Magnetism - General Properties

A magnet, when suspended from a string, will align itself along the north - south direction.

Two like poles of a magnet will repel each other, while opposite poles will attract.

Earth is a giant magnet.

Magnets are attracted to metal objects. Either end of the magnet will attract metal.

Magnets will polarize metal, so that when in contact, the metal will become a magnet too.

Magnets exist with dual poles.

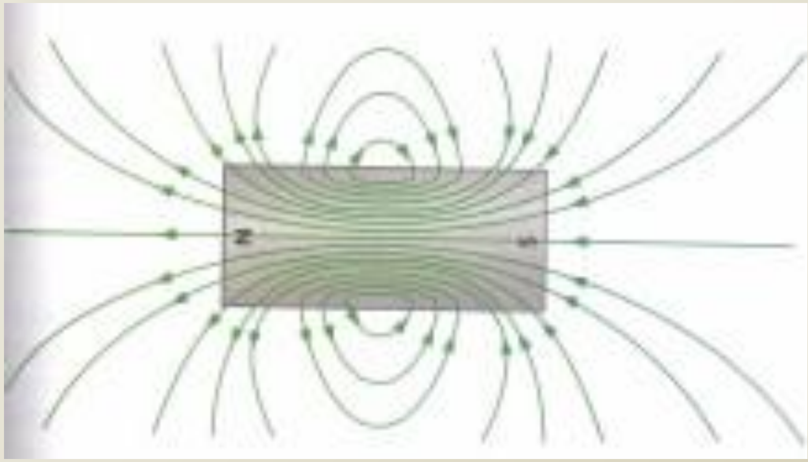
Permanent magnets are typically made of ALNICO.

Magnetic Fields

Forces between magnets exist, either attractive or repulsive.

It is possible to use magnetic fields to show the forces.

Magnetic field lines come out of the N-pole and return to the S-pole, and form a loop.



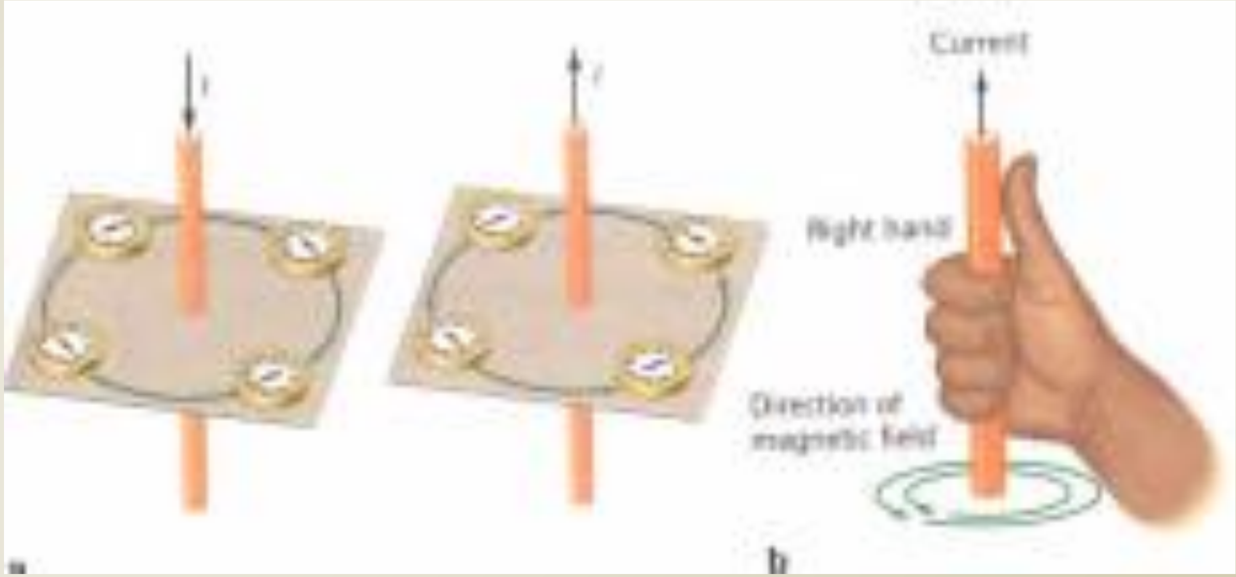
Electromagnetism

Oersted discovered that an electric current, running through a wire, when the wire is laid over a compass, will repel the needle of the compass. The needle ended up perpendicular to the current flow in the wire.

