

MAGNETISM

Magnetic phenomena are generally associated with iron and steel.

In reality magnetism is an electric phenomenon.

Any moving charge is a magnet.

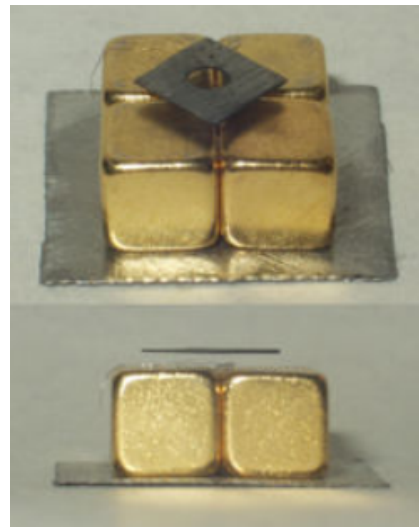
Three types of Magnetism:

Ferromagnetism-iron/steel

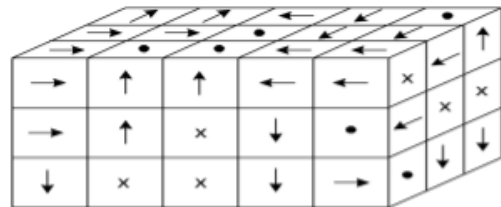
Diamagnetism- a weak repulsion from an applied magnetic field

Paramagnetism- (opposite of diamagnetism) a weak attraction to an applied magnetic field

(potassium superoxide exhibiting paramagnetism)



Atoms are magnetic because their electrons (and nuclei) are moving (spinning) charges. Iron simply has a strong total magnetic effect when all the electrons' individual effects are added.



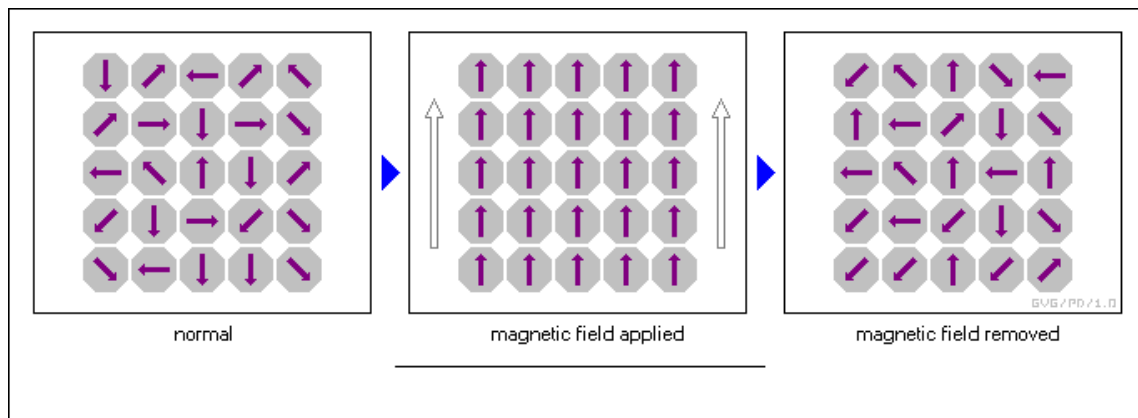
600 BC- Greek philosophers describe magnetic properties of lodestones (ferric ferrite)

1086- First description of a magnetic compass by Chinese scientist Shen Kua

1600- William Gilbert publishes *De Magnete* in which he describes the Earth's magnetism

1819- Hans Orsted discovers electromagnetism, noticed a compass needle deflect when near a wire with a current.(in the very early 19th century).

1830- Joseph Henry builds the first electromagnetic motor; it has little practical use



1831- Faraday discovers electromagnetic induction (showed through induction the intimacy of current and magnetism).

1862- Maxwell combined electricity and magnetism theoretically to explain light and radio waves.

