MIND MAP

Magnetism and Matter

Magnetisation

$$\vec{M} = \frac{\vec{m}_{net}}{V} = \frac{\text{Net Magnetic Moment}}{\text{Volume}}$$

$$\vec{B} = \vec{B}_0 + \vec{B}_m$$

$$\underset{\mu_0\vec{H}}{\downarrow} \quad \underset{\mu_0\vec{M}}{\downarrow}$$

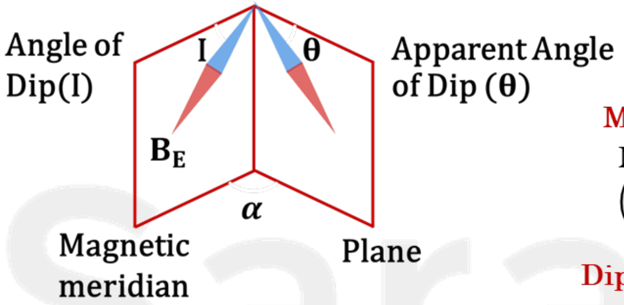
$$\vec{B} = \mu_0\,(\vec{H} + \vec{M})$$

$$\vec{B} = \mu_0\,(1 + \chi)\vec{H}$$

$$\vec{M} = \vec{H}\,\chi$$

$$\boxed{\vec{B} = \mu_0\mu_r\,\vec{H}}$$

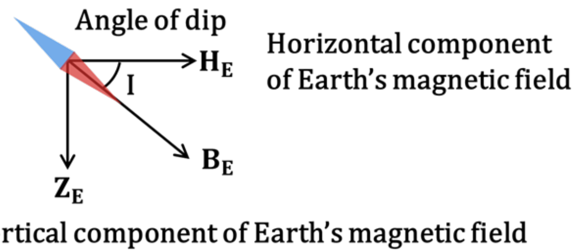
$$\boxed{\vec{B} = \mu\,\vec{H}}$$



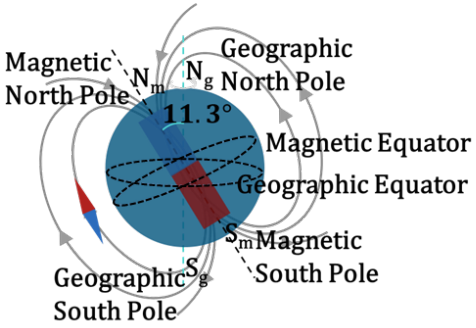
$$B_E \cos I = H_E$$

$$B_E \sin I = Z_E$$

$$\tan I = \frac{Z_E}{H_E}$$



Earth's Magnetic Field

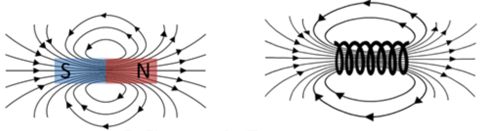


Magnets

Same poles repel

Opposite poles attract each other

The magnetic field lines of a magnet and Solenoid form continuous closed loops.



Magnetism and Gauss's Law

Net magnetic flux through any closed surface $\left(\oint \vec{B} \cdot \vec{dA}\right)$ is always zero.

Dipole in Uniform Magnetic Field

$$T = 2\pi\sqrt{\frac{I}{mB}}$$

Electrostatic Analog	
$\vec{B}$	$\vec{E}$
$\vec{m}$	$\vec{p}$
μ_0	$\frac{1}{\varepsilon_0}$
$\vec{\tau} = \vec{m} \times \vec{B}$	$\vec{\tau} = \vec{p} \times \vec{E}$
$U = -\vec{m}.\vec{B}$	$U = -\vec{p}.\vec{E}$
$\vec{B}_{axial} = \frac{\mu_0}{4\pi}\frac{2\,\vec{m}}{r^3}$	$\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2\,\vec{p}}{r^3}$
$\vec{B}_{eq} = -\frac{\mu_0}{4\pi}\frac{\vec{m}}{r^3}$	$\vec{E}_{eq} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$

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Paramagnetic

Magnetisation of paramagnetic material is inversely proportional to the absolute temperature.

$$\boxed{\chi = C\frac{\mu_0}{T}}$$

Curie's Law-

Diamagnetic

Superconductors cooled to very low temperatures show both perfect conductivity and perfect diamagnetism.

$\chi = -1$

$\mu_r = 0$

Meissner Effect.

Ferromagnetic

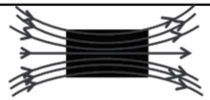
At high enough temperature, a ferromagnet becomes a paramagnet. This temperature of transition from ferromagnetic to paramagnetic is called Curie Temperature T_C.

Fe → 1043 K Ni → 631 K

Above Curie Temperature in paramagnetic phase,

$$\chi \propto \frac{1}{T - T_C}$$

Classification of Magnetic Materials

Properties	Diamagnetic	Paramagnetic	Ferromagnetic
χ	$-1 \le \chi < 0$	$0 < \chi < k$	$\chi >> 1$
μ_r	$0 \le \mu_r < 1$	$1 < \mu_r < 1 + k$	$\mu_r >> 1$
μ	$\mu < \mu_0$	$\mu > \mu_0$	$\mu >> \mu_0$
Magnetisation	Weak Magnetisation in opposite direction	Weak Magnetisation in Same direction	Strong Magnetisation in Same direction
Movement in magnetic field	(Weak tendency) From strong to weak magnetic field	(Weak tendency) From weak to strong magnetic field	(Strong tendency) From weak to strong magnetic field
Magnet	Weak Repulsion	Weak Attraction	Strong Attraction
E.g	Bi, Au, Pb, Si, H_2O, NaCl, N_2 (STP)	Al, Na, Ca, O_2(STP)	Fe, Co, Ni, Gd
Magnetic Field Lines			

Permanent Magnets

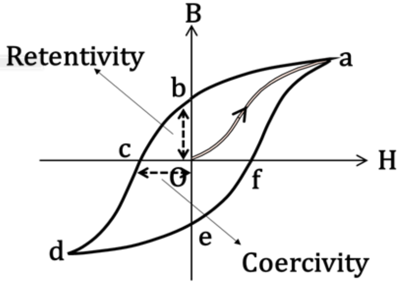
High Retentivity

High Coercivity

Electromagnets

Low Retentivity

Low Coercivity



Hysteresis Loss

It is the energy lost in form of heat during a complete cycle of magnetization and demagnetization.