When current runs through a wire, iron filings will align themselves in concentric circles around the wire. Thus, the current produces a magnetic field in closed loops around the wire.

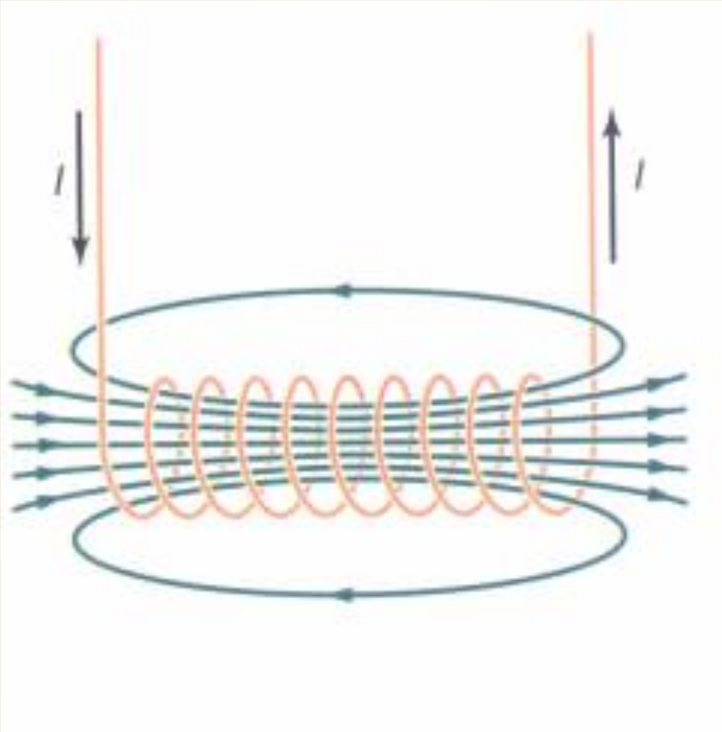
First Right Hand Rule

First Right Hand Rule - Grasp wire with right hand. Place thumb pointing in current direction. Your fingers then point in the direction of the magnetic field.



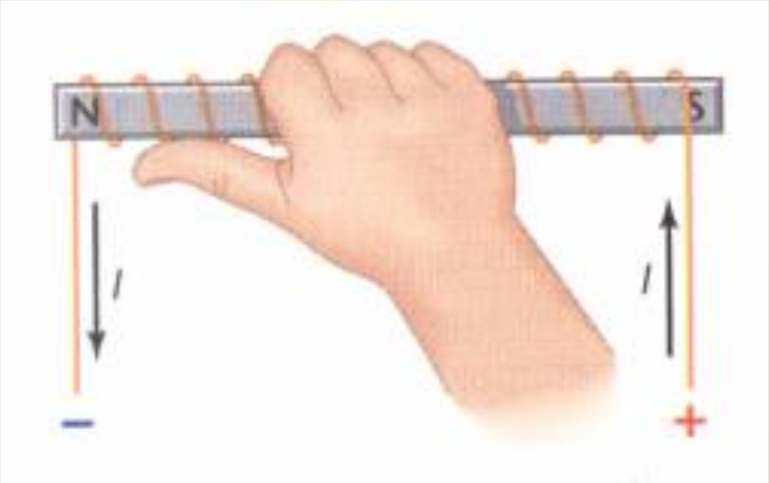
Electric Coils

When electric current flows in a coil wrapped around a metal object, the metal then acts like a permanent magnet. If allowed to rotate, the new magnet will align itself to the N/S poles.



