Indian Institute of Technology, Delhi
Department of Physics
Minor I

PYL422/EPL446 Spintronics

Total marks 15

Time: 60 min

1 Consider two spins, defined by the spin angular momenta S_1 and S_2, undergo some interaction given by an interaction strength A. What would be the resulting ground state of the coupled system if A > 0? Assume that the eigenvalue of S^2 =3/4. [2.5]

2\. a) Consider a ferromagnet introduced to an external magnetic field H_{ext}. Show that the $\vec{\nabla} \cdot \vec{H}_{ext}$ is non zero. [1]

b) Show that the internal magnetic field within the ferromagnetic material is different from H_{ext}. [1.5]

c) If the susceptibility is measured as the induced magnetization due to external field, show that the ratio of measured susceptibility (experimental) and internal susceptibility is given by

$$\frac{\chi_{experimental}}{\chi_{internal}} = \frac{1}{1 + N \cdot \chi_{internal}}$$

where, N is the demagnetization factor. [2]

d) If the magnet is cooled down from above the Curie temperature T_C, show that the measured susceptibility (in a very small field) is the inverse of the demagnetization factor. [1.5]

3 a) Consider a compound containing octahedrally coordinated Fe^{2+}. Write down the total spin angular momentum (S) for low spin and high spin state at zero temperature. Atomic no. of Fe is 26. [3.5]

b) If the low spin energy level lies just 50 meV below the high-spin level, at what temperature would you expect spin crossover from low spin state to high-spin state to occur? [1.5]

4\. a) Discuss the role of orbital quenching in defining the magnetic ground state of 3d ions. [2]

b) For a ferromagnet, it can be shown that $3k_BT_c = g_J\mu_B(J+1)\lambda M_s$. Estimate the Weiss molecular field for Gd (T_c= 292 K, J=S=7/2). [1.5]

5\. In a cubic crystal, the magnetocrystalline anisotropy energy is given by

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$$E = K_1(\alpha_1^2 \alpha_2^2 + \alpha_2^2 \alpha_3^2 + \alpha_1^2 \alpha_3^2) + K_2 \alpha_1^2 \alpha_2^2 \alpha_3^2 + \dots$$

where K's are anisotropy constants and α's are the direction cosines. Estimate the value for E for [100] and [111] directions.

[3]

$\hbar = 1.054 \times 10^{-34}$ Js, $k_B = 1.38 \times 10^{-23}$ J/K, $\mu_B = 9.274 \times 10^{-24}$ J/T, $\mu_0 = 4\pi \times 10^{-7}$ Tm/A

Note. All notations used in the questions have their usual meanings.