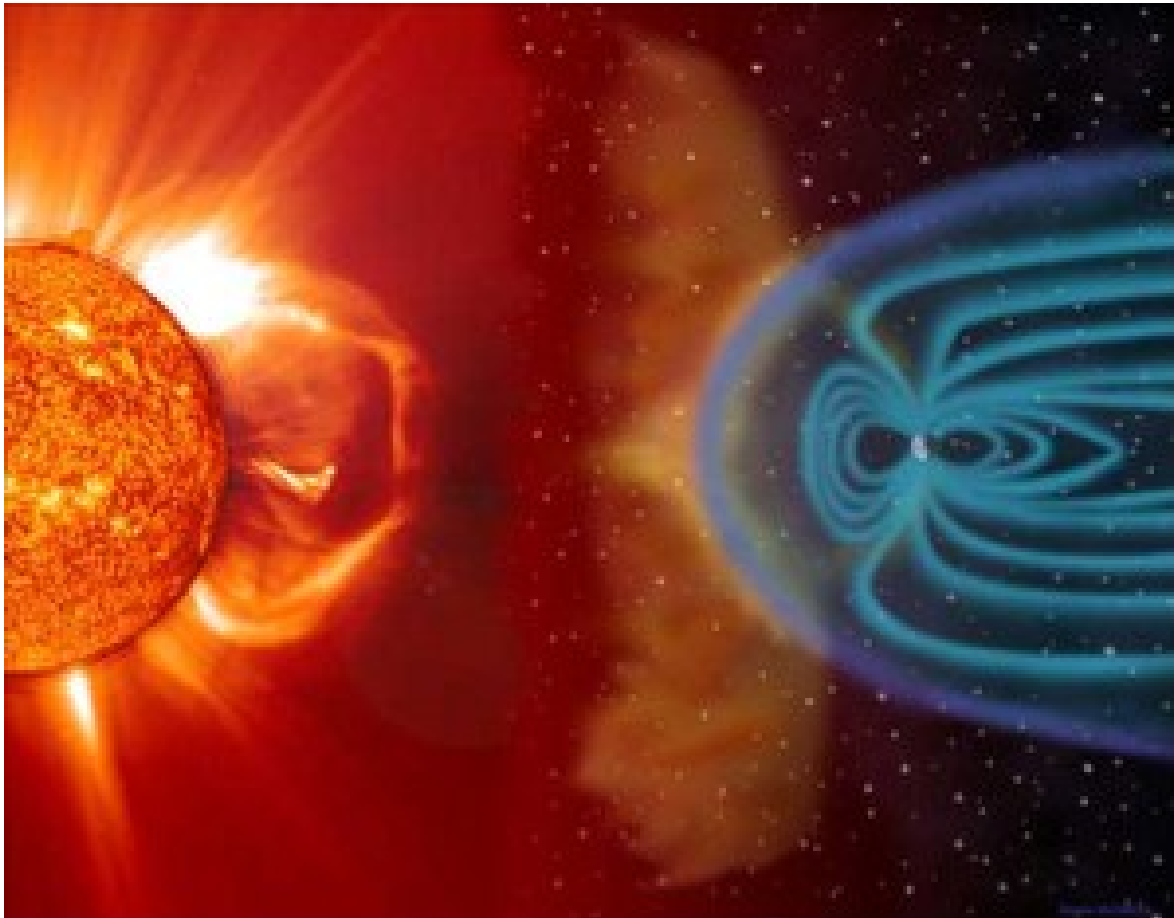
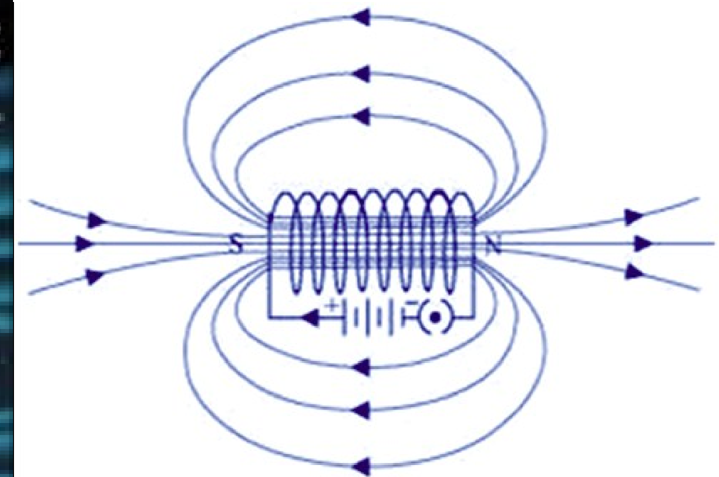
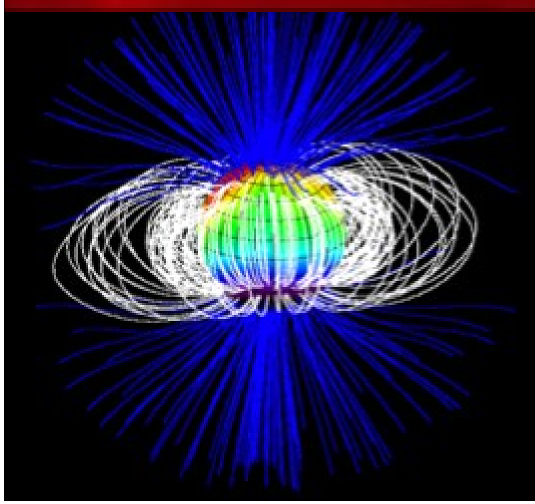
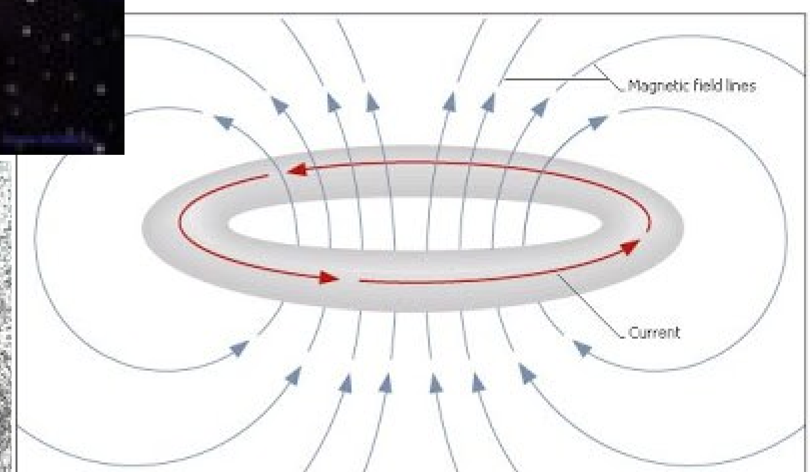




Magnetism

Schay G.





Magnetic Fields and Electricity

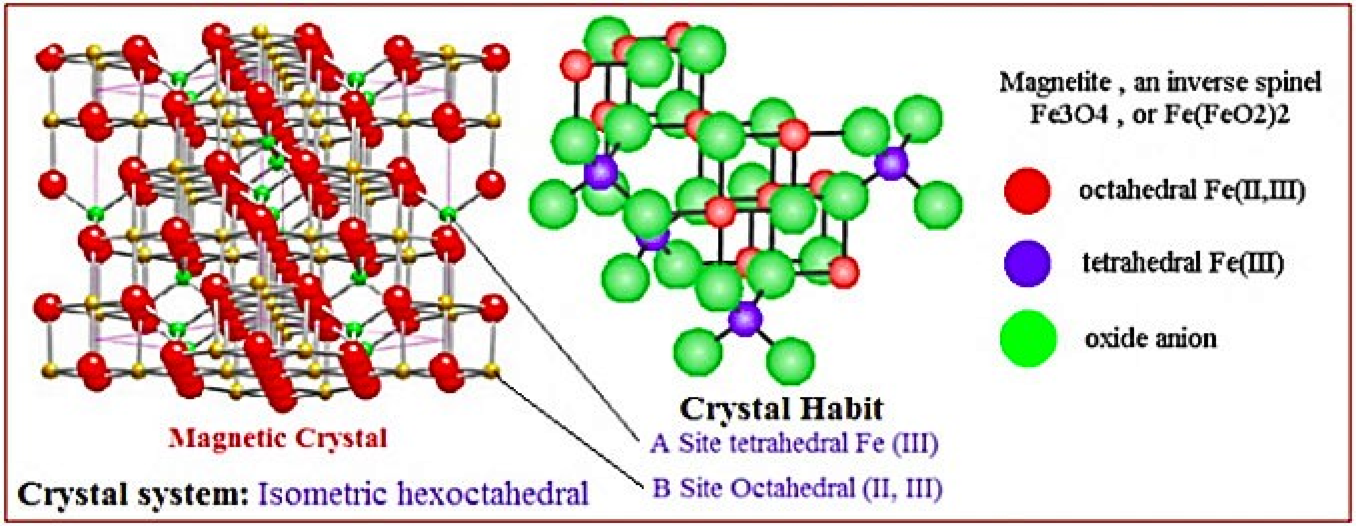
Hans Christian Oersted predicted in 1813 that a connection would be found between electricity and magnetism. In 1819 he placed a compass near a current-carrying wire and observed that the compass needle was deflected. This discovery demonstrated that electric currents produce magnetic fields. As shown here, the magnetic field lines circle around the current-carrying wire.

