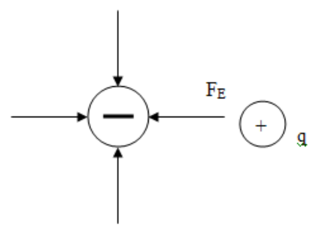
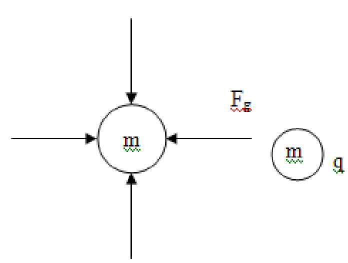
Lesson 1
Magnetism

Recall other fields studied in this unit.

Electric Field:



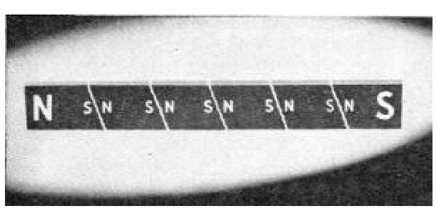
Gravitational Field:



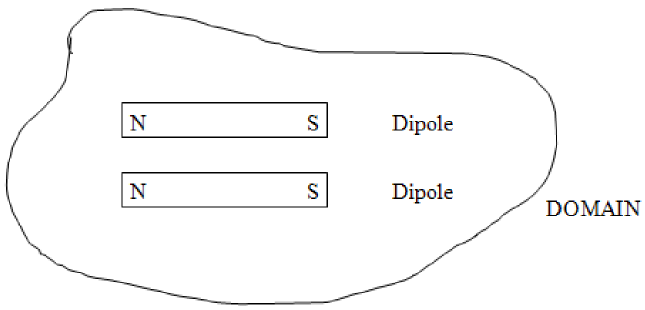
- Magnetic fields occur naturally in substances that have a magnetic character, such as iron, nickel and cobalt.
- Ancient Greeks discovered magnetic forces by observing the magnetic effects of rock they called lodestone. Chemical analysis has shown that lodestone gets its magnetic properties from the presence of an oxide of iron (Fe_3O_4), known today as magnetite.
- The term "magnetism" comes from Magnesia, a Greek province where this material was found.
- Magnetic character is created from within the matter, not just from the presence of matter as in a gravitational field, where gravity is created by the presence of mass.
- Magnetic forces are more versatile than gravitational or electric since they can affect magnetic substances as well as electric charges (more on this later).

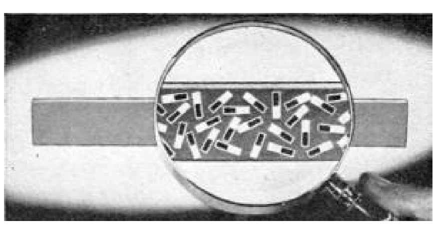
Domain Theory

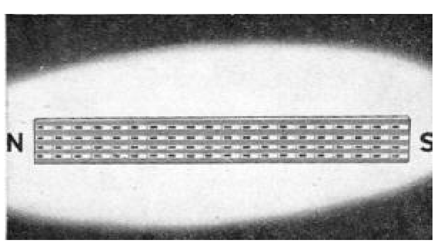
- In magnetic materials there are two opposite magnetic elements (i.e. north and south poles) neither of which can exist without the other.
- North seeking pole is the name given to the end of a magnet that points towards the north pole.
- No matter how often a bar magnet is broken into pieces, each piece is a complete magnet with a north and south pole.



- These N-S pole pairs are referred to as magnetic dipoles. Several dipoles aligned together are referred to as a domain.
- Domain theory states that if magnetic dipoles within a magnetic material all line up in the same direction, then a larger magnetic domain is produced.

