Chapter 5 Physics

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1 Chapter 5.1

1.1 Charge

Charge is measured in coulombs, C. All protons have a charge of where ϵ represents the permittivity of the medium. The general equation for the force between two charges in a medium is:

$$F = \frac{q_1 q_2}{4\pi\epsilon_0\epsilon_r r^2}$$

1.2 Electric Current

Charged particles can be made to flow to transfer useful energy. The flow of charge is an electric current.

2 Chapter 5.2

All electric currents produce a magnetic field around them. The ends of a magnet that point to north are called north (seeking) poles, and the other end was the south (seeking) pole.

The most simple magnets are dipole magnets, which have a north and a south pole. **because electric currents are a flow of moving charge, all electric currents have magnetic fields around them**.

Magnetic fields can be represented using field lines, where the lines go from magnetic north to magnetic south. The field is strongest where the field lines are drawn closer together, however these lines never cross.

2.1 Fields in a straight line and in a solenoid

The field produced by a current flowing in a straight line can be determined by the right hand rule.

When a coil of wire is wrapped so that the turns do not overlap, and the wire is significantly longer than it is wide, it is said to be a **solenoid magnet**. Solenoids produce strong, uniform magnetic fields inside them.

Reversing the direction of current in the solenoid would reverse the polarity of the magnetic field. The strength of the magnetic field can be increased by:

- increasing the current in the wire
- increasing the number of coils in the wire

- using a meterial with a higher magnetic permeability, which is defined as the ability of a medium to transfer a magnetic field. (This can be compared to the electric permittivity)

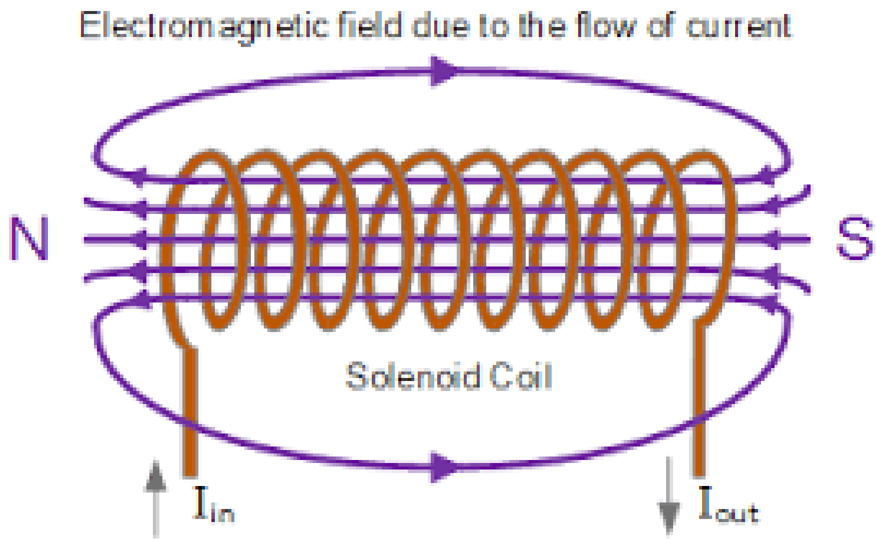

Figure 1: Strong uniform field

2.2 Magnetic Force

When a current is passing through a lightweight flexible conductor in a strong magnetic field, the conductor will experience a force.

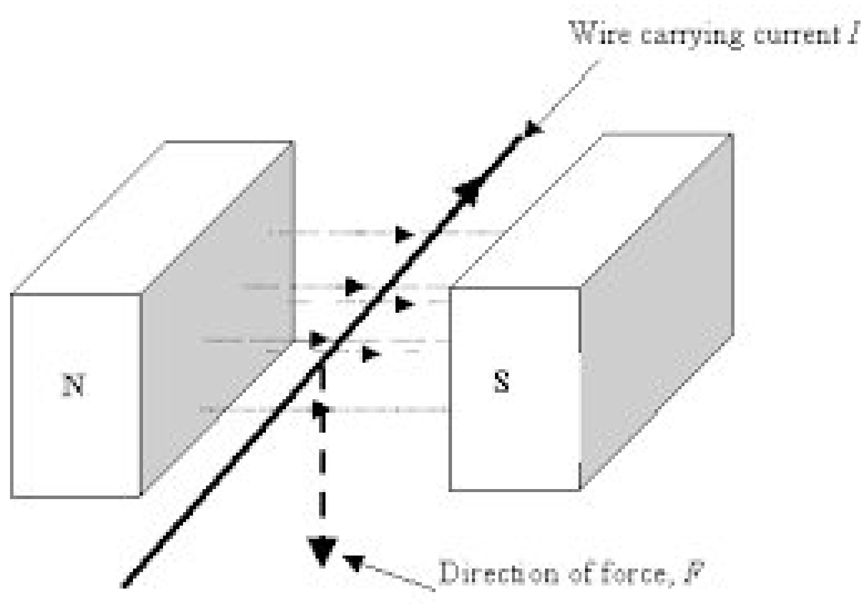

Figure 2: Current carrying wire through a magnetic field

Above the wire, the magnetic field from the bar magnet and the charge carriers in the wire act in different directions, and combine to produce a weaker field. The fields below the wire act in the same direction, and combine to produce a stronger magnetic field. The difference in field strength causes the wire to move downwards.