Magnesia

Μαγνησία

Magnetic stones (Lodestone) was found in the area in the antiquity (ancient greeks)

(probably the magnetic field of lightning were the source of magnetism)



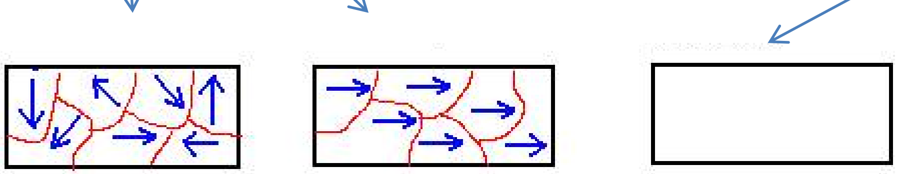
maghemite
qubic Fe_2O_3

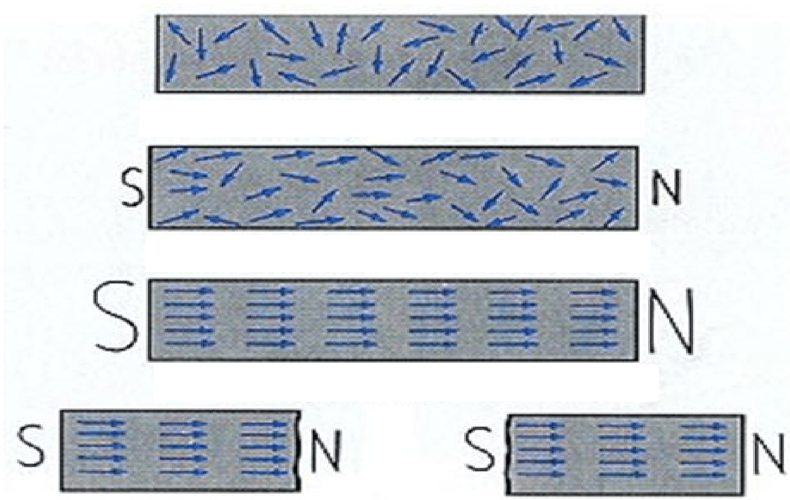
magnetite
$Fe_2+Fe_3+2O_4$

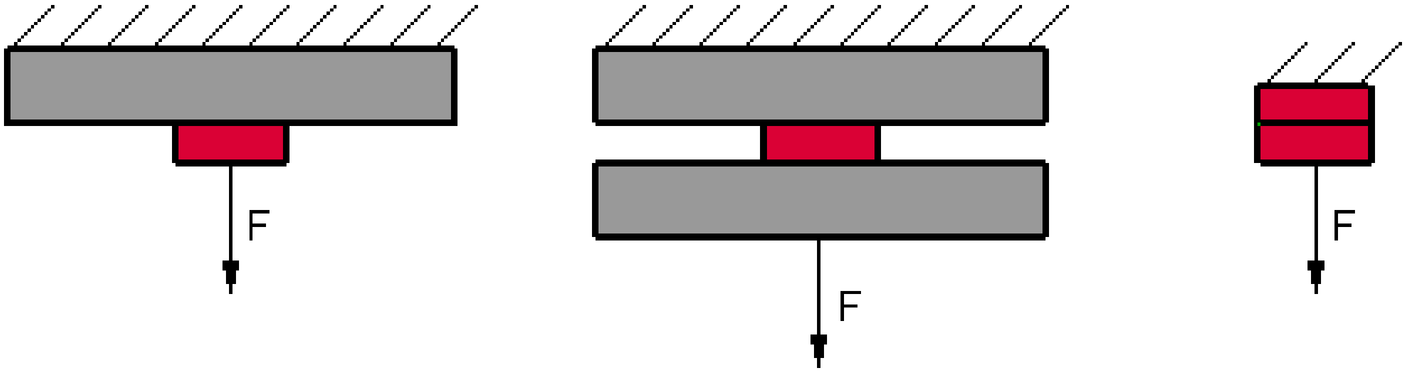
Lodestone

A piece of iron, which is originally nonmagnetic can be magnetized (magn.polarization)

This is nonmagnetic material







Magnetic polarization: a material behaves as a magnet under the influence of an external magnetic field, but only during the field is present.

Permanent magnet: they act as magnetic dipoles even without external magnetic influence.

Ferromagnetic substances: Ni,Gd,Co,Fe.
These can be magnetized to become a permanent magnet
(mostly by magnetizing when heated, and then cooling down)

Materials in magnetic field:

diamegnetic (e.g. noble gases, water, bizmut, etc)
The magnetization due to external field is weak, but opposing the applied field. This creates a repulsion effect.

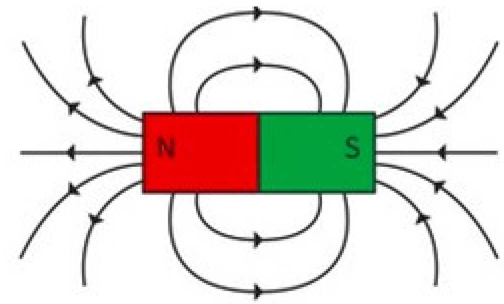
paramagnetic (e.g. Alu,Na,K, etc)
The magnetization is weak, but parallel to the applied field.

Ferromagnetic (e.g. Fe,Co,Ni, etc) they can form permanent magnets, and have a hysteresis curve. After becoming magnetized by an applied field they retain a remanant magnetism after the applied field is turned off.

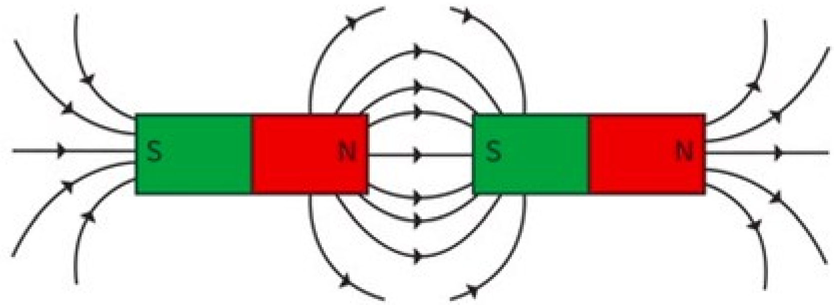
Dia, para : they are only magnetized during the applied external field is present.

Every magnet has TWO poles.

It means **there is no magnetic monopole.**
(and no "magnetic charge" separation)

