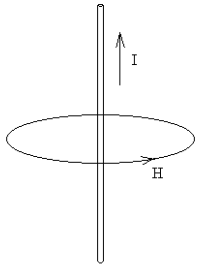
Magnetism

MAGNETIC FIELD *H*

When electrical current flows through a conductor a magnetic field H is generated in the space around it and its intensity is proportional to the current.
In a long and straight conductor (see figure below)



where the current i flows, the magnetic field H at a distance r from the conductor becomes:

$$H = \frac{i}{2p\,r}$$

Since the current is measured in ampere (A) and the radius in meters (m) the unit of measure of H is ampere/meter (A/m). This is the unit of measure of H that should be used by the present standard, in compliance with the International Standard (SI), but it is still often used the unit of measure of CGS standard , the oersted (Oe) which is:

1 Oe = 79.58 A/m

MAGNETIC INDUCTION *B*

While the magnetic field H is only generated by the electrical currents, the magnetic induction B holds all possible field sources, like the field generated by ferromagnetic materials.
In vacuum (and with great approximation in the air too), the fields H and B are linked by relationship:

$$B = m_0 H$$

Where μ_0 is the magnetic permeability of vacuum which is $4\pi \cdot 10^{-7}$ henry/meter (H/m).
In case the media is not the vacuum but a ferromagnetic material (for example iron), the field B is calculated:

$$B = mH = m_{r0}\, m_0 H$$

where μ is the material permeability, defined as the product of vacuum permeability with the magnitude μ_r, named relative permeability , based on the material.
The relative permeability depends from the magnetic field H, and can be very high for some materials like iron, cobalt and nickel. For example, for iron it is about 5000.
The unit of measure of magnetic induction in the SI is the tesla (T). Very often the gauss (G) of CGS standard is used which means:

$1G = 10^{-4}\,T$
When considering magnetic fields in air both H or B can be used (even though B is mainly used).
When considering magnetic fields within ferromagnetic materials the magnetic induction B must be used.

Europe
Laboratorio Elettrofisico Srl , Via G. Ferrari 14
20014 Nerviano (Milano) Italy
ph.+39 0331 589785 fx.+39 0331 585760
info@laboratorio.elettrofisico.com

Asia
PRO-PII Technology Corp.
Tel: +886 2 87973606 Taipei Office
Tel: +86 2153016655 Shanghai Office
propii@propii.com.tw

USA
Laboratorio Elettrofisico USA Inc.
P.O. Box 5677, Deptford, NJ 08096
ph.+1 856-3841003 fx.+1 856-3841004
b.palakow@laboratorio.elettrofisico.com

Magnetism

MAGNETIC FLUX Φ

The flux of the mean magnetic induction B perpendicular to a measuring surface formed by a coil of N windings of a surface A is defined as:

$$\Phi = N \cdot A \cdot B$$

The unit of measure of flux is than Tesla x square meter (T . m^2) which is named Weber (Wb).
The related unit of measure of CGS standard (little used) is Maxwell (Mx) :

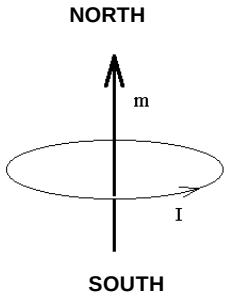
$$1\ Mx = 10^{-8}\ Wb$$

MAGNETIC MOMENT

The magnetic moment m of a round winding of surface A in which flows a current *i* is:

$$m = iA$$

The unit of measure is the ampere·m^2. The magnetic moment for the magnetism is as the electrical charge for the electrostatics: it is comparable to a small magnet with north and south poles.



Magnetic moments are generated by the electron of materials atoms which rotates around the nucleus as well as themselves. Therefore the atomic electrons act as many microscopic magnets inside the material.
These magnets can be randomly located (in this case there are not magnetic effects combined and the material is amagnetic) or they can be located in the same direction to add up and produce a macroscopic effect (in this case the material is magnetic).
Magnetisation M is the sum of all elementary magnetic moments divided by the material volume:

$$M = \frac{\sum m}{V}$$

(where the symbol Σ means “sum”). The unit of measure of the magnetisation M is ampere/meter (A/m) that is the same unit of measure of the magnetic field H.

FUNDAMENTAL RELATIONSHIP OF MAGNETIC FIELDS

H, B and M fields are bound by a fundamental relationship:

$B = \mu_0 (H + M) = \mu_0 H + J$

It must be emphasized that the total magnetic field B is given by the contribution of the field H (due to currents only) and by the field M (due to the material magnetism).
The usual definition is indicated too and it uses the vector of intrinsic magnetisation J, equal to $\mu_0 M$ (J is also named magnetic polarisation). The intrinsic magnetisation is simply a way (often used) to express the magnetisation M in Tesla (or gauss) instead of A/m.

Europe
Laboratorio Elettrofisico Srl , Via G. Ferrari 14
20014 Nerviano (Milano) Italy
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b.palakow@laboratorio.elettrofisico.com