pole attracted to Earth's magnetic north pole (and vice versa). This is why compasses will always point north.



The magnetic field of an object can be plotted using a compass to trace the field's direction. Iron filings can also be sprinkled around a magnet to show its magnetic field.

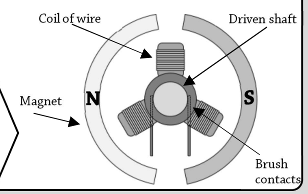
APPLICATIONS OF THE MOTOR EFFECT

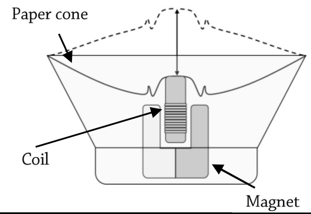
HT ONLY

All **electric motors** use the same principle:

A current-carrying wire in the presence of a magnetic field experiences a force that turns a shaft.

A current flows through the coil furthest to the left, causing it to generate its own magnetic field. This field opposes the field of the North Pole permanent magnet. A force is exerted on the coil pushing it away from the permanent magnet, turning the shaft. The coil now touches the other brush contact, causing the current to change direction, so now the field of the coil opposes the South Pole permanent magnet, and the process repeats. Three coils make the rotation of the shaft smoother.





A **loudspeaker** also uses the motor effect. An alternating current is sent through a coil attached to a paper cone. The coil is positioned within the magnetic field of a permanent magnet. The coil and cone therefore experience a force due to the current, so the size and frequency of the alternating current match the size and frequency of the cone's movement.