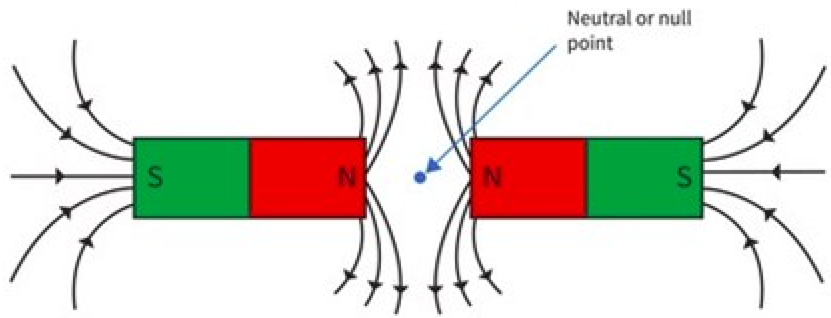


Opposite poles attract



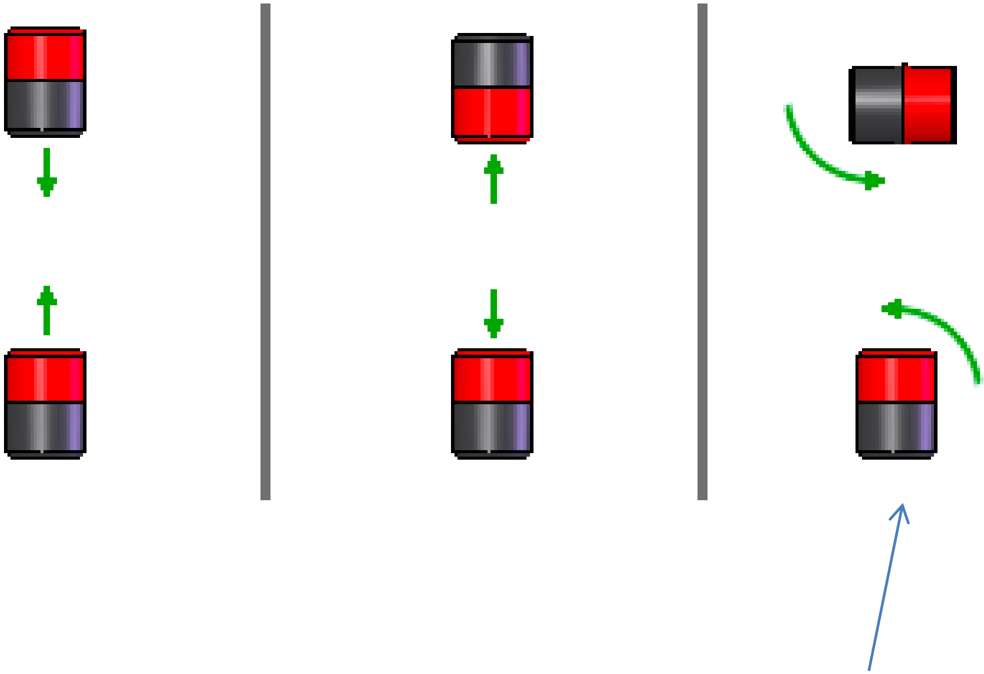
Attraction between opposite poles

Like poles repel each other



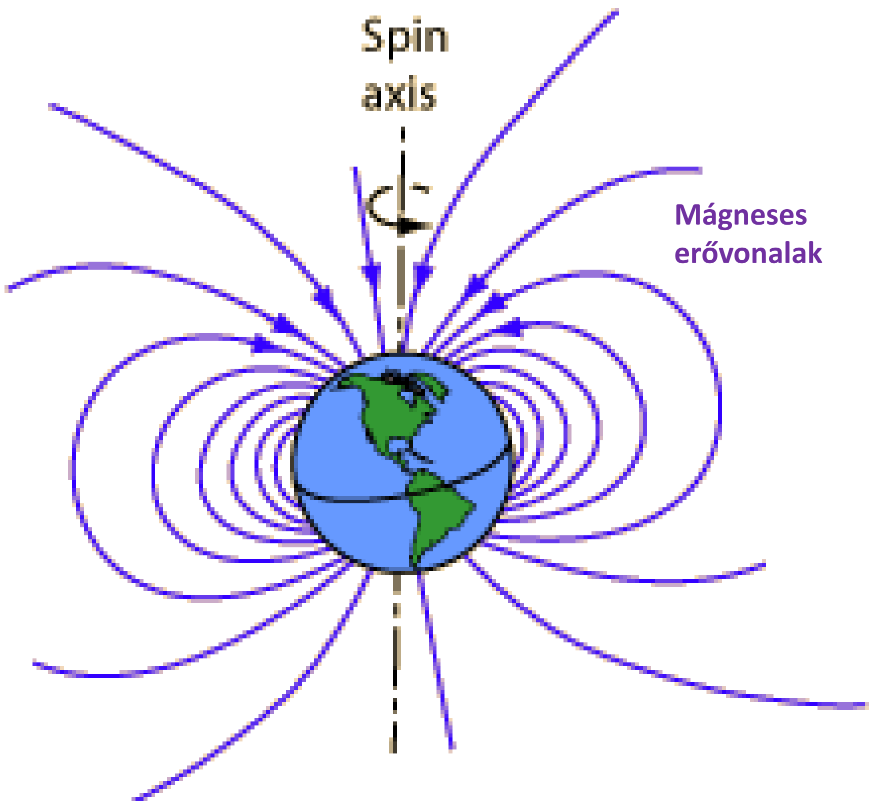
Repulsion between like poles

Green Arrows Indicate Magnetic Forces



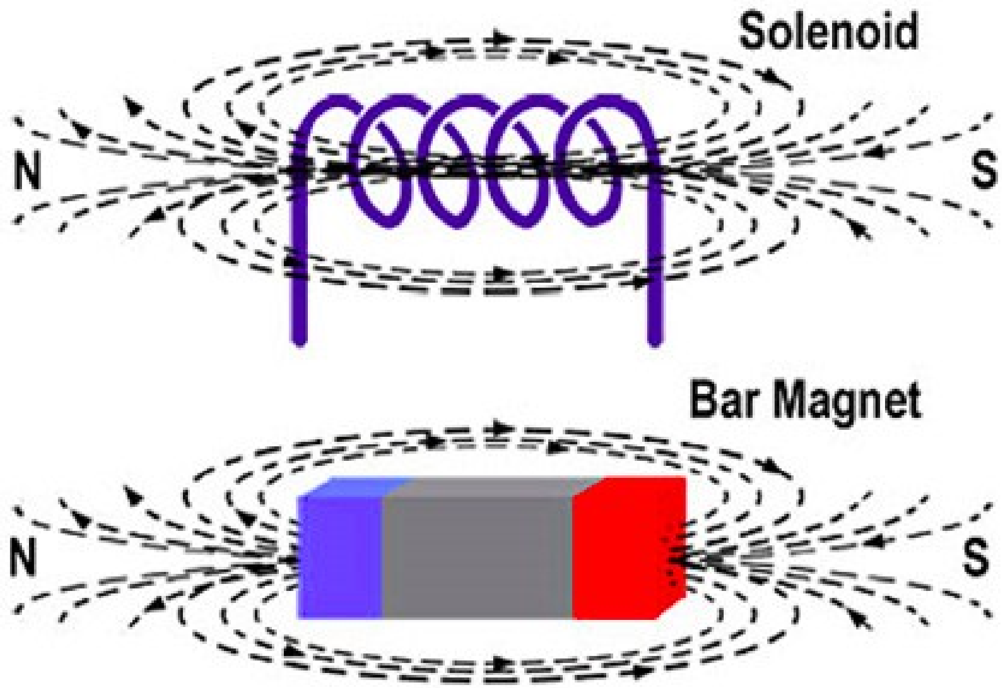
Magnetic force can also rotate an object.

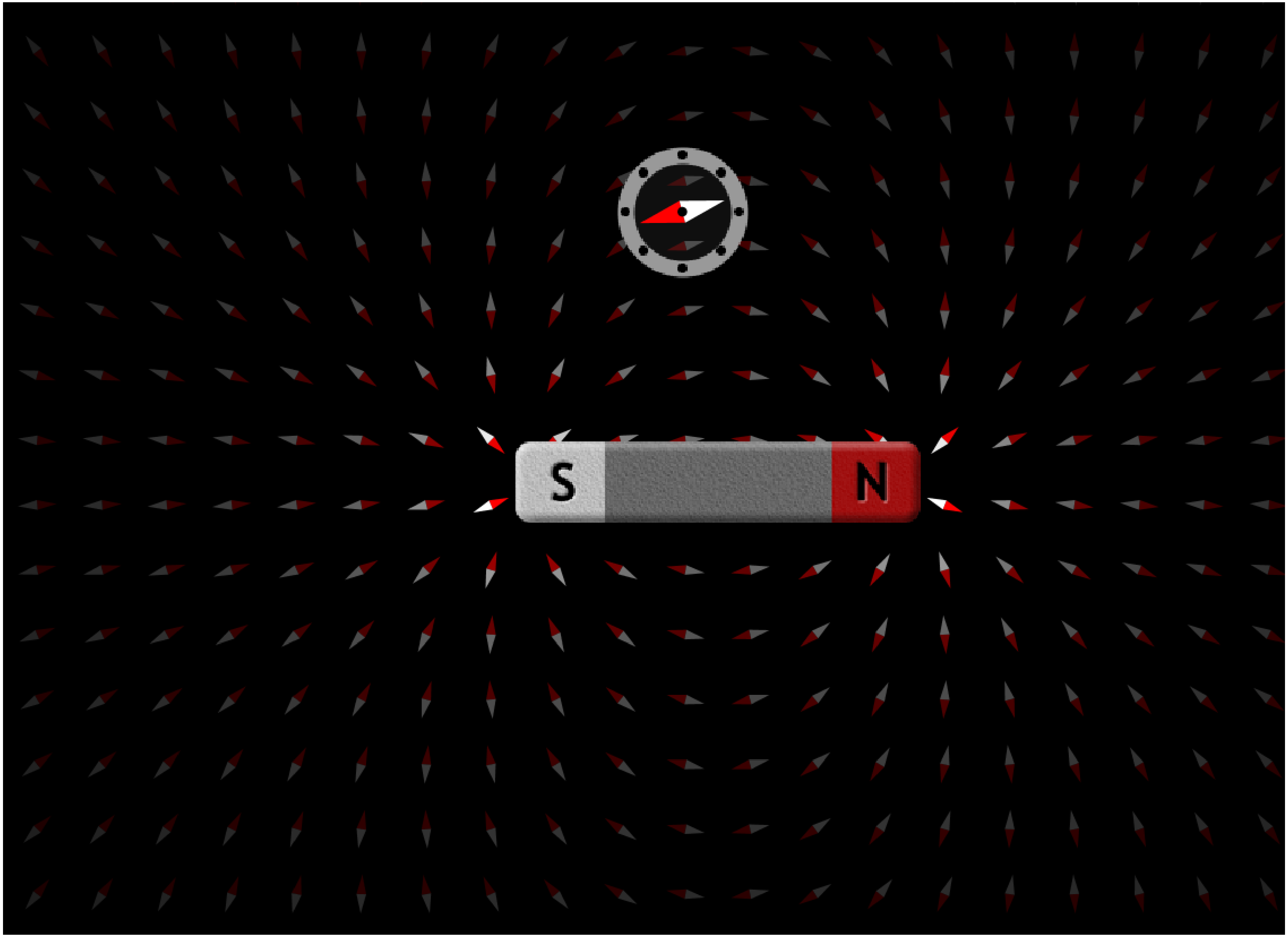
The compass interacts with the magnetic field of the Earth…



North pole is the pole of a magnet facing north when suspended and allowed to turn freely

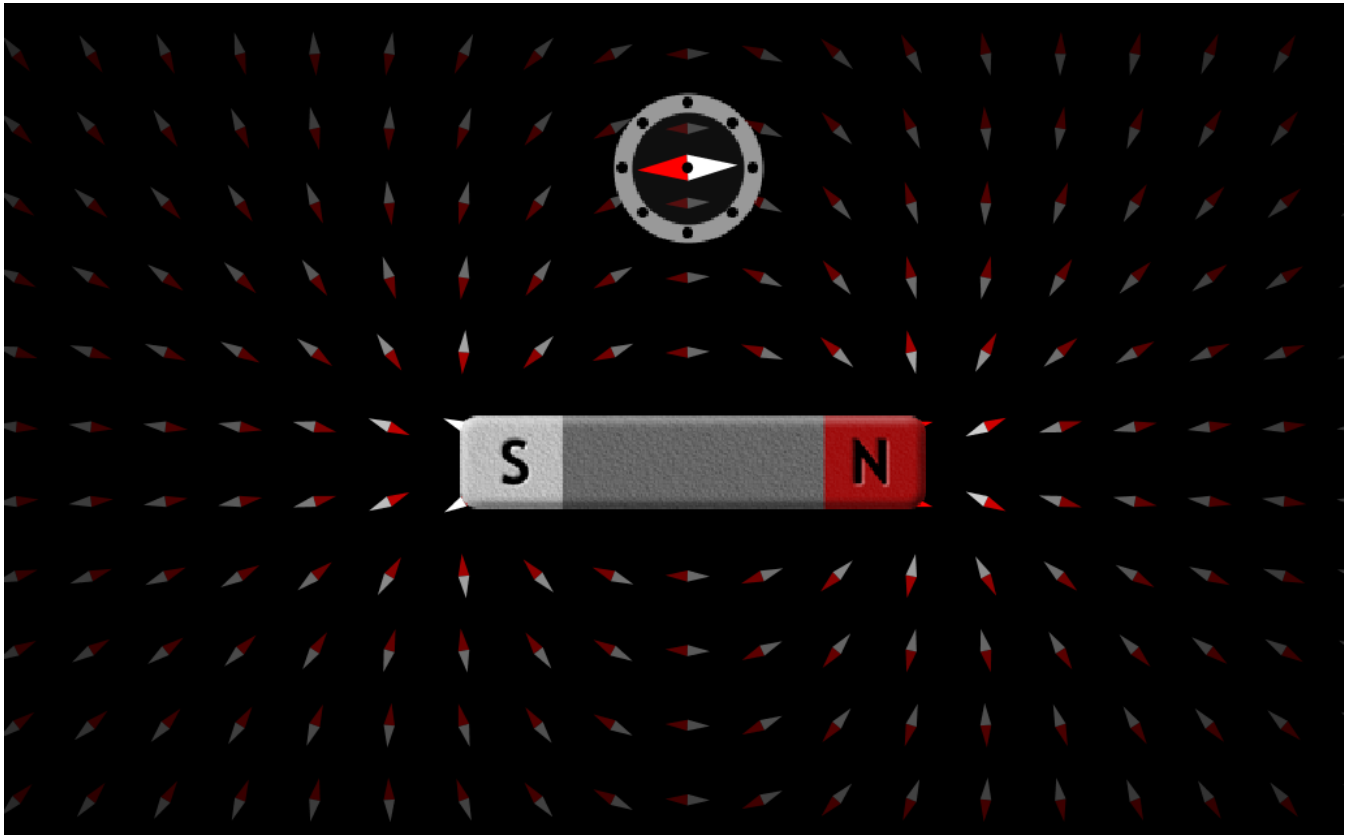
Not only permanent magnets have magnetic effect, but currents too.