1905- Einstein showed how "Special Relativity" made magnetism merely a complexion of electricity under motion. He showed that the assumption of a constant speed of light for all observers allowed all magnetic effects to be able to be derived from electrostatics! (*Most text books on Special Relativity state "categorically" that Special Rel effects can only be observed at relativistic speeds -not true. Charges moving in a wire only drift along at best at centimeters each second yet magnetic effects are easily seen!*)



$B = \text{Mag. Field Strength}$

Equations:

$$F = qvB \sin \theta$$

$$F = ILB \sin \theta$$

$$r = mv/qB$$

$$B = (\mu_0/2\pi)I/r$$

$$F = \mu_0 I_1 I_2 / 2\pi L$$

$$B = v (E/c^2)$$

$q = \text{charge}$

$v = \text{velocity}$

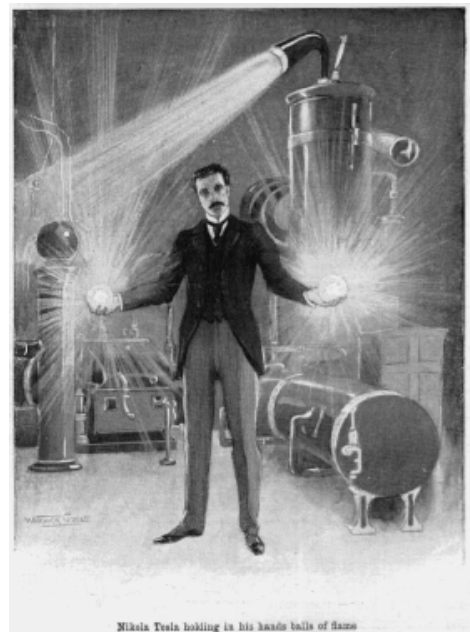
$I = \text{current}$

$L = \text{length}$

$$\mu_0 = 4 \times 10^{-7} \text{ T/A}$$

A Tesla is the measurement of magnetic field strength.

$1\text{T} = \text{kg/sC}$
(Symbolized by B)



Maxwells Equations:

$$\oint \mathbf{E} \cdot d\mathbf{A} = q/\epsilon_0$$

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This is Maxwell's first equation.

Charge and Magnetic field

It represents completely covering the surface with a large number of tiny patches having areas dA . We represent these small areas as vectors pointing outwards, because we can then take the dot product with the electric field to select the component of that field pointing perpendicularly outwards (it would count negatively if the field were pointing inwards) -- this is the only component of the field that contributes to actual flow across the surface. (Just as a river flowing parallel to its banks has no flow across the banks).

The *second* Maxwell equation;

Magnetic Field

Is the analogous one for the magnetic field, which has no sources or sinks (no magnetic monopoles, the field lines just flow around in closed curves). Thinking of the force lines as representing a kind of fluid flow, the so-called "magnetic flux", we see that for a closed surface, as much magnetic flux flows into the surface as flows out. This can perhaps be visualized most clearly by taking a group of neighboring lines of force forming a slender tube -- the "fluid" inside this tube flows round and round, so as the tube goes into the closed surface then comes out again (maybe more than once) it is easy to see that what flows into the closed surface at one place flows out at another. Therefore the *net* flux out of the enclosed volume is zero,

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$

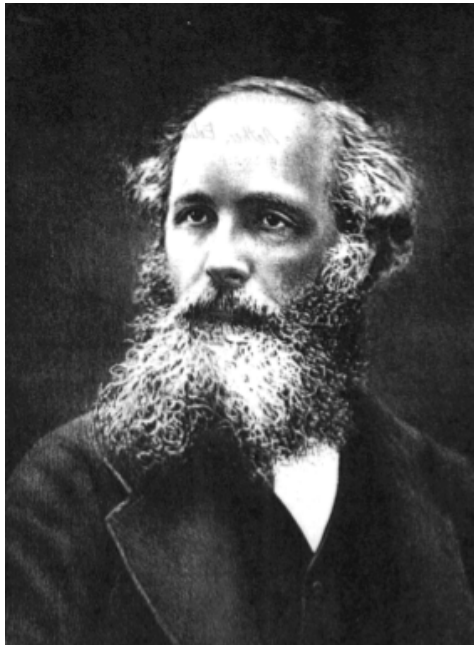
$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$

The simplest version of Maxwell's third equation is the electrostatic case:
The path integral $\oint \mathbf{E} \cdot d\mathbf{s} = 0$ for electrostatics.