In order for there to be a force, the wire must pass **across** the magnetic field. If the current flows in the same direction as the magnetic field, there will be no force on the wire.

The direction of the force acting upon the wire can be predicted using Fleming's left hand rule.

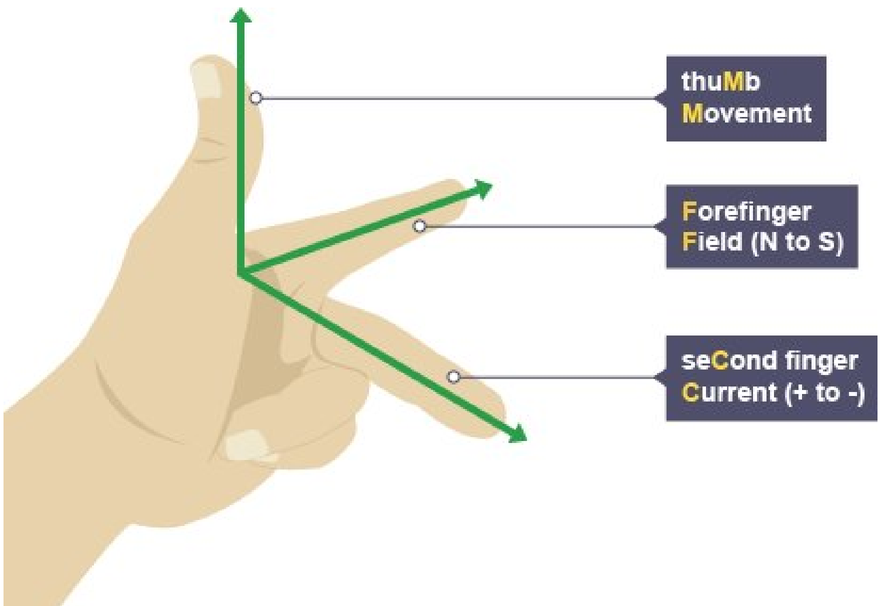

Figure 3: Fleming's left hand rule

2.3 Magnetic Field Strength and forces on individual charges

Following on from electric field strength and gravitational field strength, it would be reasonable that the magnetic field strength is magnetic force divided by charge. However, the size of the magnetic field is also related to the length of the wire in the field, and its direction in terms of θ.

Magnetic field strength is also called magnetic flux density. The units for magnetic field strength is $NA^{-1}m^{-1}$. The unit given to it is the **tesla**.
The equation for magnetic field strength is:

$$B = \frac{F}{ILsin\theta}$$
$$F = BILsin\theta$$

The forces that act on the wire are acting on the moving charges within them. The force on a wire is just the sum of the force on each current. A charge moving distance X $\rightarrow Y, inatimet, atadistanceL. F = BILsin\theta$
$L = vt$
$I = \frac{q}{t}$

therefore by cancelling the 't's
$F = Bevsin\theta$

2.4 Direction of magnetic forces of charged particles

Any charged particle moving across a magnetic field will experience a force that is perpendicular to its instantaneous velocity. The direction of the force can be predicted by its left hand rule **(remembering that the direction of current is the direction a proton would move in)**.

A force that is perpendicular to its instantaneous velocity is a condition of circular motion.
Therefore, any charged particle that moves perpendicularly across a magnetic field will experience circular motion.
if the centripetal force for circular motion is $\frac{mv^2}{r}$, and the force for a charged particle is moving through a magnetic field is qvB, these two can be equated to each other:

$$
\begin{aligned}
Bevsin\theta =& \frac{mv^2}{r} \\
Be =& \frac{mv}{r} && \text{(remembering that } \sin(90) = 1\text{, and dividing by } v\text{)} \\
r =& \frac{mv}{qB} && \textit{(NOT in data book)}
\end{aligned}
$$

This equation shows that for a given mass, charge, and magnetic field strength, the radius of the particle is proportional to its speed, v.
A charge that loses kinetic energy and velocity (due to collisions with other particles) will 'spiral' inwards.