Indian Institute of Technology, Delhi
Department of Physics
Major

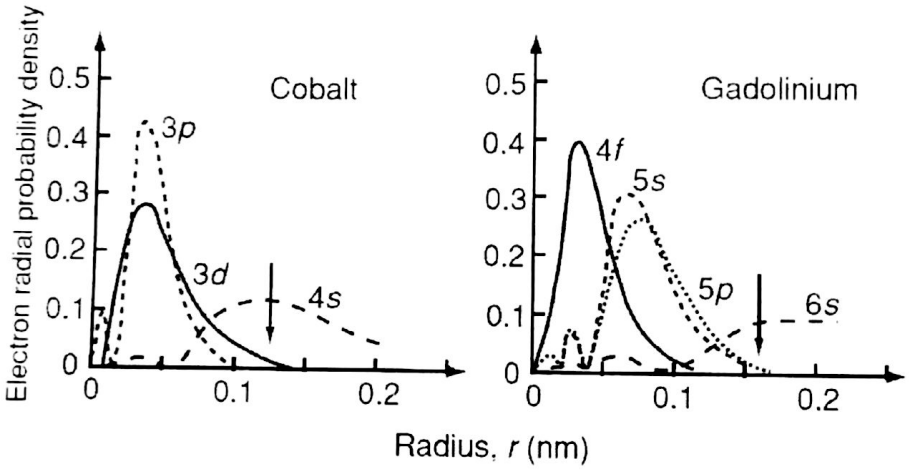
PYL422/EPL446 Spintronics

Total marks: 45 Time: 2 hrs

1. Consider a fictitious alloy of two elements $A_{1-x}B_x$ where x is the percentage of substation of B atoms in A. Assume that the no. of valence electrons of A and B as 7 and 5 respectively.
a) what would be the average valence electrons of the alloy? [2]
b) explain in brief how the Fermi energy will change with increasing substitution of B atoms in A. [2]

2. For a strong ferromagnet, determine the total magnetic moment in unit of μ_B if the total no. of d electrons is 8. [3]

3.



In the above figure, compare and discuss the localized or delocalized behavior of 3d and 4f electrons. [3]

4. Consider a system of two electrons having spatial coordinates $\vec{r}1$ and r2 respectively.
Write the wave function for the system for both singlet and triplet states. [3]

5. What is exchange anisotropy in magnetism? Explain in brief the exchange bias in a magnetic heterostructure. [3]

6. a) What is the origin of the spin disorder scattering of electrons in a magnet? [2]
b) Show that magnetoresistance for a GMR sensor is

$$\frac{\Delta\rho}{\rho} = \frac{(1-\alpha)^2}{(1+\alpha)^2} \quad \text{where,} \quad \alpha = \frac{\rho_\downarrow}{\rho_\uparrow}$$

Neglect spin flip scattering for the derivation. [4]

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7. For magnetoresistance of a ferromagnet, Kohler's rule can be generalized as

$$\frac{\Delta\rho}{\rho} \propto a\left(\frac{H}{\rho}\right)^2 + b\left(\frac{M}{\rho}\right)^2$$

where, ρ, H, M have usual meanings. a and b are constants.
Explain qualitatively why "b" should be negative for AMR effect. [3]

8. What is the difference between a half metal and a strong ferromagnet? [2]

9. In M-H data of a magnetic material, the hysteresis loops are often described by the behavior of the magnetic domains.
a) Explain how formation of domains leads to the reduction of total energy of a magnetic system. [2]
b) Discuss how the domains are separated by different type of magnetic walls. [3]
c) Draw schematic diagrams for 180° and 90° domain wall. Given the possibility to form both these domain walls in a magnetic sample, which one would be more favorable and why? [1+2]
d) Name an experimental tool that you will use to observe a domain wall. [1]

10. a) For a magnetic data storage device made of a material of Uniaxial anisotropy constant K1= 1X10^5 Jm-3, estimate the minimum particle size which would offer a stable magnetic information to be written. [2]
b) Consider that a single bit is recorded in the magnetization of one such particle. What would be the storage density per square inch? [2]

11. a) Spin currents and charge currents are fundamentally different and that is exploited in spintronics. Describe in brief, in terms of life-time and interaction forces (e.g., charge-charge and spin-spin), the major differences for spin and charge current. [3]
b) Discuss the basic requirements for semiconductor spintronics. [2]

$\hbar$=1.054X10^{-34} Js, k_B= 1.38 X 10^{-23} J/K, μ_B= 9.274 X10^{-24} J/T, μ_0= 4πX10^{-7} Tm/A

Note: All parameters used in the questions have their usual meanings.

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