The full version of *Maxwell's third equation* is:
$$\oint \mathbf{E} \cdot d\mathbf{s} = -d/dt(\oint \mathbf{B} \cdot d\mathbf{A})$$

Maxwells 4th Equation:

path integral $\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0(\oint \mathbf{j} \cdot d\mathbf{A} + \mathbf{e}_0 \cdot d/dt (\oint \mathbf{E} \cdot d\mathbf{A}))$ (over surface spanning path)



One final equation is commonly included with Maxwell's Equations and that is the Lorentz-Force Law:

The Lorentz force is the force on a moving charged particle from an electromagnetic field.

$$F = q(E + vB)$$

where q is the charge of the particle, E is the electric field strength, v is the speed of the particle and B is the magnetic field strength.

This can be broken down into;

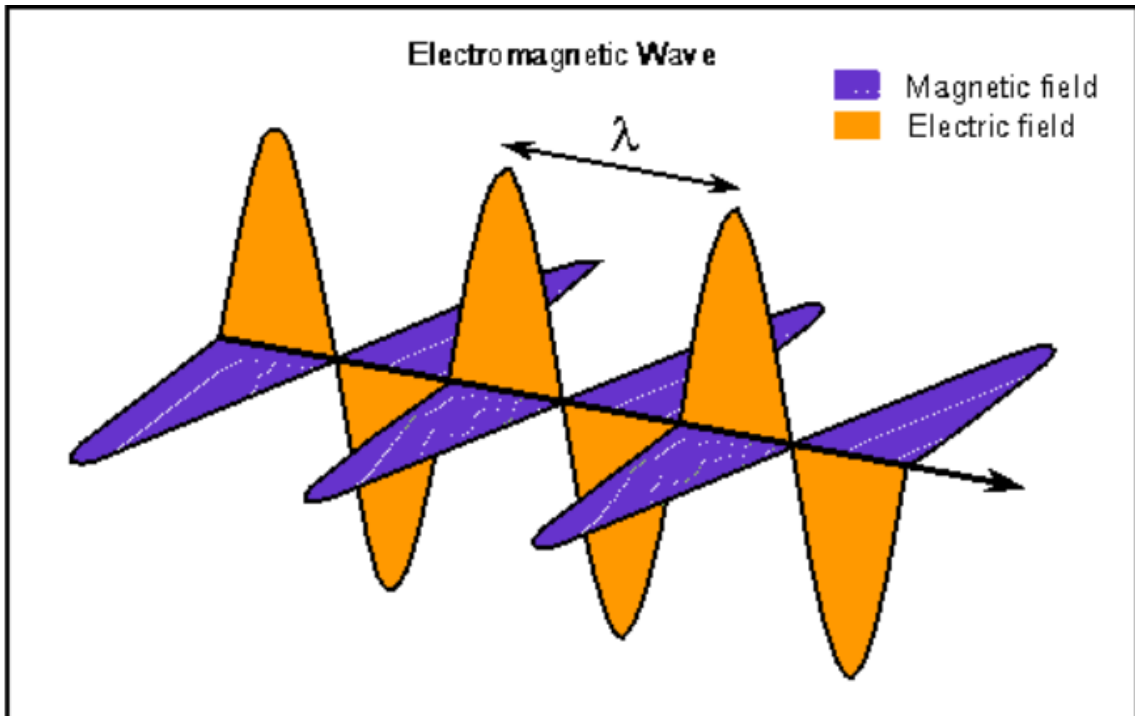
$$F = F_e + F_m$$

Sometimes only the equation $F_m = qvB$ is called the Lorentz Force equation.

When this is applied to a current carrying wire it gives us our second equation. The force can be called the Laplace Force and the equation can be transformed into;

$$F = ILB = BIL$$

where I is the current, L is the length of the wire and B is the magnetic field strength.



$$F_g = 6.67 \times 10^{-11} \text{ N}$$

$$F_e = 9 \times 10^9 \text{ N}$$

$$F_m = q v B = (1 \text{ C}) (10^7 \text{ m/s}) (1 \text{ T}) \\ 10^7 \text{ N}$$

