Force on a current carrying wire

To be able to calculate the size of the force on the wire
To be able to explain why a wire with a current flowing through it will experience a force
To be able to state the direction of the force on the wire

We will be looking at the force a current carrying wire experiences when it is in a magnetic field. Before we look into the size and direction of the force we need to establish some basics.

Conventional Current

We know that the current flowing in a circuit is due to the negative electrons flowing from the negative terminal of a battery to the positive terminal.

Negative to Positive is the flow of electrons

Before the discovery of the electron scientist thought that the current flowed from the positive terminal to the negative one. By the time the electron was discovered many laws had been established to explain the world around them using current as flowing from positive to negative.

Positive to Negative is the Conventional Current

Magnetic Field Lines

We are familiar with the shape of a magnetic field around a bar magnet. Magnetic field lines leave the North Pole of the magnet and enter the South Pole. The poles of a magnet are stronger than the side because there are more field lines in the same area of space.

Magnetic field lines go from North to South

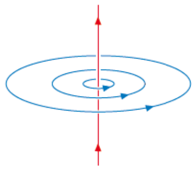
A 3D Problem

We will be looking at movement, fields and currents in 3D but our page is only 2D. To solve this problem we will use the following notation: A dot means coming out of the page and a cross means going into the page. Imagine an arrow fired from a bow, pointy end means it's coming towards you, cross means its moving away.

⊙ out of the page, ⊗ into the page

Current Carrying Wires

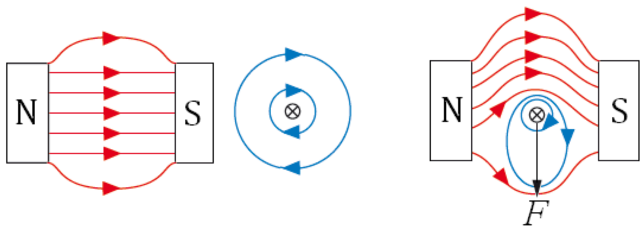
When a current flows through a straight piece of wire it creates a circular magnetic field. The Right Hand Grip Rule shows us the direction of the magnetic field. If we use our right hand and do a thumbs up the thumb is the direction of the conventional current and the fingers point the direction of the field lines.



Right hand thumbs up

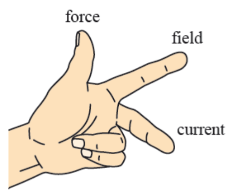
Force on a Current Carrying Wire

When a wire is placed between a North and South Pole (in a magnetic field), nothing happens.
When a (conventional) current flows through the wire it experiences a force due to the magnetic fields of the magnet and the wire. If we look at the diagram we can see that the magnetic field lines above are more compact than below. This forces the wire downwards.



Fleming's Left Hand Rule

This rule links the directions of the force, magnetic field and conventional current which are all at right angles to each other. Your first finger points from North to South, your middle finger points from positive to negative and your thumb points in the direction of the force.



Size of the Force

The size of the force on a wire of length l, carrying a current I placed in a magnetic field of magnetic flux density B is given by the equation:

$$\boxed{F = BIl}$$

Here the wire is at 90° to the magnetic field lines.
When the wire is at an angle of θ with the magnetic field the force is given by:

$$\boxed{F = BIl\sin\theta}$$

If we rearrange the equation to $B = \frac{F}{Il}$ we see that 1 Tesla is the magnetic flux density (field strength) that causes a 1 Newton force to act on 1 metre of wire carrying 1 Amp of current.

Magnetic Flux Density is measured in Tesla, T

This equation looks very familiar if we compare it to the force in a gravitational and electric field.

$$F = m.g \qquad F = q.E \qquad F = Il.B$$