All moving charges create a magnetic field. If the charge is moving at right angles to the flux lines of a fixed magnetic field then the field it creates interacts strongly with the fixed magnetic field and the charge experiences a maximum motor effect force.

When a **moving** charge is placed in a magnetic field, it may experience a force.

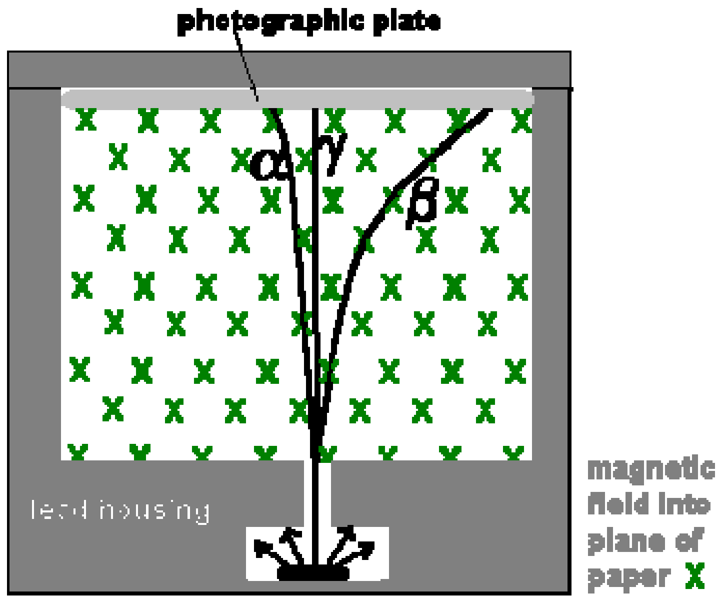
The maximum force it experiences is when it is travelling at right angles to the flux lines. When it is parallel to them it is zero. The relationship can be determined by the sine of the angle the velocity of the particle makes with the flux lines. (When the angle is zero (parallel) then force is zero as sin 0^o = 0 and it is maximum when angle is 90^o sin 90^o = 1)

The **size of the force** can be increased by:

. increasing the strength of the magnetic field it experiences;

. increasing the size of the charge on the particle.

. decreasing the mass of the particle.



radioactive source emitting alpha, beta and gamma rays

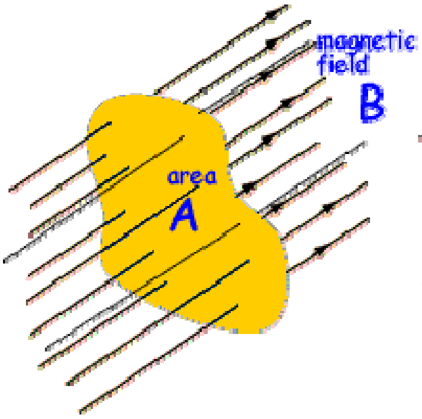
You can use FLHR to check that the particles have been moved in the correct direction.

Remember that the second finger represents the current - this is the finger that has to point in the direction of the velocity vector of positive charge movement. If you have a negative charge it has to point in the opposite direction to the velocity vector of that particle!

Note that the bigger mass of the alpha particle outweighs the bigger charge factor. This makes it change direction less than the beta particle... the force has less effect. The gamma is unaffected as it has no charge!

	Symbol	Unit	Unit equivalent
Magnetic Flux	ϕ	Wb (weber)	V s
Magnetic Field (or magnetic flux density)	B	T (tesla)	Wb m^{-2} or V s/m^2

Magnetic fields surround and are created by electric currents, magnetic dipoles, and changing electric fields. A magnetic field is a **vector field** that permeates space. It can exert a **magnetic force** on moving electric charges and on magnetic dipoles (such as permanent magnets).



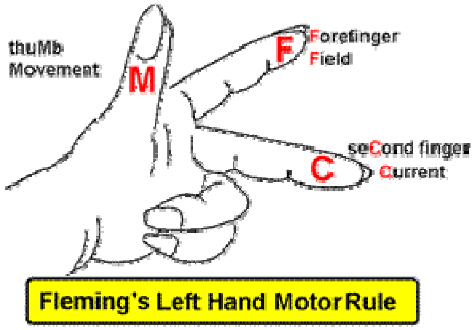
When placed in a magnetic field, fixed magnets (magnetic dipoles) tend to align their axes to be parallel with the magnetic field. That is why iron filings line up to show the field lines when sprinkled around a magnet. They become little tiny magnets are line up - axes parallel to the field lines from the permanent magnet.

A changing magnetic field can induce an electric field - electromagnetic induction.

Magnetic Fields are formed around **moving charges** (and therefore around current carrying wires - as they have a net movement of charge!).