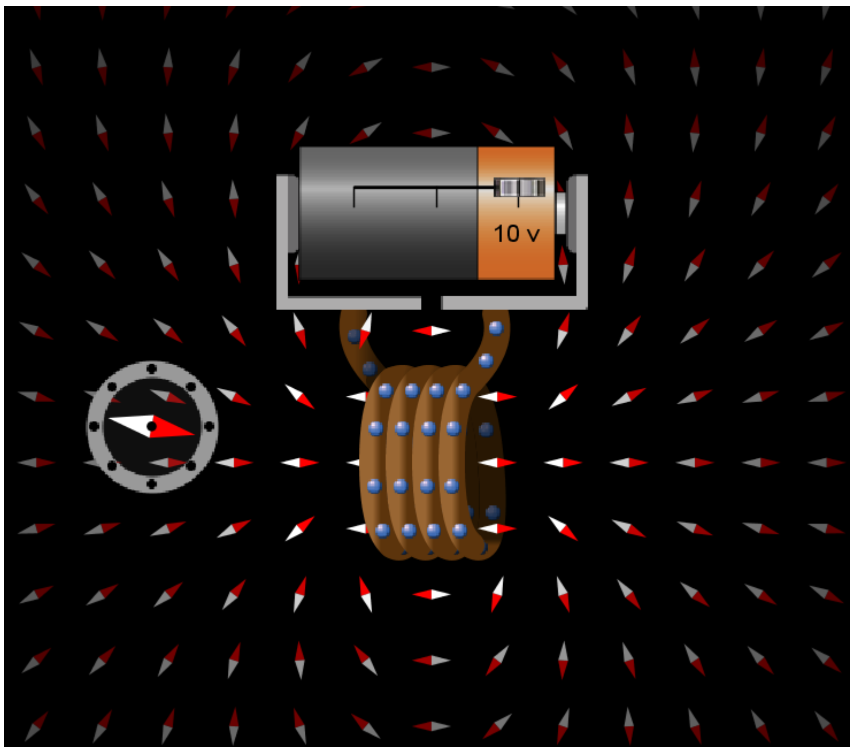

S
N

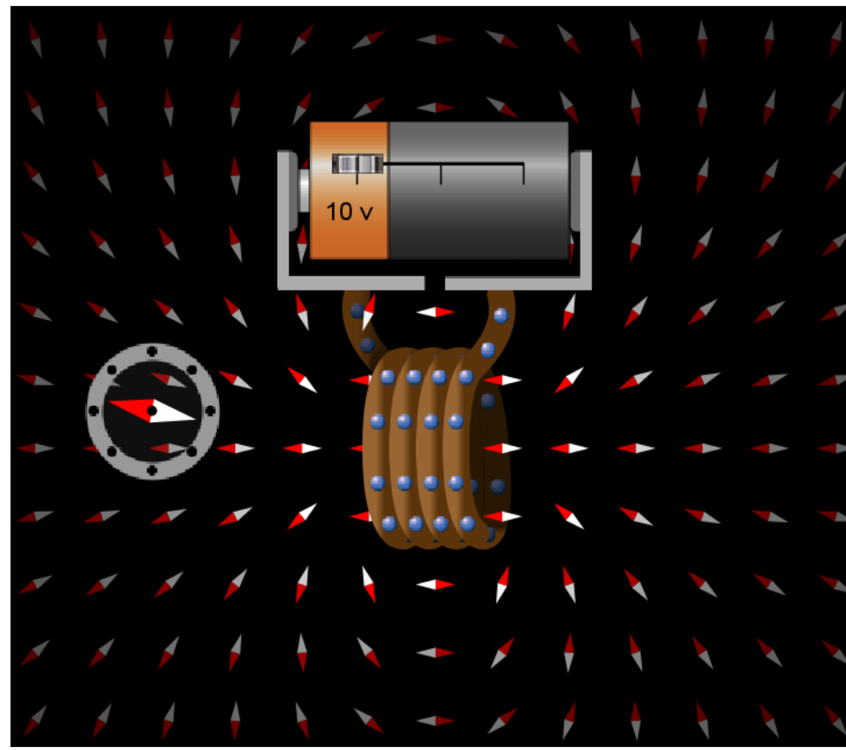
Since there is a way to map the interaction everywhere in space, so re-using the electrostatics concepts we introduce the **magnetic field** term.

It tells the size and direction of force (or torque) acting on a testing object.

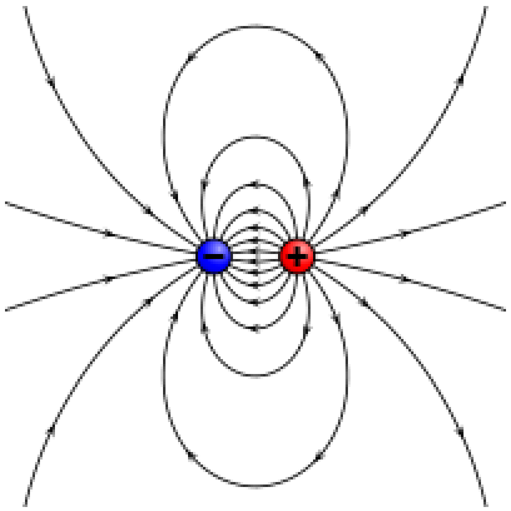


The magnetic field is more complicated than electrostatics, since **moving charges are coupled to magnetic fields.**



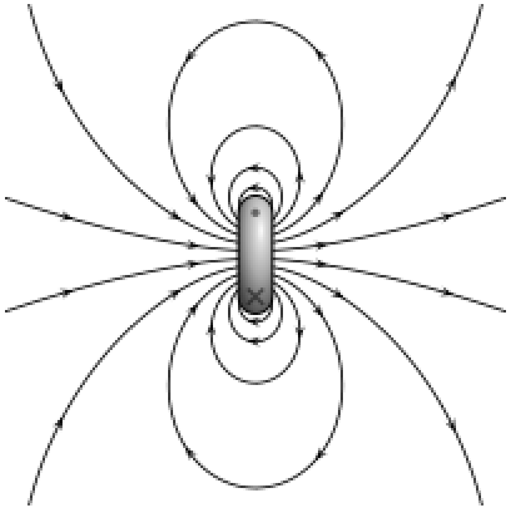


Two models were proposed



Poisson-model: in all materials there are small magnets, like a dipole.
This is the H-field. (magnetic field strength)

unit: A/m
With this was the magnetic moment also introduced:
m=p*l (p is the pole strength, l is the length)

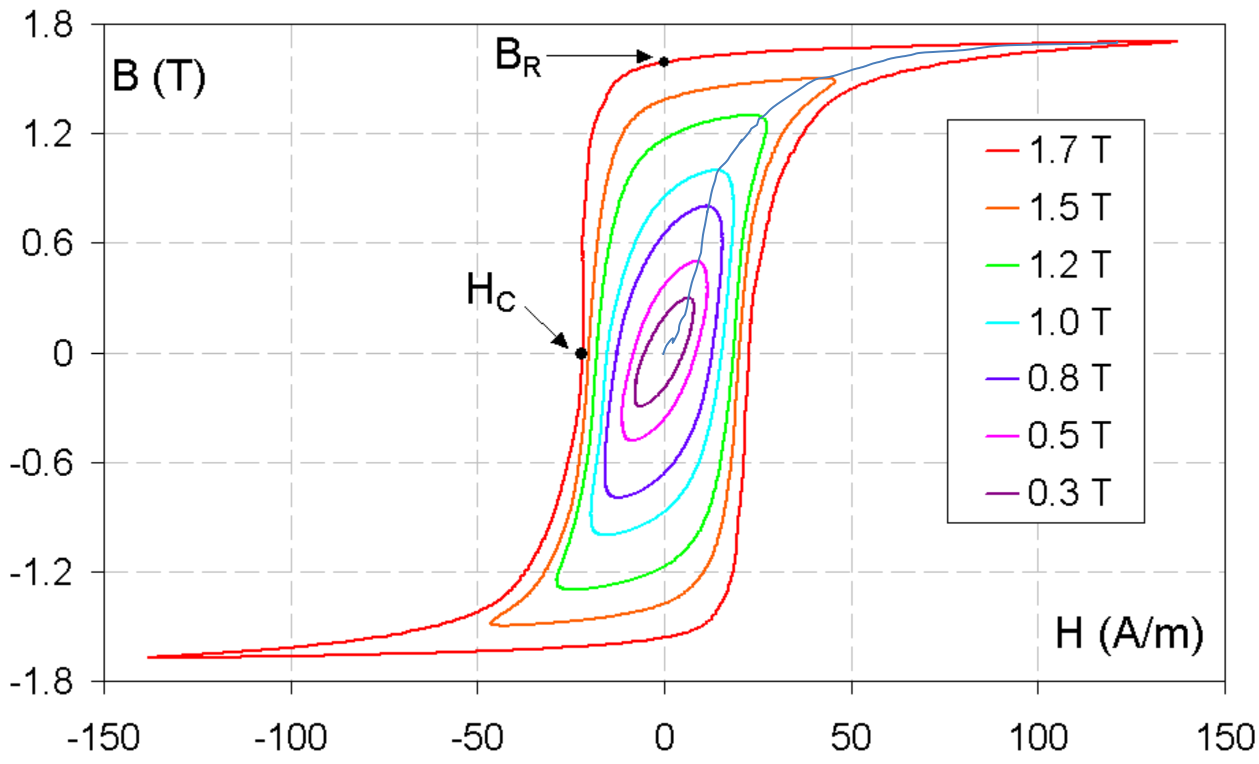


Ampere-model: a magnet is produced by moving charges.
This is the B-field, or magnetic flux density or simply magnetic field.
unit: N/Am = Tesla (T)
m=I*A where I is the current, and A is the loop area.
(the flux density of the earth is 20...70 μT)

The two models give the same result outside of materials, but not inside.

Extension material ☺

Hysteresis curve in ferromagnetic materials



Br : remaining magnetization

Hc: coercivity, the resistance of a magnetic material to changes in magnetization, equivalent to the field intensity necessary to demagnetize the fully magnetized material.

n.B.: H is the magnetic field strength which creates the flux density in the material.

Today we know that magnetism is a result of orbital-magnetism and spin together.

There is a similar realtionship between H and B as E and D.

