Lecture 1

Maxwell equation in material

SI:

$$\nabla \cdot \vec{D} = \rho$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = \mu_0 \left(\vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t} \right)$$

Gaussian:

$$\nabla \cdot \vec{D} = 4\pi\rho \quad \text{(Gauss)}$$

$$\nabla \cdot \vec{B} = 0 \quad \text{(Gauss)}$$

$$\nabla \times \vec{E} = -\frac{1}{c}\frac{\partial \vec{B}}{\partial t} \quad \text{(Maxwell - Faraday)}$$

$$\nabla \times \vec{H} = \frac{4\pi}{c}\vec{J} + \frac{1}{c}\frac{\partial \vec{D}}{\partial t} \quad \text{(Ampere - Maxwell)}$$

SI:

$\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$; where $\vec{P} = N\vec{p}/V$

$\vec{B} = \mu_0 \vec{H} + \vec{M}$

$\vec{D} = \varepsilon \vec{E}$

$\vec{p}$ is Electric dipole

$\vec{p} = q\vec{d} \equiv statC \cdot cm$

Gaussian:

$\vec{D} = \vec{E} + 4\pi\vec{P}$

$\vec{B} = \vec{H} + 4\pi\vec{M}$

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

$\mu\vec{H} = \vec{H} + 4\pi\vec{M}$

$$\vec{M} = \frac{\mu - 1}{4\pi}\vec{H}$$

SI: $\vec{M} = \frac{1}{\mu_0}\chi_m \vec{H}$

Gaussian: $\vec{M} = \chi_m \vec{H}$; where $\mu = 1 + 4\pi\chi_m$

SI:

$\vec{B}$ is measured in T

$\vec{H}$ is measured in A/m

Gaussian:

$\vec{B}$ is measured in Gauss

$\vec{H}$ is measured in Oersted

$\vec{H}$ - applied magnetic field

$\vec{B}$ - magnetic flux density

$\vec{M}$ - magnetisation per volume $= \frac{N \cdot \vec{\mu}}{V}$

$$\Phi(\vec{r}) = \int d^3\vec{r}\,' \frac{\rho(\vec{r}\,')}{|\vec{r}-\vec{r}\,'|}$$, where $\rho \equiv$ charge density

$\vec{E} = -\nabla\Phi$

$\nabla^2\Phi = 4\pi\rho$

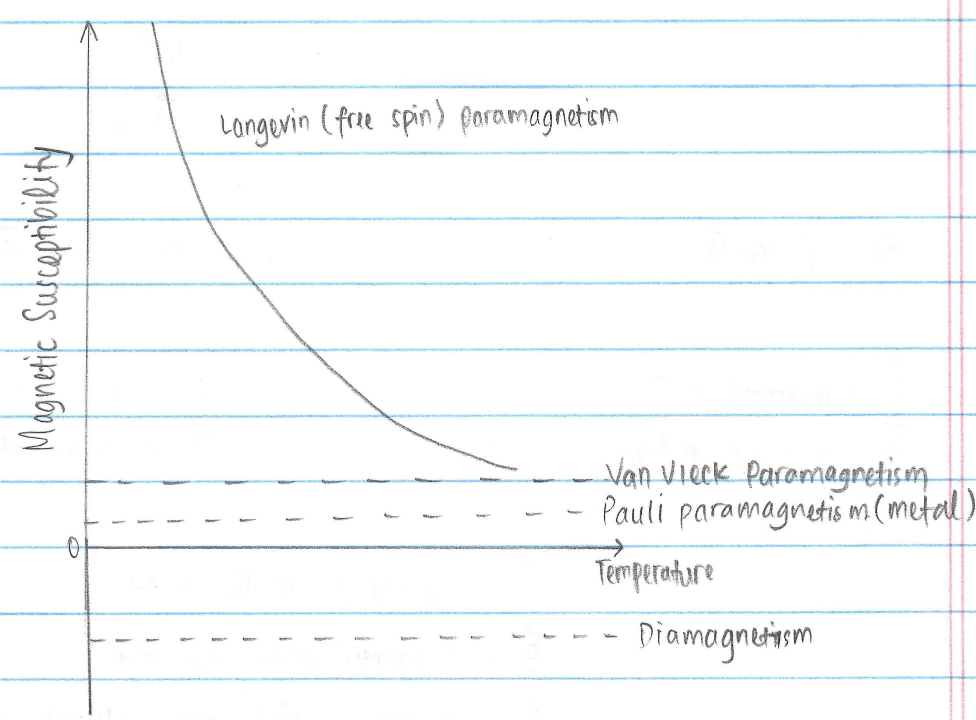
Energy density in vacuum : $u = U/V = 1/8\pi\,(E^2+B^2)$

Poynting vector : $\vec{S} = c/4\pi\,(\vec{E}\times\vec{B})$

What are the units for electric & magnetic dipoles?

$\vec{p} \equiv$ statC cm (ESU units) / Debye (Gaussian units)

$\vec{\mu} \equiv$ erg/G (Gaussian units)



- Diamagnetism (Larmor): Lenz's law on atomic electron
- Longevin paramagnetism : "Free spin" in magnetic field align with field.
- Pauli paramagnetism : alignment of conduction electrons with field $\chi \propto N(E_F)$
- Van vleck paramagnetism $J=0$ but $S, L \neq 0$, so Q.M. mixing