L22 Magnetic Materials (dipole moments in it).

$\vec{H} = \frac{1}{\mu_0}\vec{B} - \vec{M}$

$\vec{M}$ = Magnetization induced by magnetic field

In a linear mat. ⇒ $\vec{M} = \chi_m \vec{H}$ by convention (not $\vec{M} = \frac{1}{\mu_0}\chi_m \vec{B}$).

$\vec{H}$ = applied field

χ_m : magnetic susceptibility

$\vec{P} = \varepsilon_0 \chi_e \vec{E}$

$\chi_m > 0$: paramagnetic

$\chi_e > 0$ always.

$\chi_m < 0$: diamagnetic.

Diamagnetic	χ_m	Paramagnetic	χ_m
* Bismuth	-1.7×10^{-4}	O_2	1.7×10^{-6}
Gold	-3.4×10^{-5}	Al	2.2×10^{-5}
Water	-9.0×10^{-6}	* Liquid O_2	3.9×10^{-3}
CO_2	-1.1×10^{-8}	* Gd	4.8×10^{-1}

$\vec{B} = \mu_0(\vec{H} + \vec{M}) = \mu_0(1+\chi_m)\vec{H} = \mu\vec{H}$

μ : permeability.

◎ Superconductors $\chi_m = -1$

$\therefore \vec{B} = \mu_0(1+\chi_m)\vec{H} = \mu_0 \cdot (1-1)\vec{H} = 0$: Perfect shielding of applied $\vec{H}$.

EX Infinit solenoid with n and I is filled w/ linear mat of χ_m.

n : winding # density.

$\vec{H}$ is from the free current.

$\therefore \vec{H} = \frac{1}{\mu_0}\vec{B}_0 = \frac{1}{\mu_0}\mu_0 n I \hat{z} = n I \hat{z}$.

$\therefore \vec{B} = \mu_0(\vec{H} + \vec{M}) = \mu_0(1+\chi_m)\vec{H} = \mu_0(1+\chi_m) n I \hat{z}$.

Therefore for $\chi_m > 0$ (paramagnetic), $|\vec{B}| > |\vec{B}_0|$

$\chi_m < 0$ (diamagnetic), $|\vec{B}| < |\vec{B}_0|$.

Bound surface current $\vec{K}_b = \vec{M} \times \hat{n} = \chi_m(\vec{H} \times \hat{n}) = \chi_m n I(\hat{z} \times \hat{s})$
$= \chi_m n I \hat{\varphi}$

↳ produces additional field $\vec{B}_b$ and changes the total $\vec{B} = \vec{B}_0 + \vec{B}_b$

(*) We know $\vec{\nabla}\cdot\vec{B}=0$. Since $\vec{B}=\mu\vec{H}$, does it guarantee $\vec{\nabla}\cdot\vec{H}=0$?

$\vec{\nabla}\cdot\vec{H}=0$ is true only in a homogeneous linear magnetic material.

$$\vec{\nabla}\cdot\vec{H}=\vec{\nabla}\cdot\left(\frac{\vec{B}}{\mu}\right)=\frac{1}{\mu}\vec{\nabla}\cdot\vec{B}+\vec{B}\cdot\vec{\nabla}\left(\frac{1}{\mu}\right)\neq 0$$

in general, especially $\mu=\mu(\vec{r})$.

HW 6.16 & 6.17.

- Ferromagnetism.

  $\vec{M}\neq 0$ for $\vec{H}=0$: spontaneous magnetization.