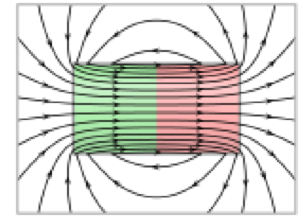
$$\mathbf{H = B/\mu_0 - M}$$

M is the magnetiation of the material, usually $M=\chi H$ (but not for ferromagnetis material!),

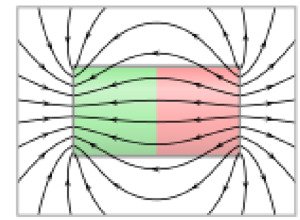
χ magnetic susceptibility,

μ_0 vacuum magnetic permeability

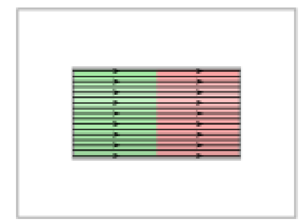
In vacuum the H and B only differ in a constant (just like E,D)



$\vec{B}$

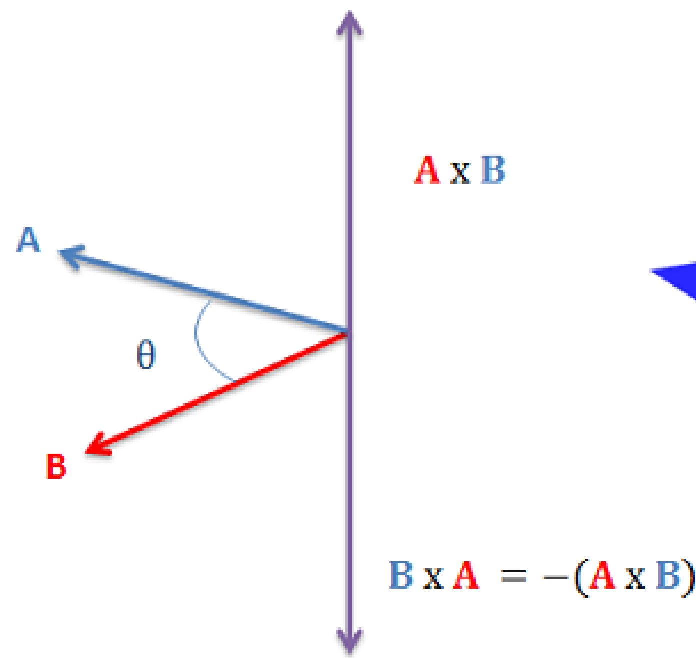


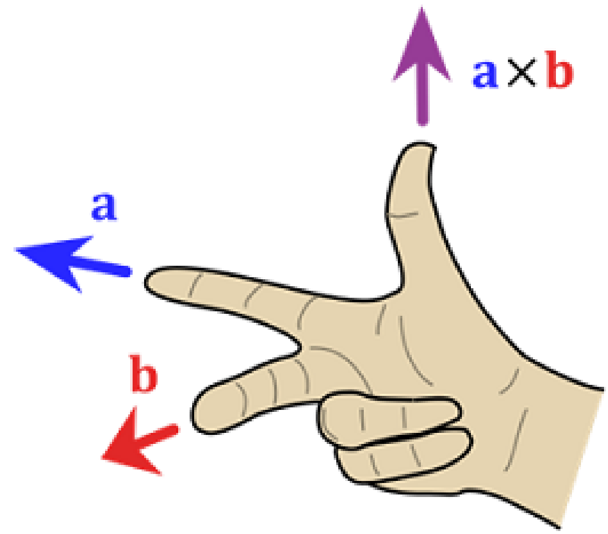
$\vec{H}$

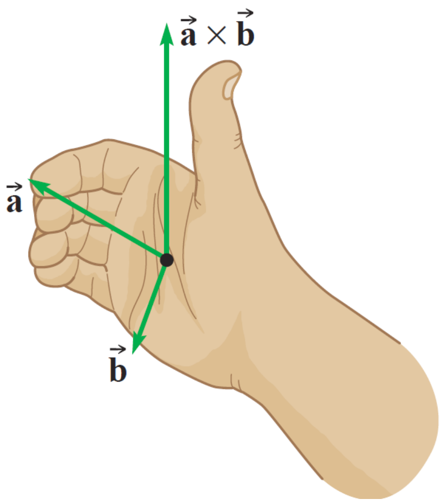


$\vec{M}$

Vector cross product



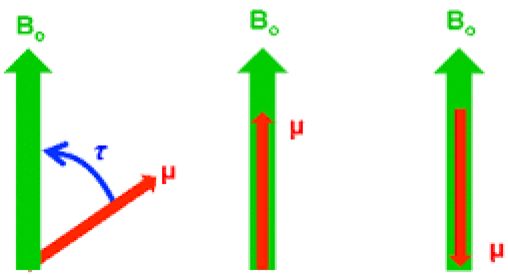


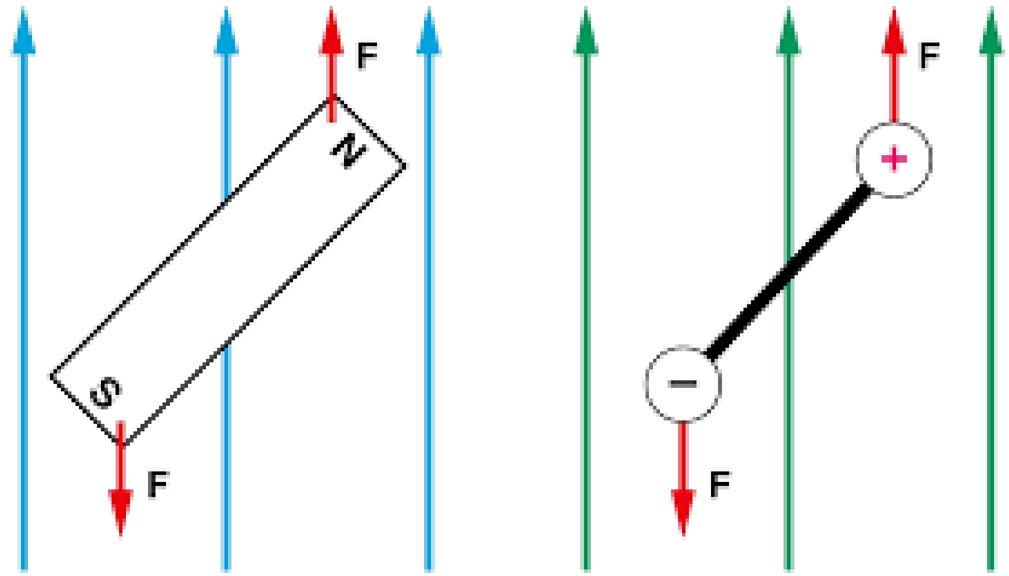


In a magnetic field (B) onto a magnetic dipole (m) a torque (τ) is acting.
(just like on to electric dipoles)

$$\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}$$

Often B is measured
through τ





Torque -> work -> potential energy!

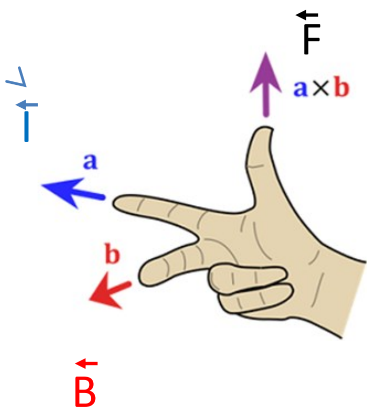
.

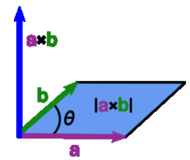
SPIN: “built in” magnetic property of electrons and protons -> NMR/MRI

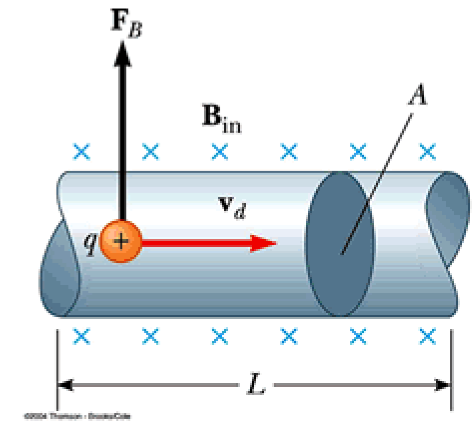
The relationship is bidirectional between current and magnetism

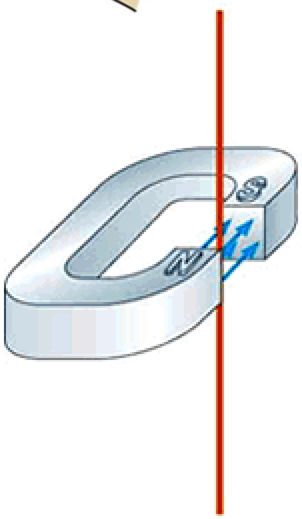
Lorentz force causes a force to act on a wire in magnetic field
F=I*B*L, RHR (right hand rule)