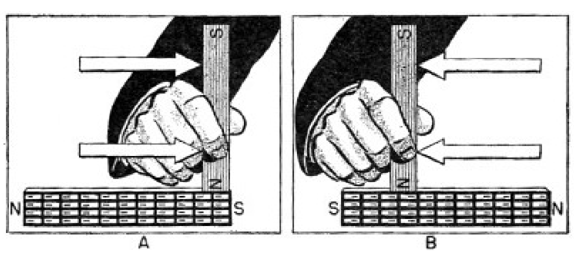






Ferromagnetic Material:
Materials that are made of domains that can be readily aligned to create a larger object of magnetic character. When a ferromagnetic material is placed in a field, the lines of the field find it easier to pass through the material than the space surrounding the material. (Ferromagnetic materials have a high magnetic permeability). Ferromagnetic materials are so permeable that they react well even in very weak external magnetic fields. Some examples of ferromagnetic materials are iron, nickel, cobalt.

Magnetic Induction:
When the domains of a material are randomly oriented, the material shows no permanent magnetism. Introducing an external magnet can induce the domains to become aligned with that of the external magnet. The material will then become a temporary magnet (eg. iron). When the external magnet is removed, the domains return to their random orientations and the magnetism disappears.



Permanent and Temporary Magnetism:
In some materials like steel, it is difficult to re-orient the domains. This material will retain its magnetic properties. These types of materials form permanent magnets.

Demagnetization:
Ferromagnetic materials can lose their magnetic strength. Domains can lose their alignment over time thereby weakening the magnet. Even permanent magnets can be weakened. If a magnet is heated its strength weakens but it will generally return when the magnet cools. However if a magnet is heated above a certain temperature called the Curie point, the magnet will be destroyed.

Material	Curie Point (°C)
Iron	770
Cobalt	1131
Nickel	358

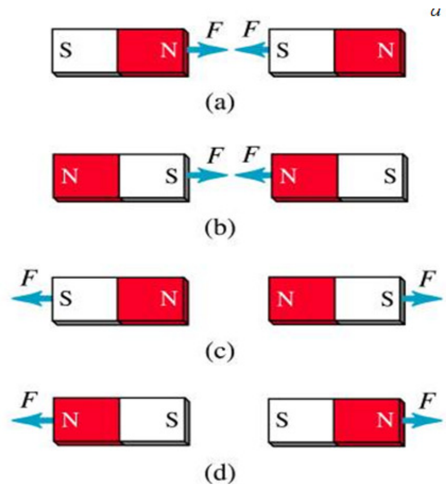
Reverse Magnetization:
A magnet's polarity can be reversed. If the magnet is placed in a large external magnetic field, the domains can reverse over time.

Breaking a Magnet:
If a magnet is broken, each piece of the broken magnet still maintains its aligned domains.

Maximum Strength:
There is a limit to how strong an individual magnet can be. Once all the domains are aligned, the magnet's strength cannot be increased any further.

Law of Magnetic Forces:

- Like poles repel each other.
- Unlike poles attract each other.
- The force of attraction varies inversely as the square of the distance between the poles ($F\alpha\frac{1}{d^2}$).



Magnetic Force is an example of a force that acts at a distance (as were the gravitational and electric forces).

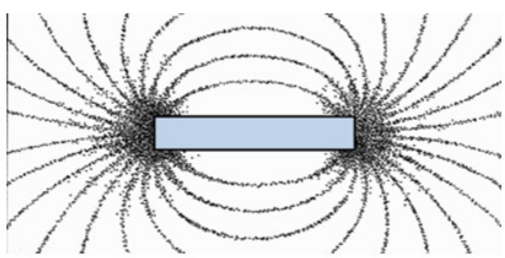
Recall:

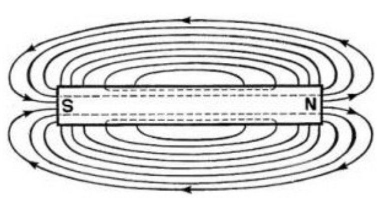
- Gravitational Field (direction a 1.0 kg mass would take if placed in the field).
- Electric Field (direction a positive test charge would take if placed in the field).

What kind of definition is used for what happens in a magnetic field?