Second Right Hand Rule

Second Right Hand Rule - Grasp coil with the right hand. Curl your fingers around the loop in the direction of the current. Your thumb points to the North pole of the magnet.

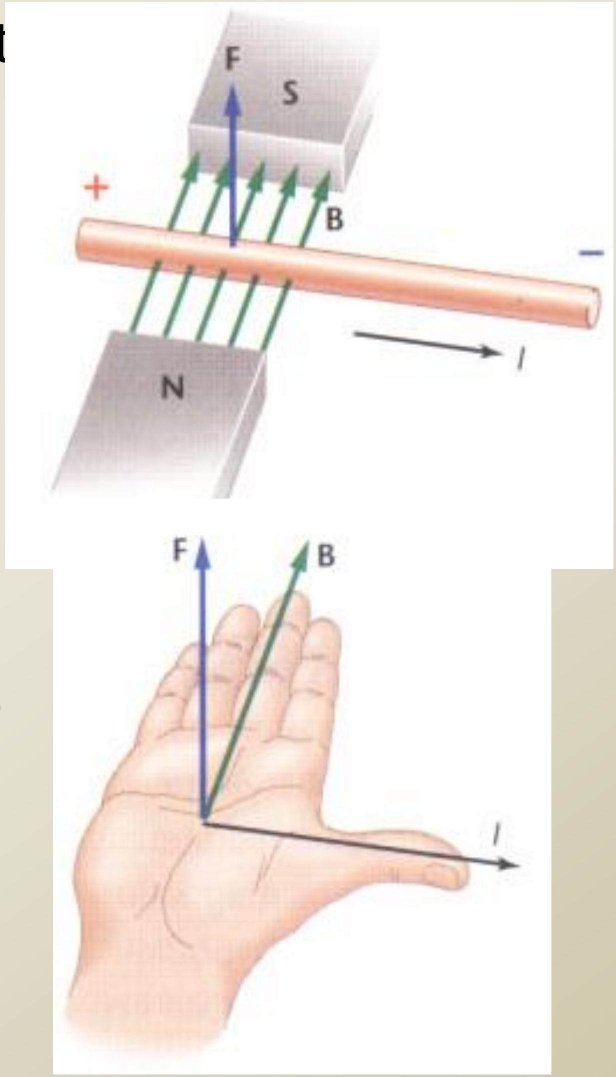


Force due to magnetic field

When a wire with an electric current is put between two different poles of a magnet, the wire will move. We can predict the direction of this force by using the:

Third Right-Hand Rule: Point your fingers of your right hand in the direction of the magnetic field. Point your thumb in the direction of the current. The direction that your palm is pointing is the direction of the force.

The direction of the force is always perpendicular to the magnetic field.



Calculating Magnetic Field Size

It is possible to calculate this force. Experiments show that the force depends on the strength of the magnetic field (B), the current in the wire (I) and the length of the wire that lies in the magnetic field (L), or:

$$F = BIL$$

We can measure force, current and length, but not B, so we can use the following formula to get B:

$$B = F/IL$$

The strength of the field is called magnetic induction, which has a symbol T (Tesla).

How do magnets work?

Ampere proposed an idea.

1) Electrons act as tiny electromagnets.

2) The magnetic fields of electrons can add together. Many millions together constitute a domain.

3) Each domain has its own direction for its magnetic field. When the metal is not in a magnetic field, the domains point in all directions, canceling each other out.