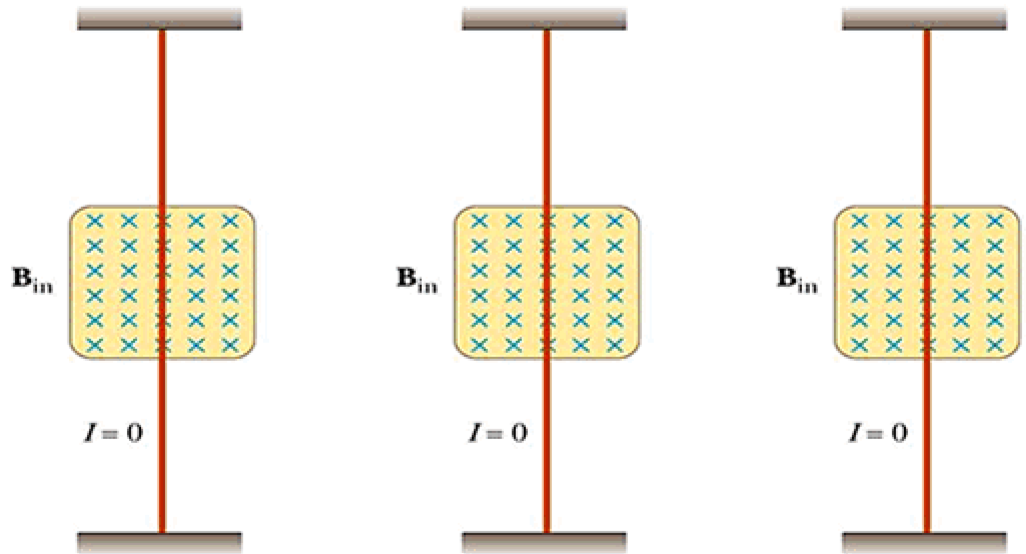
vectorial cross product

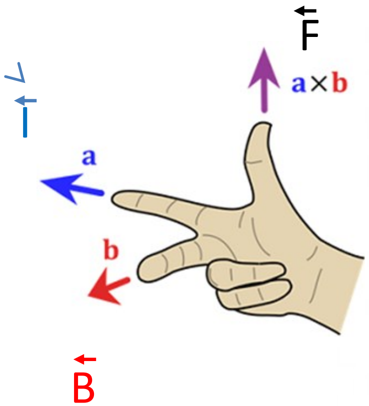


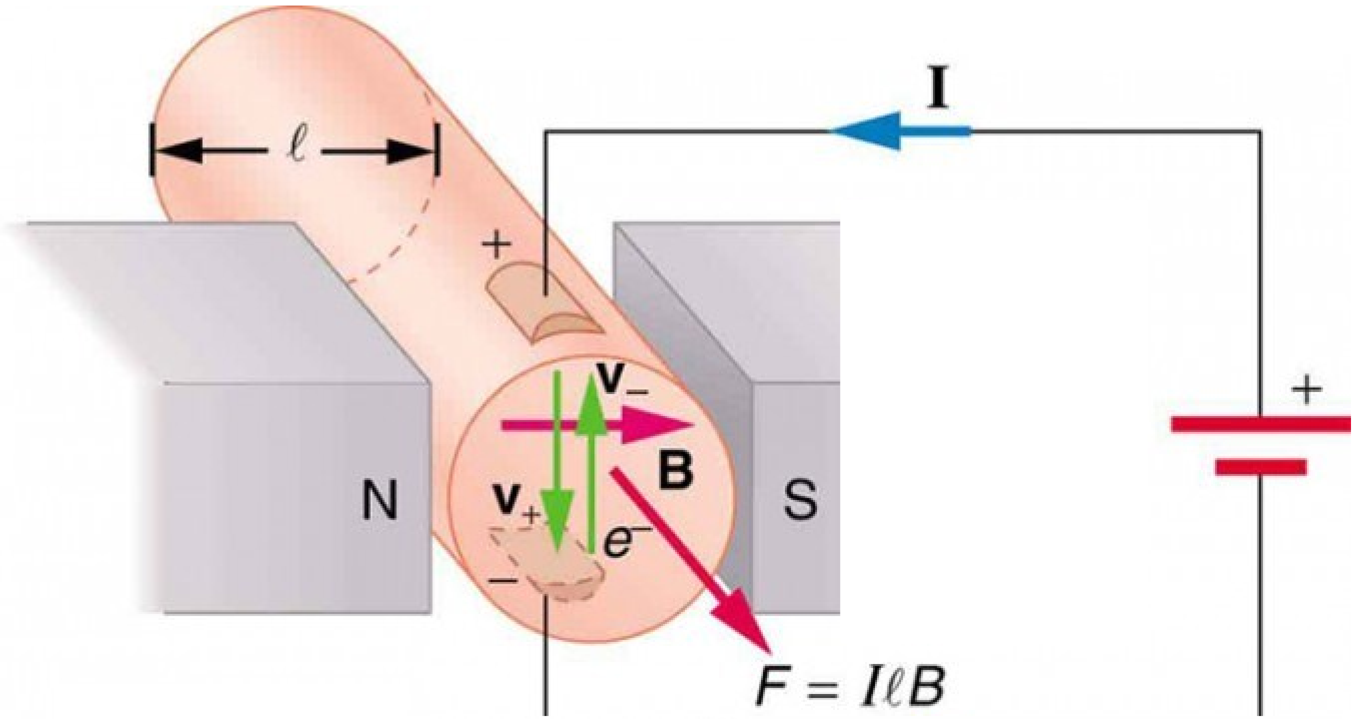




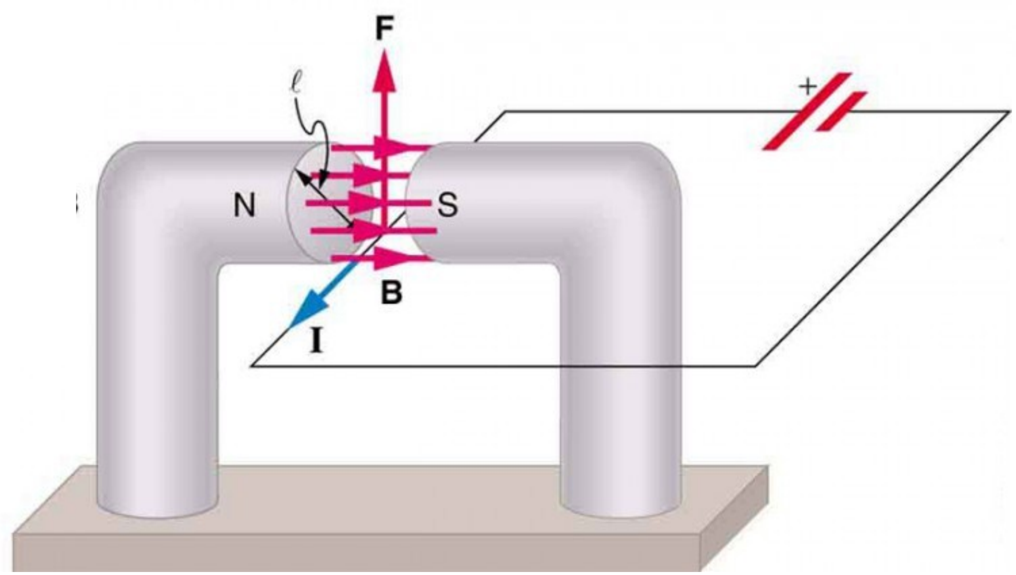




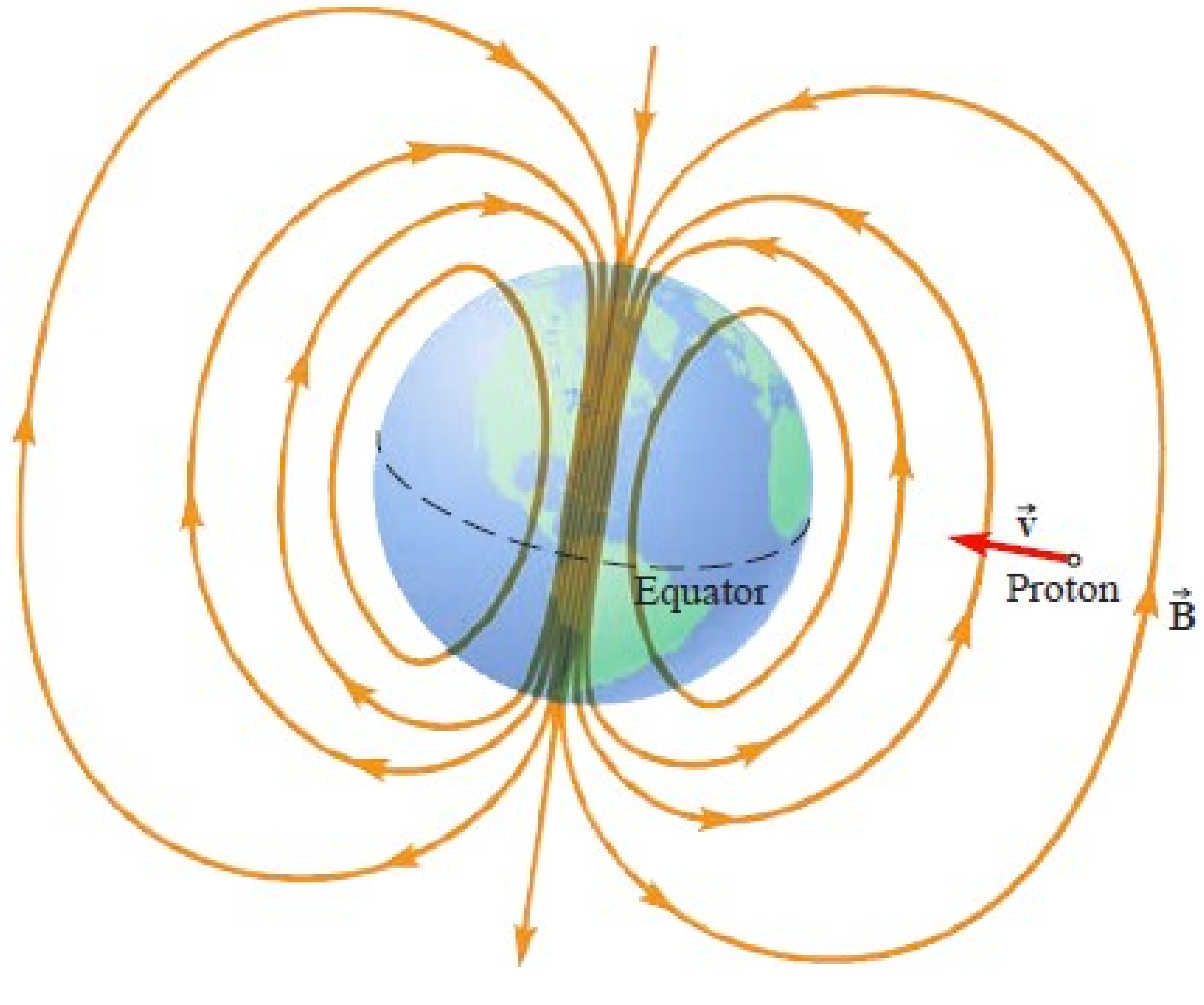




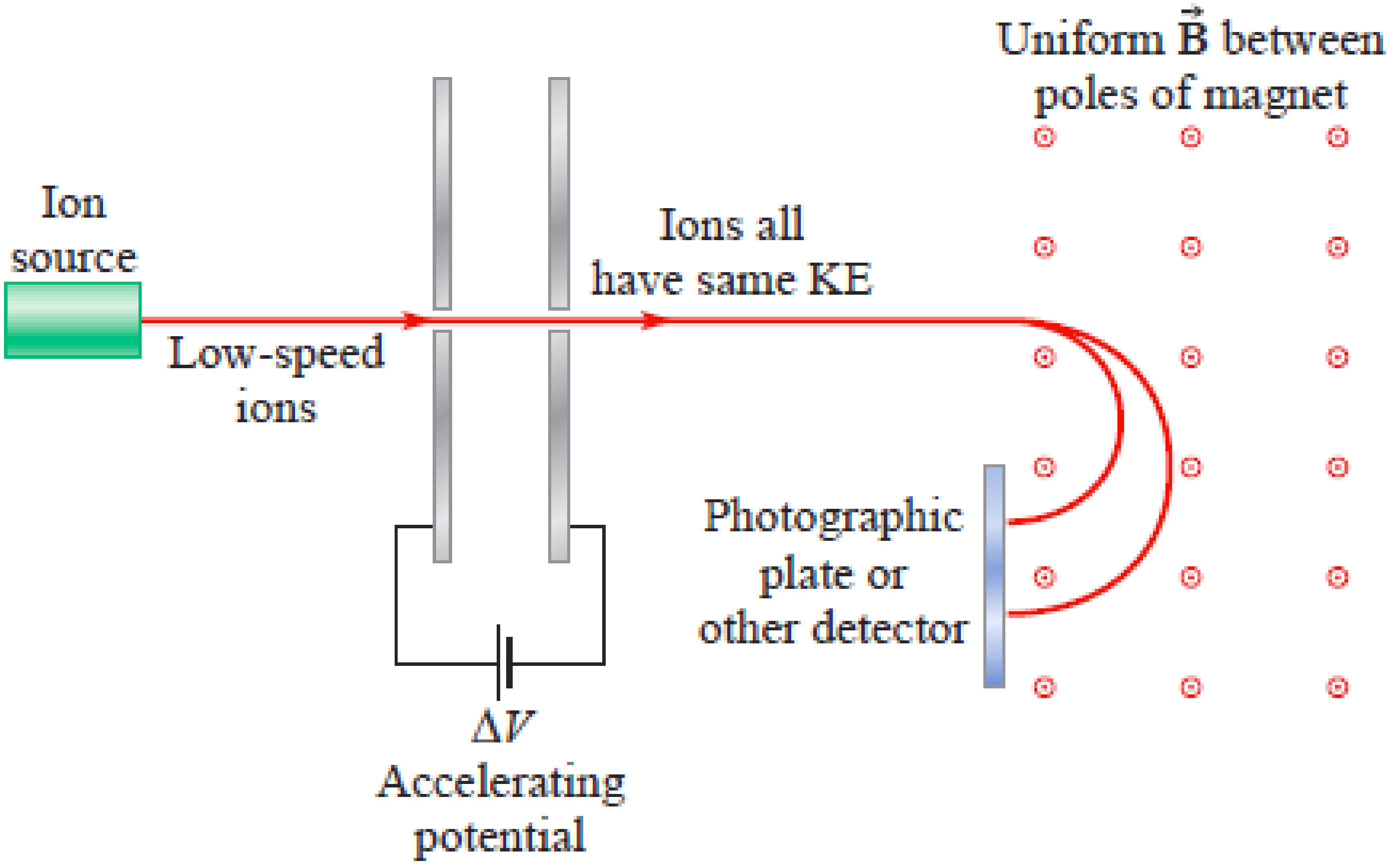
Since electrons are moving, so
Lorentz force is acting
F=q*v*B ha merőlegesség van.
(F = q* **v** x **B**)

