Answer on Question #53674, Physics Solid State Physics

Obtain an expression for paramagnetic susceptibility of free electrons on the basis of the classical laws. Discuss its inadequacy and show pouli modified it?

Answer:

Magnetic susceptibility

$$\chi_{\alpha\beta} = -\frac{\partial^2 F}{\partial B_\alpha \partial B_\beta}\bigg|_{B=0}$$

where $F = -T \ln Z$ the free energy.

Partition function

$$Z = \left(\int \exp\left[-E_i / T \right] d\Omega \right)^N$$

where N is the number of dipoles (per unit volume); $E_i = -\mu_i B \cos\theta$; the solid angle $d\Omega = \sin\theta d\theta d\varphi$.

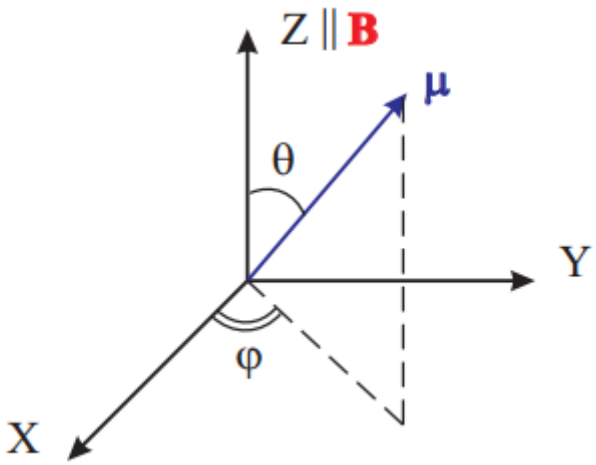

Fig.1

Then

$$\chi_p = N\mu L\left(\frac{\mu B}{T}\right)$$

where $L(x)$ is the Langevin function ($L(x) = cth(x) - \frac{1}{x}$).

For small $x << 1$ ($\mu B << T$) - the weak magnetic fields (or higher temperature) can be decomposed into a number of function Langevin.

$$L(x)\big|_{x<<1} \approx x/3$$

Hence we get paramagnetic susceptibility

$$\chi_p = \frac{N\mu^2}{3kT}$$

Langevin's theory contradicts the third law of thermodynamics. The fact that $T \to 0$ the entropy of the system should also go to zero. However, the calculation of entropy in the classical theory of Langevin paramagnetism leads to the fact that as the temperature approaches absolute zero the entropy of the system becomes infinity. The reason for this contradiction is that in the derivation of the formula does not take into account the spatial quantization of the magnetic moments.

Paramagnetic properties are possessed atoms with unpaired spins or uncompensated angular momentum (atoms with an odd number of electrons, or partly filled inner electron shell). Character is defined by the rules of filling of shells Hund. Under these rules, the spins of electrons in the shell always add up so as to give the maximum

possible (subject to the Pauli exclusion principle) the value of the angular momentum and magnetic moment.