Key points 04/20 lecture

Definition of magnetization: $\mathcal{M} = \frac{1}{V} \left\langle -\frac{\partial \mathcal{H}}{\partial B} \right\rangle$

$\mathcal{H}$: classical or quantum Hamiltonian

B: Strength of external magnetic field

In canonical ensemble: $\mathcal{M} = kT \left(\frac{\partial}{\partial B} \frac{\log Q_N}{V} \right)_{T,V,N}$

$\mathcal{M}$: average induced magnetic moment per unit volume of the system along the direction of an external magnetic field $\vec{B}$.

Paramagnetism discussion based on the following single-particle Hamiltonian:
($\chi > 0$)

$$\hat{\mathcal{H}} = \frac{\hat{\vec{p}}^2}{2m} - \hat{\vec{\mu}} \cdot \vec{B} \; ; \; \hat{\vec{\mu}} = -g_s \mu_B \frac{1}{\hbar} \underbrace{\hat{\vec{S}}}_{\frac{1}{2}\hat{\vec{\sigma}}}$$

$\rightarrow$ spin degree of freedom

Diamagnetism discussion based on the following single-particle Hamiltonian:
($\chi < 0$)

$$\hat{\mathcal{H}} = \frac{1}{2m} \left(\hat{\vec{p}} + \frac{e}{c} \hat{\vec{A}} \right)^2$$

$A_x = -By$
$A_y = A_z = 0$

$$= \frac{1}{2m} \left(\hat{p}_x - \frac{e}{c} B \hat{y} \right)^2 + \frac{\hat{p}_y^2}{2m} + \frac{\hat{p}_z^2}{2m}$$

$\rightarrow$ motional degree of freedom

susceptibility

$\chi = \frac{\partial M}{\partial B}$