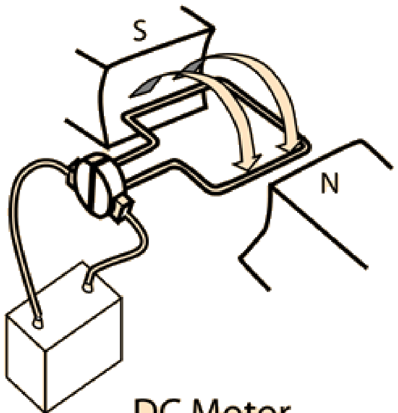


Protection against cosmic charged particles

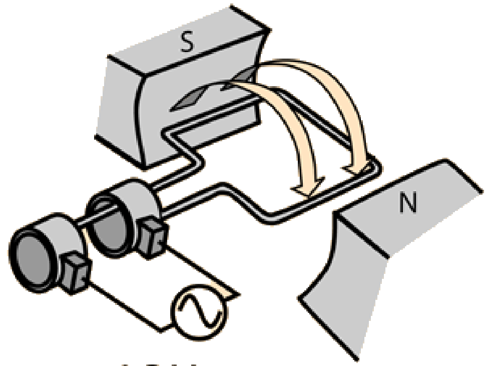


Mass spectrometer

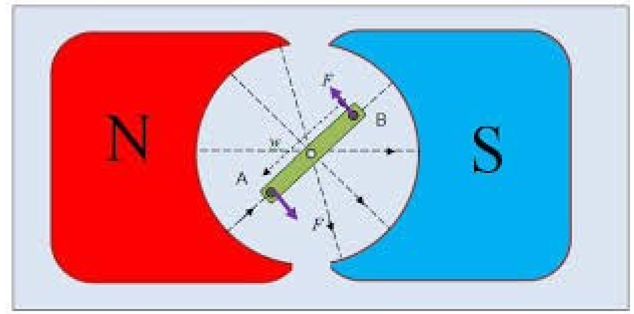


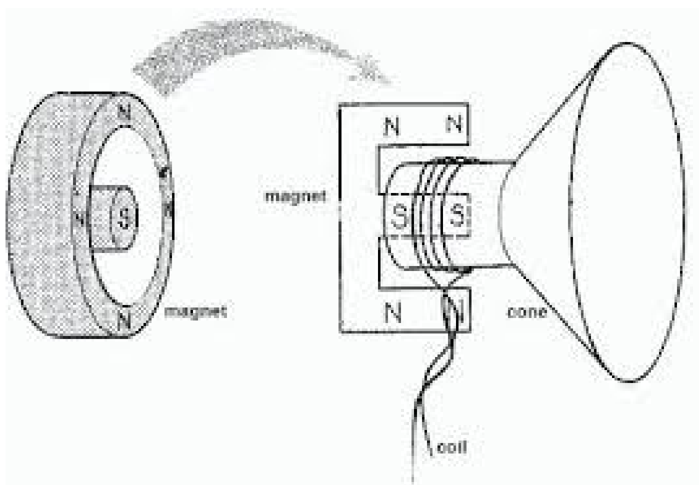


DC Motor

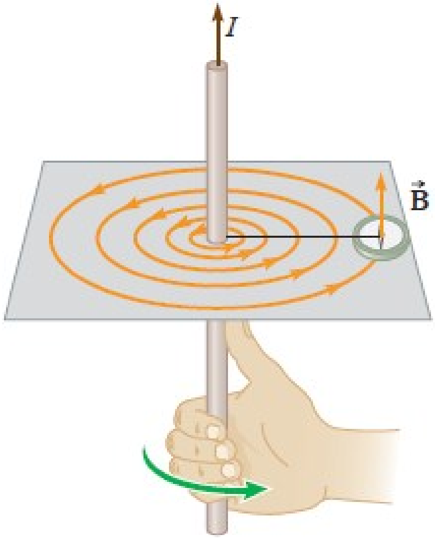


AC Motor





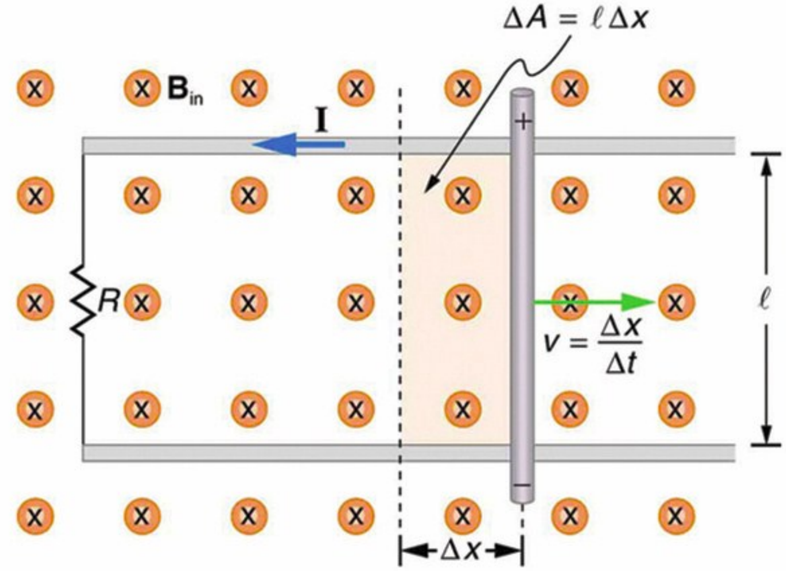
Flowing electric current generates magnetic field.



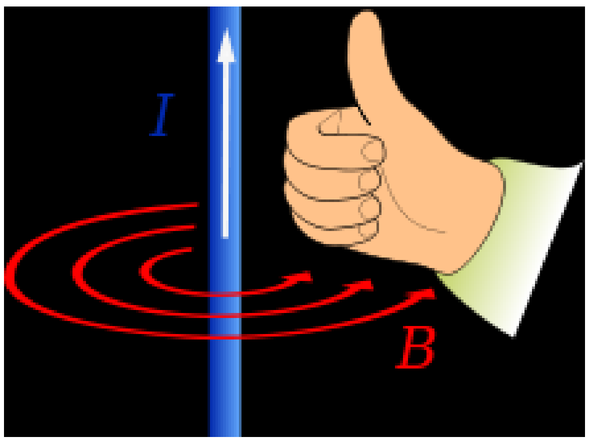
Again a right hand rule…

INDUCTION

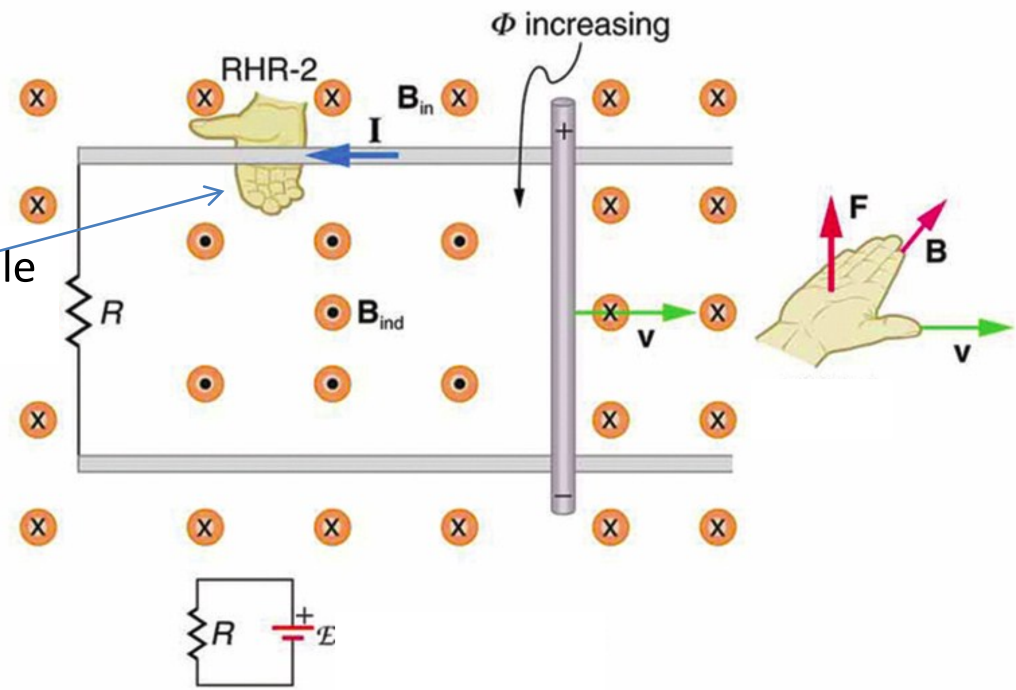
Changing magnetic flux (Φ) also creates voltage.