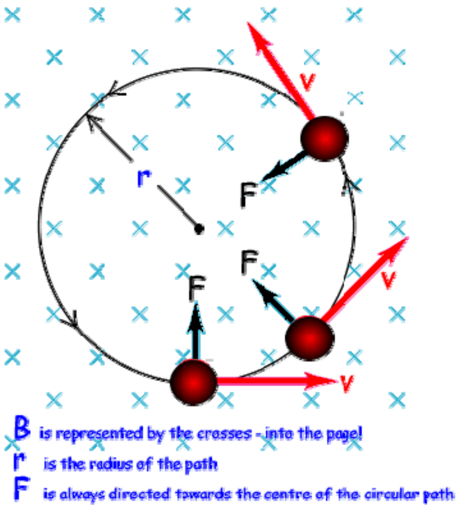
The **field lines show the direction a plotting compass would point** if placed at that point in the field. They always form complete loops (unless they start and finish on a magnet - then the domains inside the magnetic material would complete the loop) and they NEVER cross.

Magnetic fields have an effect on **moving** charges at right angles to them - and only **moving**charges produce magnetic fields.



If the charge you are dealing with is NOT at right angles to the field you will have to find out the velocity vector that is at right angles to the field .

The force the charge experiences is at right angles to its velocity (i.e. in another plane) and at right angles to the field lines (the three are mutually at right angles to each other) ... you use Flemming's Left Hand Motor Rule to find out how the charge is affected by a field.



The thumb points in the direction that the charged particle will experience a force towards.

- The **forefinger** points in the direction of the field.
- The **second finger** points in the direction of conventional current (points in the direction the charged particle is travelling IF IT IS POSITIVE!!).

If you are looking at the effect on an electron you have to have the second finger pointing in the opposite direction to its velocity...

$$F = qvB$$

where

- B = the magnetic field's flux density
- v = velocity of the charged particle
- q = the charge on the charged particle

If a charge enters a **uniform field** it will therefore experience a **constant force** at right angles to its velocity - making it move in a circle.

F (magnetic) becomes F (centripetal)

So **$qvB = mv^2/r$**

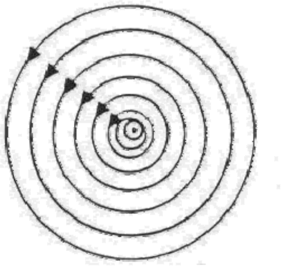
Rearranging we get that $r = (mv)/(qB) = p/(qB)$

This means that:

- the **faster it is travelling** the bigger the circles it will make
- also the bigger its **mass** is the bigger the radius of those circles

So, the bigger its **momentum** the less effect the field will have on its motion

- increase the **strength of the field** and you'll have more effect on its motion (smaller circles),
- increase its **charge** and you'll have more affect on its motion too.

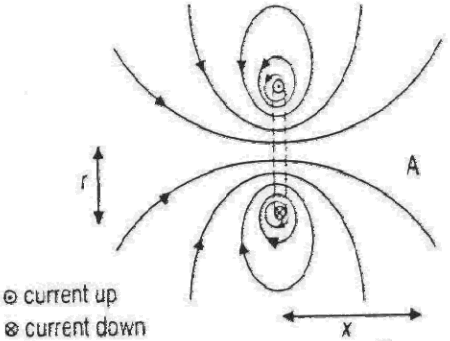


Magnetic Field for a long straight wire

Field close to wire a distance r from it

$$B = \frac{\mu_0 I}{2\pi r}$$

Close to the wire the circles of the field lines are virtually uniformly spaced but they do get further apart when you get further away...



Field at centre

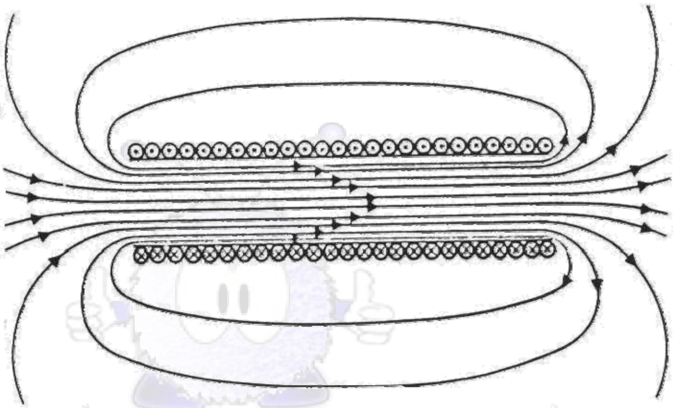
$$B = \frac{\mu_0 I N}{2r}$$

Field at A

$$B = \frac{\mu_0 I N}{2} \frac{r^2}{(r^2 + x^2)^{3/2}}$$

Magnetic Field for a flat circular coil

Solenoids are useful to the physicist as you can perform experiments within a uniform magnetic field and know it's value too by setting the current to give you the field you require.



Uniform field within solenoid

$B = \mu_0 n I$

n = number of turns per unit length

Magnetic Field for a solenoid (a long helical coil)