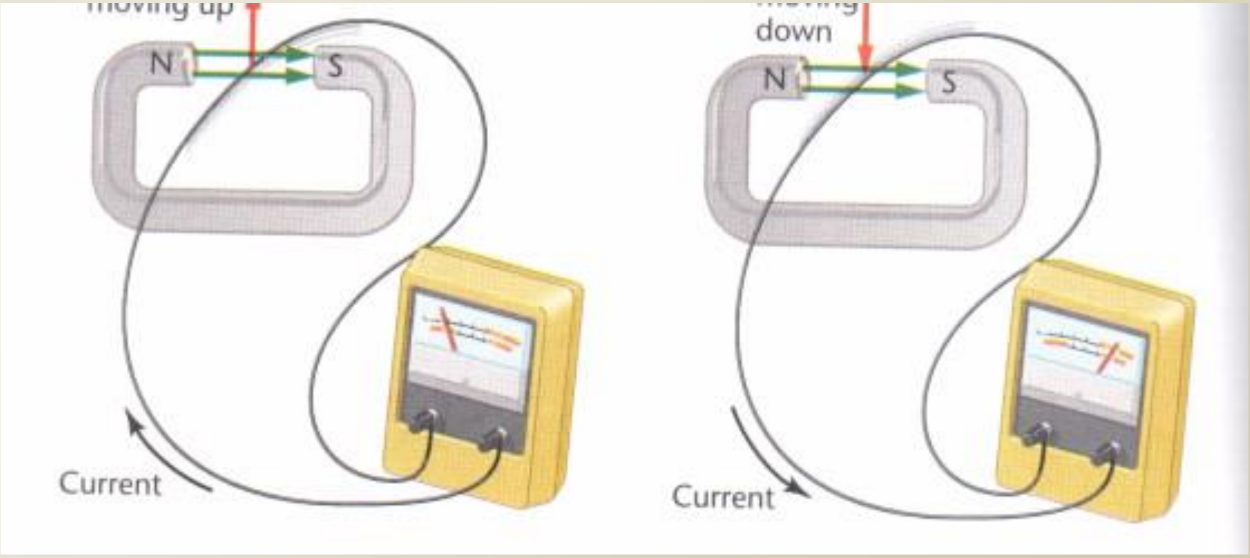
4) When in a magnetic field, the domains line up, so that they point in the same direction of the magnetic field.

Electromagnetic Induction

Oersted discovered that electricity deflects a compass, thereby causing a magnetic field. Faraday worked to determine if magnetism could cause electricity.

Faraday discovered that it was possible to produce a current from a magnetic field.

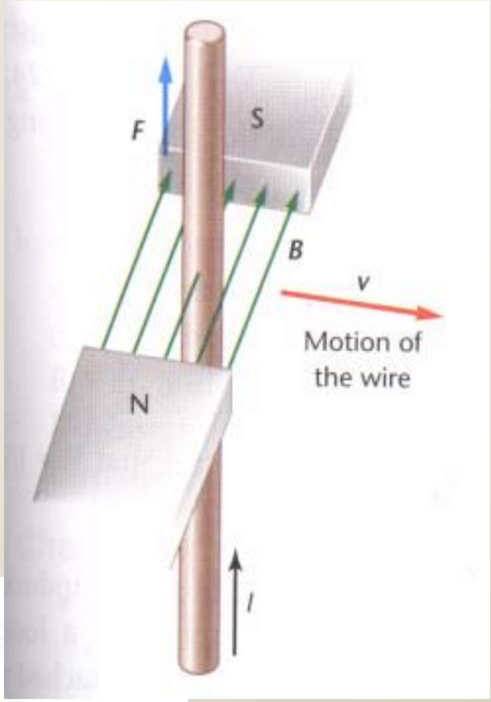
To generate a current, you must move a conductor in relation to a magnetic field.

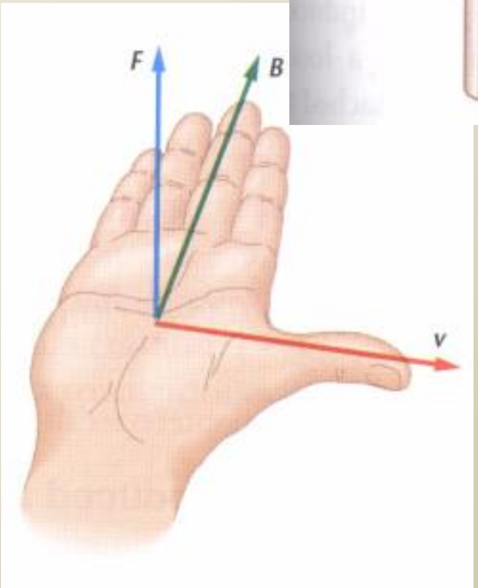


Fourth Right Hand Rule

To determine the direction of the current, we use a Fourth Right Hand Rule:

Hold your right hand so that your thumb points in the direction the wire is moving, and your fingers point in the direction of the magnetic field. The direction your palm is pointed is the direction in which the current is moving.