(a)

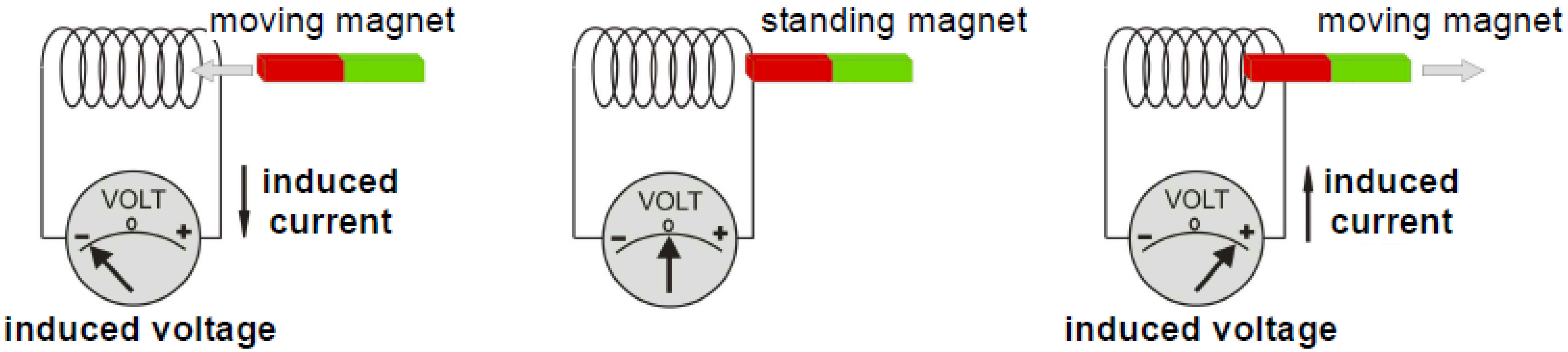


Lenz rule



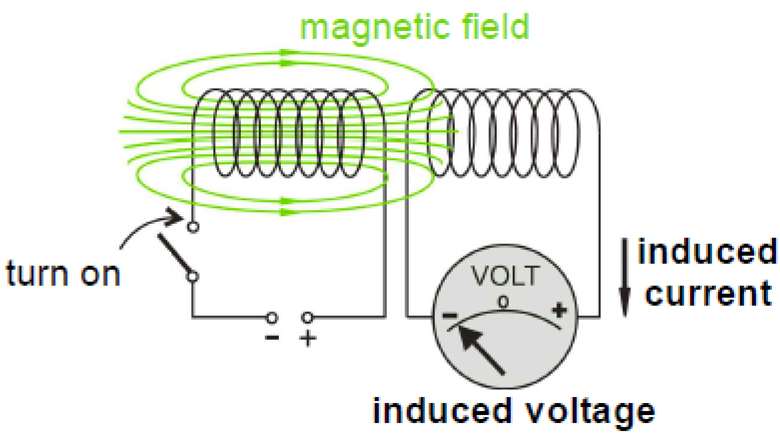
Lenz rule: the induced voltage or current is opposing the change.

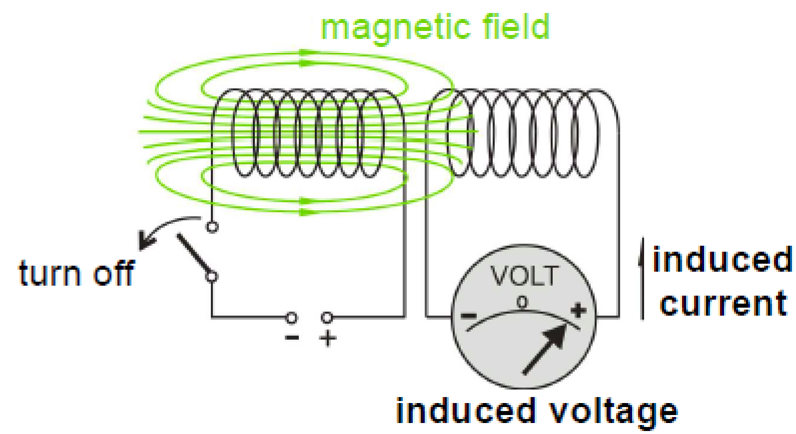
The flux can be changed by moving a magnet



Faraday: flux change in a closed loop creates electromotive force.

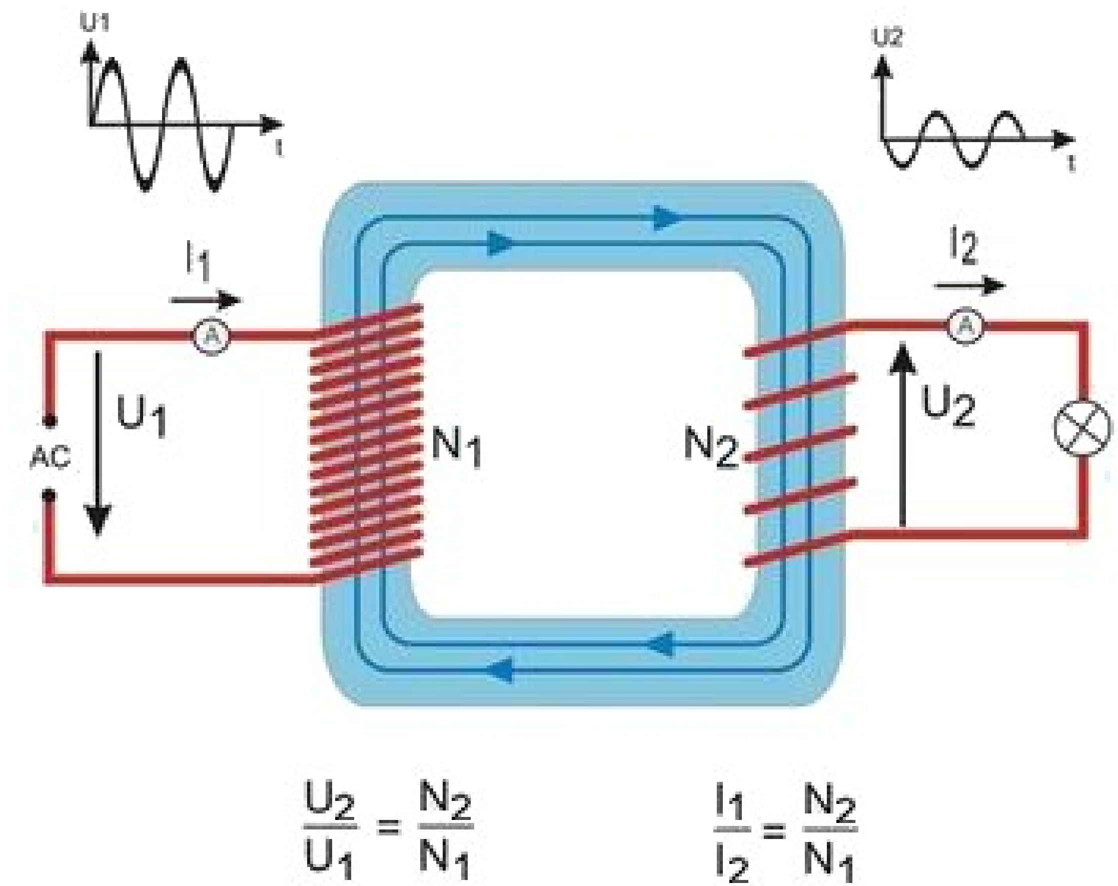
Since the current is also creating a magnetic field, the two coils (choke) can interact without movement. This is the induction.



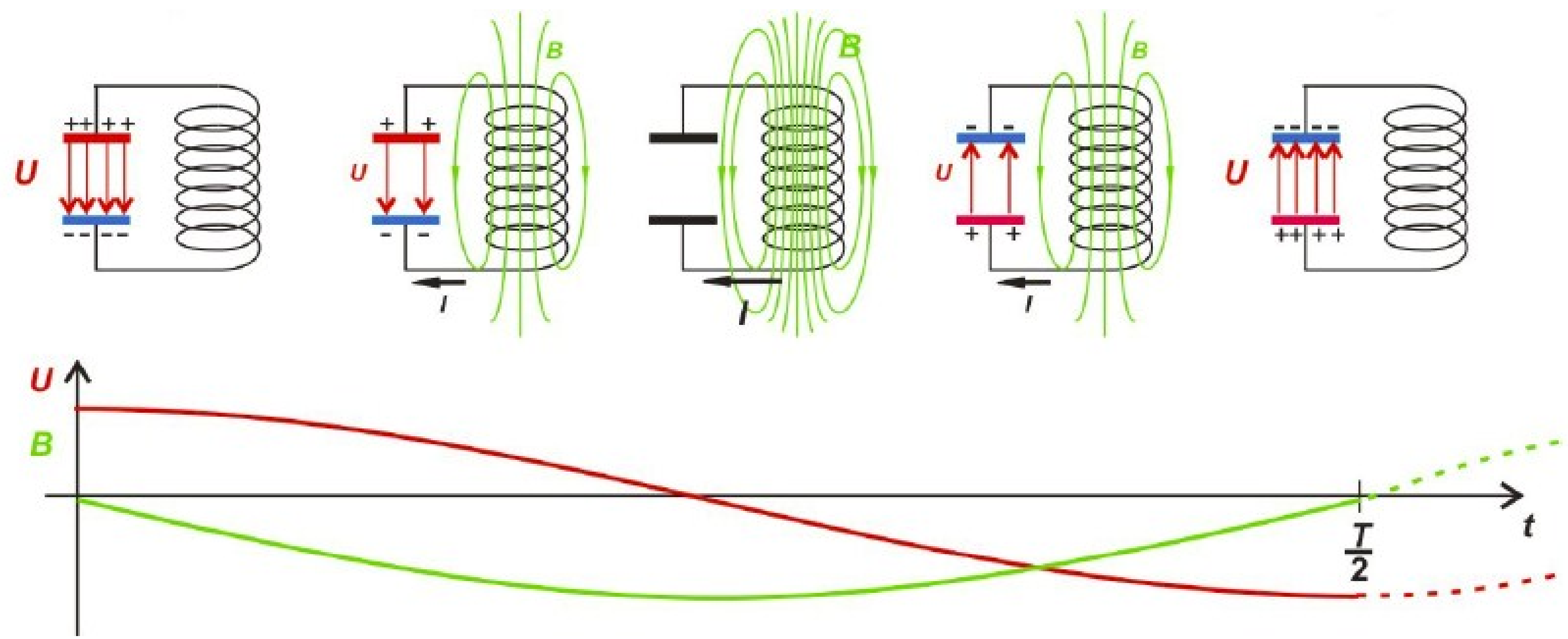


there is **self-induction**.
A measure of it is the **inductivity**, unit is Henry (Vs/A)

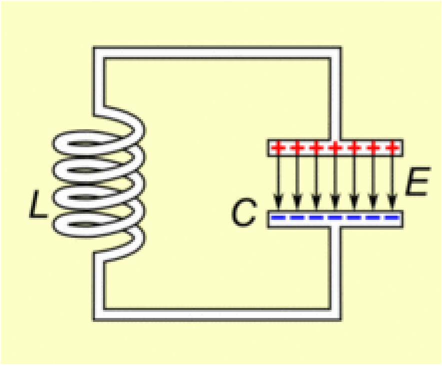
transformer



LC circuit



$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



Motor or generator