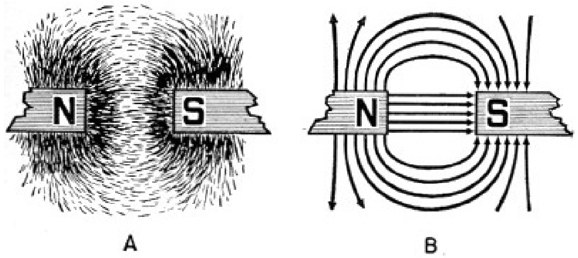
Mapping Magnetic Fields:
To map a magnetic field a test compass is used. The direction of a magnetic field is defined as the direction in which the north pole of a test compass would point when placed at that location in the field.

1. **Single Bar Magnet**

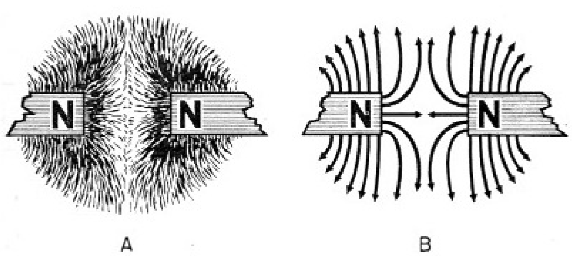




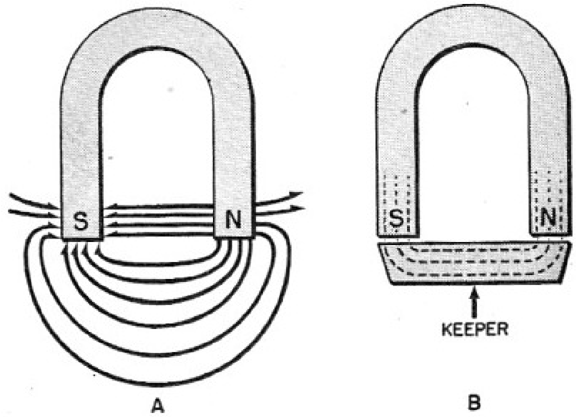
2. Opposite Poles



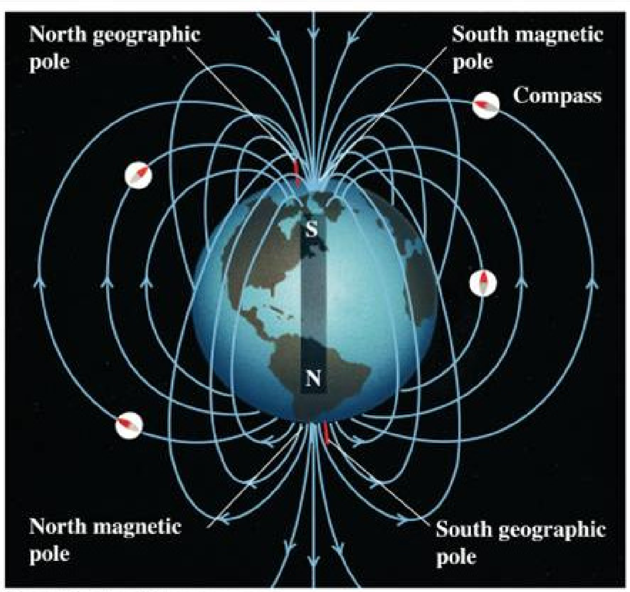
3. Like Poles



4. Horseshoe magnet



5. Earth's magnetic field



It is believed that Earth's magnetic field is created by the flowing motion of hot liquid metals under the Earth's crust. Earth is enveloped by a magnetic field called the magnetosphere that extends far into space.

Notice that the north geographic pole is actually a south magnetic pole (so field lines go into the north geographic). Earth's magnetic field has reversed over the years (see p. 632).

Earth's magnetic poles do not coincide with the geographic poles (which are on Earth's axis of rotation). South magnetic pole for example, is about 1300 km from the north geographic. This must be taken into account when using a compass.

Magnetic Declination:
Angular difference between magnetic north and true (geographic) north.

Notice that magnetic field lines are parallel to Earth at the equator and perpendicular to it at the poles.