Topics in Nanosciences

Assignment-3

KBT=E2/C

P1. What capacitance is needed to permit the exchange of exactly one electron at 273 K?

\frac{e^2}{2C} \geq k_B T [2]

c=4pieepsilonr

P2. Calculate the size (radius in nm) of a sphere-shaped quantum dot of Si that would produce an observable single electron effect at room temperature (300 K).
Given: Dielectric constant of Si = 11.5; Permittivity of vacuum = 8.85×10^{-12} $F.m^{-1}$; $k = 1.38 \times 10^{-23}$ JK^{-1}; 1 eV = 1.602×10^{-19} J. [10]

P3. A magnetic hard disk contains a total of 10^{11} single domain bits of size 30 x 30 x30 nm^3. The crystalline anisotropy energy is K = 5×10^6 $ergs.cm^{-3}$. What is the reversal frequency of the bits for the whole disk (i.e. the number of bits reversing per second and losing the information) at 300 K? How would it change if the bit volume is reduced by a factor of 50 and the total number of bits increased to 10^{12}? Will the error rate be significant in any of the two cases? Take the frequency factor f_0 to be 10^{10} s^{-1}.

$\tau = \tau 0 \exp(KV/kT)$ [6]

P4. Compare the frequency of flipping of spins in nanoparticles of 10 and 20 nm diameter at 300 K. Given, crystalline anisotropy energy constant K = 0.25×10^6 Jm^{-3} and the frequency factor $f_0 = 10^9$ s^{-1}.

$\tau = \tau 0 \exp(KV/kT)$ [6]

P5. Two colorless solutions are given to you: one containing aq. sugar solution and the other aq. potassium cyanide solution. How can you distinguish/identify them by using the optical property of an aqueous gold nanoparticle solution? Give scientific explanations for your choice of experimental designs/observations. spr —> color change due to combination [2.5+2.5]

P6. You are provided with a silver nanoparticle solution. Explain how you can use it to detect whether an industry wastewater contains mercuric ions or not. heavy metal reaction,Change in [3]
SPR signal D e t e c t i o

P7. Explain how "superparamagnetism" is different from bulk paramagnetism. [3]

same, individual paticle have very high magnetic moment, indivual magnet,magnetic moment kt>kv (nano magnetism)

P8. What are the most important differences between the optical properties of gold nanoparticles and cadmium selenide quantum dots? [3]

metal np, semiconductor
metal->surface plasmon resonance,
semiconditor ->quantum confinment

P9. How can one use plasmon coupling to measure the distance between particles? Why does one not use an optical microscope to measure a similar distance? Te xt [6]

plasmon couplig energy decreas, more neareser more decrease —> lambda incrase—>nm —>optical visibsle wavelength so cant measure

P10. Consider the following Figures which schematically show the mechanism of a GMR device composed of the nanoscale ferromagnetic layers of cobalt separated by the nanoscale nonmagnetic layer of copper.
The upward or downward smaller arrows with black circles indicate up-spin or down-spin electrons respectively. The upward or downward medium-length arrows in the blue layers (left and right layers) show the directions of the magnetic moments in the respective layers.

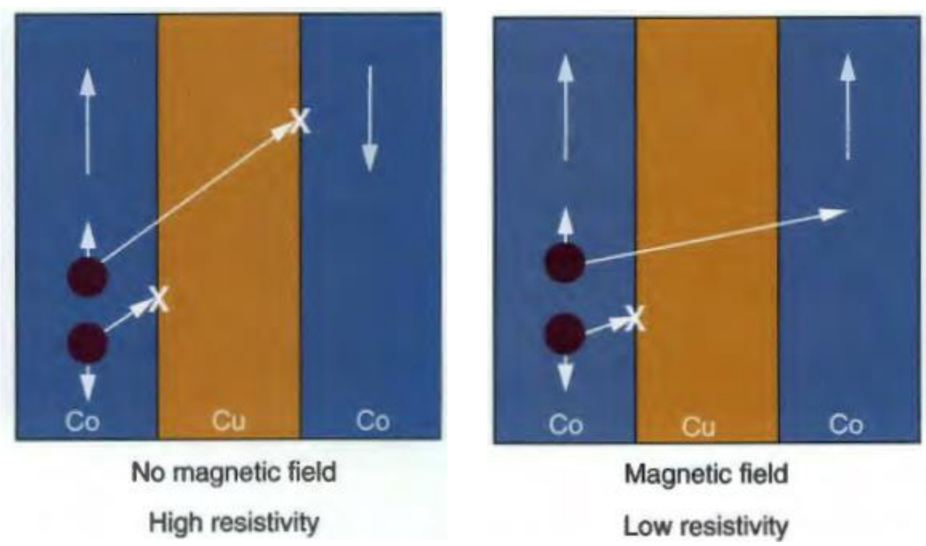
(a) Explain:

(i) why the down-spin electron gets scattered at the Co-Cu interface (slanted small arrow, left panel).

(ii) why the up-spin electron gets scattered at the Cu-Co interface (slanted long arrow, left panel)?

On the other hand, explain why the up-spin electron does not get scattered at the Cu-Co interface (slanted long arrow, right panel, Figure with magnetic field)?

(b) What are the effects of such scattering on the electrical resistance of such systems? [6+4]



two peaks correpnding to trasverse longitdeu

P11. Schematically draw to show and state the major changes that will appear in the UV-visible absorption spectral band when a silver nanosphere is elongated into a rod-shaped nanoparticle. [4]

spr in metal, quantum confinement

P12. Explain the following observation: "In the size range where copper, silver, and gold nanoparticles show size-dependent colors, the semiconductor crystallites do not show the color change when the particle size is varied. [3]

spr ki form, heat —> quantum confinemtn effect —>"fluoresence

P13. What are the fates of the absorbed energies in the cases of the plasmonic nanoparticles and semiconductor quantum dots? (In other words, once the light energy is absorbed in the above two cases, to what major form of energy will it convert to?) [2]

P14. The figure below shows the variation of the real part of the dielectric constant of gold as a function of wavelength in the visible region of the spectrum.

(i) ***On the graph, show the estimated wavelengths*** of the surface plasmon resonances (SPRs) of Au nanoparticles (whose diameter is very much smaller than the wavelength of visible light) when they are immersed in water and are immersed in the blood (refractive index, n_m of water = 1.33 and for blood $n_m \approx 1.40$) respectively.

(ii) If you compare the absorbance values, in which system (water or blood) do you expect to see higher values of Absorbance and why? [4+3]