Electromotive Force (EMF)

When a wire is moved in a magnetic field, there is a force applied to the charges in the wire. This force separates the charges, causing a potential difference (voltage). This potential difference is called the induced EMF. The EMF will cause a current to flow.

The EMF depends on the magnetic field (B), the length of the wire (L) and the speed the wire is pulled through the field (V):

$$EMF = BLv$$

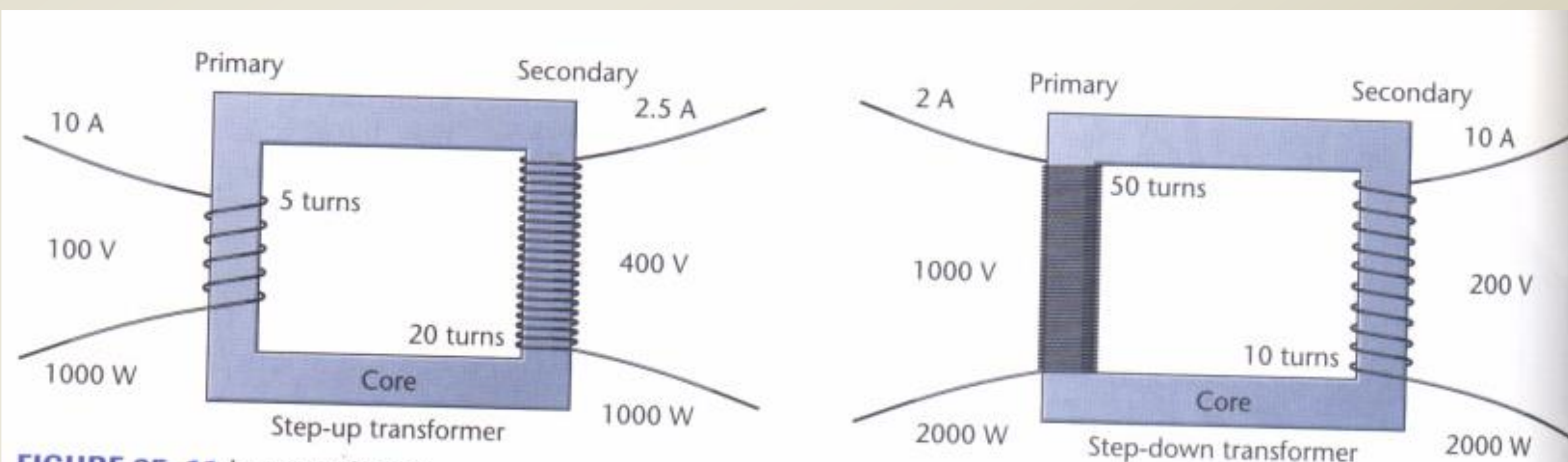
Generators and Motors

- A generator is a device that moves a coil of wire in a magnetic field. Generators usually turn a coil of wire in the magnetic field, pulling the charges and separating them, causing a potential difference that induces a current.
- A motor is a device that works in the opposite way. Current through a wire causes a magnetic field that allows the magnets in the motor to be attracted/repelled. This causes motion.

Transformers

A transformer is used to increase and decrease the amount of voltage and current in a system. The power does not change.

A transformer is made of two coils wrapped around the same iron core. The primary coil has an AC current running through it. This changing current varies the magnetic field. The varying magnetic field induces a current in the coil at the other end of the core.



Transformers

The proportion of coils determines the voltage and the current through the secondary.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \text{and} \quad \frac{I_s}{I_p} = \frac{V_p}{V_s}$$